

# Pearson BTEC Level 3 National Diploma in Applied Science



## Specification

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*First teaching from September 2016*

*First certification from 2018*

Issue 10



# **Pearson BTEC Level 3 National Diploma in Applied Science**

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First teaching September 2016

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### **Edexcel, BTEC and LCCI qualifications**

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### **About Pearson**

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This specification is Issue 10. We will inform centres of any changes to this issue. The latest issue can be found on our website.

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# Welcome

With a track record built over 30 years of learner success, BTEC Nationals are widely recognised by industry and higher education as the signature vocational qualification at Level 3. They provide progression to the workplace either directly or via study at a higher level. Proof comes from YouGov research, which shows that 62% of large companies have recruited employees with BTEC qualifications. What's more, well over 100,000 BTEC students apply to UK universities every year and their BTEC Nationals are accepted by over 150 UK universities and higher education institutes for relevant degree programmes either on their own or in combination with A Levels.

## Why are BTECs so successful?

BTECs embody a fundamentally learner-centred approach to the curriculum, with a flexible, unit-based structure and knowledge applied in project-based assessments. They focus on the holistic development of the practical, interpersonal and thinking skills required to be able to succeed in employment and higher education.

When creating the BTEC Nationals in this suite, we worked with many employers, higher education providers, colleges and schools to ensure that their needs are met. Employers are looking for recruits with a thorough grounding in the latest industry requirements and work-ready skills such as teamwork. Higher education needs students who have experience of research, extended writing and meeting deadlines.

We have addressed these requirements with:

- a range of BTEC sizes, each with a clear purpose, so there is something to suit each learner's choice of study programme and progression plans
- refreshed content that is closely aligned with employers' and higher education needs for a skilled future workforce
- assessments and projects chosen to help learners progress to the next stage. This means some are set by you to meet local needs, while others are set and marked by Pearson so that there is a core of skills and understanding that is common to all learners. For example, a written test can be used to check that learners are confident in using technical knowledge to carry out a certain job.

We are providing a wealth of support, both resources and people, to ensure that learners and their teachers have the best possible experience during their course. See *Section 10* for details of the support we offer.

## A word to learners

Today's BTEC Nationals are demanding, as you would expect of the most respected applied learning qualification in the UK. You will have to choose and complete a range of units, be organised, take some assessments that we will set and mark, and keep a portfolio of your assignments. But you can feel proud to achieve a BTEC because, whatever your plans in life – whether you decide to study further, go on to work or an apprenticeship, or set up your own business – your BTEC National will be your passport to success in the next stage of your life.

Good luck, and we hope you enjoy your course.

## Collaborative development

Students completing their BTEC Nationals in Applied Science will be aiming to go on to employment, often via the stepping stone of higher education. It was, therefore, essential that we developed these qualifications in close collaboration with experts from professional bodies, businesses and universities, and with the providers who will be delivering the qualifications. To ensure that the content meets providers' needs and provides high-quality preparation for progression, we engaged experts. We are very grateful to all the university and further education lecturers, teachers, employers, professional body representatives and other individuals who have generously shared their time and expertise to help us develop these new qualifications.

In addition, universities, professional bodies and businesses have provided letters of support confirming that these qualifications meet their entry requirements. These letters can be viewed on our website.

### Summary of Pearson BTEC Level 3 National Diploma in Applied Science specification Issue 10 changes

Summary of changes made between the previous issue and this current issue	Page number
Changes made to <i>Unit 3: Science Investigation Skills</i> External assessment.	Page 14

### Summary of Pearson BTEC Level 3 National Diploma in Applied Science specification Issue 9 changes

Summary of changes made between Issue 8 and Issue 9	Page number
The last paragraph of the <i>Qualification and unit content</i> section has been amended to allow centres delivering the qualification above to alter the content to reflect the context of the country where it is being delivered.	Page 7
<i>Unit 3: Science Investigation Skills</i> <b>Summary of assessment</b> Wording updated to reflect the removal of the requirement for learners use primary information/data or undertake a practical investigation. Secondary data/information for assessment will be provided by Pearson. <b>Essential content</b> Minor amendments to content for B2, D2, E1, E2, F1, G1, G2, G3, H1 and H2 to add clarification to existing content where required. <b>Grade descriptors</b> Updated for Pass and Distinction to reflect the removal of the requirement for learners use primary information/data.	Pages 41, 43-46 and 47
<i>Unit 18: Industrial Chemical Reactions</i> <b>Essential guidance for assessment decisions</b> Learning aim A – removal of requirement to work out an equilibrium constant.	Page 193

If you need further information on these changes or what they mean, contact us via our website at: [qualifications.pearson.com/en/support/contact-us.html](http://qualifications.pearson.com/en/support/contact-us.html).

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# Introduction to BTEC National qualifications for the applied science sector

This specification contains the information you need to deliver the Pearson BTEC Level 3 National Diploma in Applied Science. The specification signposts you to additional handbooks and policies. It includes all the units for this qualification.

This qualification is part of the suite of Applied Science qualifications offered by Pearson. In the suite there are qualifications that focus on different progression routes, allowing learners to choose the one best suited to their aspirations.

All qualifications in the suite share some common units and assessments, allowing learners some flexibility in moving between sizes. The qualification titles are given below.

Some BTEC National qualifications provide a broad introduction that gives learners transferable knowledge and skills. These qualifications are for post-16 learners who want to continue their education through applied learning. The qualifications prepare learners for a range of higher education courses and job roles related to a particular sector. They provide progression either by meeting entry requirements in their own right or by being accepted alongside other qualifications at the same level and adding value to them.

In the applied science sector these qualifications are:

Pearson BTEC Level 3 National Certificate in Applied Science (180 GLH) 601/7434/1

Pearson BTEC Level 3 National Extended Certificate in Applied Science (360 GLH) 601/7436/5

Pearson BTEC Level 3 National Foundation Diploma in Applied Science (510 GLH) 601/7438/9

Pearson BTEC Level 3 National Diploma in Applied Science (720 GLH) 601/7435/3

Pearson BTEC Level 3 National Extended Diploma in Applied Science (1080 GLH) 601/7437/7.

This specification signposts all the other essential documents and support that you need as a centre in order to deliver, assess and administer the qualification, including the staff development required. A summary of all essential documents is given in *Section 7*. Information on how we can support you with this qualification is given in *Section 10*.

The information in this specification is correct at the time of publication.

## Total Qualification Time

For all regulated qualifications, Pearson specifies a total number of hours that it is estimated learners will require to complete and show achievement for the qualification: this is the Total Qualification Time (TQT). Within TQT, Pearson identifies the number of Guided Learning Hours (GLH) that we estimate a centre delivering the qualification might provide. Guided learning means activities, such as lessons, tutorials, online instruction, supervised study and giving feedback on performance, that directly involve teachers and assessors in teaching, supervising and invigilating learners. Guided learning includes the time required for learners to complete external assessment under examination or supervised conditions.

In addition to guided learning, other required learning directed by teachers or assessors will include private study, preparation for assessment and undertaking assessment when not under supervision, such as preparatory reading, revision and independent research.

BTEC Nationals have been designed around the number of hours of guided learning expected. Each unit in the qualification has a GLH value of 60, 90 or 120. There is then a total GLH value for the qualification.

Each qualification has a TQT value. This may vary within sectors and across the suite depending on the nature of the units in each qualification and the expected time for other required learning.

The following table shows all the qualifications in this sector and their GLH and TQT values.

## Qualifications, sizes and purposes at a glance

Title	Size and structure	Summary purpose
<b>Pearson BTEC Level 3 National Certificate in Applied Science</b>	180 GLH (235 TQT) Equivalent in size to 0.5 of an A Level. 2 units of which both are mandatory and 1 is external. Mandatory content (100%). External assessment (50%).	An introduction to a vocational sector through applied learning. For learners for whom an element of science would be complementary, the qualification supports progression to higher education when taken as part of a programme of study that includes other vocational or general qualifications.
<b>Pearson BTEC Level 3 National Extended Certificate in Applied Science</b>	360 GLH (455 TQT) Equivalent in size to one A Level. 4 units of which 3 are mandatory and 2 are external. Mandatory content (83%). External assessment (58%).	Designed for learners who are interested in learning about the sector alongside other fields of study, with a view to progressing to a wide range of higher education courses, not necessarily in applied science. To be taken as part of a programme of study that includes other appropriate BTEC Nationals or A Levels.
<b>Pearson BTEC Level 3 National Foundation Diploma in Applied Science</b>	510 GLH (640 TQT) Equivalent in size to 1.5 A Levels. 6 units of which 4 are mandatory and 2 are external. Mandatory content (76%). External assessment (41%).	Designed as a one-year, full-time course of study, or as part of a two-year, full-time study programme for learners who wish to study another area alongside it, which may contrast or complement the Applied Science Foundation Diploma. If taken as part of a programme of study that includes other BTEC Nationals or A Levels, it supports progression to higher education.
<b>Pearson BTEC Level 3 National Diploma in Applied Science</b>	720 GLH (890 TQT) Equivalent in size to two A Levels. 8 units of which 6 are mandatory and 3 are external. Mandatory content (83%). External assessment (46%).	Designed to be the substantive part of a 16–19 study programme for learners who want a strong core of sector study. May be complemented with other BTEC Nationals or A Levels to support progression to higher education courses in applied science. The additional qualification(s) studied allow learners either to give breadth to their study by choosing a contrasting subject, or to give their studies more focus by choosing a complementary subject.

Title	Size and structure	Summary purpose
<b>Pearson BTEC Level 3 National Extended Diploma in Applied Science</b>	1080 GLH (1345 TQT) Equivalent in size to three A Levels. 13 units of which 7 are mandatory and 4 are external. Mandatory content (67%). External assessment (42%).	Designed as a two-year, full-time course that meets entry requirements in its own right for learners who want to progress to higher education courses in the applied science sector before entering employment. Learners can either choose a pathway which focuses on a particular occupational area, such as biomedical science, analytical and forensic science, physical science; or take a general route for further study in the sector.

## Structures of the qualifications at a glance

This table shows all the units and the qualifications to which they contribute. The full structure for this Pearson BTEC Level 3 National in Applied Science is shown in *Section 2*. **You must refer to the full structure to select units and plan your programme.**

### Key

Unit assessed externally	<b>M</b> Mandatory units	<b>O</b> Optional units
<b>BS</b> Biomedical Science	<b>AFS</b> Analytical and Forensic Science	<b>PS</b> Physical Science

Unit (number and title)	Unit size (GLH)	Certificate (180 GLH)	Extended Certificate (360 GLH)	Foundation Diploma (510 GLH)	Diploma (720 GLH)	Extended Diploma (1080 GLH)	Extended Diploma (1080 GLH)		
							BS	AFS	PS
1 Principles and Applications of Science I	90	M	M	M	M	M	M	M	M
2 Practical Scientific Procedures and Techniques	90	M	M	M	M	M	M	M	M
3 Science Investigation Skills	120		M	M	M	M	M	M	M
4 Laboratory Techniques and their Application	90			M	M	M	M	M	M
5 Principles and Applications of Science II	120				M	M	M	M	M
6 Investigative Project	90				M	M	M	M	M
7 Contemporary Issues in Science	120					M	M	M	M
8 Physiology of Human Body Systems	60		O	O	O	O	O	O	O
9 Human Regulation and Reproduction	60		O	O	O	O	O	O	O
10 Biological Molecules and Metabolic Pathways	60		O	O	O	O	O	O	O
11 Genetics and Genetic Engineering	60		O	O	O	O	O	O	O
12 Diseases and Infections	60		O	O	O	O	O	O	O
13 Applications of Inorganic Chemistry	60		O	O	O	O	O	O	O
14 Applications of Organic Chemistry	60		O	O	O	O	O	O	O
15 Electrical Circuits and their Application	60		O	O	O	O	O	O	O
16 Astronomy and Space Science	60		O	O	O	O	O	O	O
17 Microbiology and Microbiological Techniques	60			O	O	O	O	O	O

*continued overleaf*

Unit (number and title)	Unit size (GLH)	Certificate (180 GLH)	Extended Certificate (360 GLH)	Foundation Diploma (510 GLH)	Diploma (720 GLH)	Extended Diploma (1080 GLH)	Extended Diploma (1080 GLH)		
							BS	AFS	PS
18 Industrial Chemical Reactions	60			0	0	0	0	0	0
19 Practical Chemical Analysis	60			0	0	0	0	0	0
20 Biomedical Science	60				0	0	0	0	0
21 Medical Physics Applications	60				0	0	0	0	0
22 Materials Science	60				0	0	0	0	0
23 Forensic Evidence, Collection and Analysis	60				0	0	0	0	0
24 Cryogenics and Vacuum Technology	60					0	0	0	0
25 Forensic Fire Investigation	60					0	0	0	0
26 Forensic Traffic Collision Investigation	60					0	0	0	0

## Qualification and unit content

Pearson has developed the content of the new BTEC Nationals in collaboration with employers and representatives from higher education and relevant professional bodies. In this way, we have ensured that content is up to date and that it includes the knowledge, understanding, skills and attributes required in the sector.

Each qualification in the suite has its own purpose. The mandatory and optional content provides a balance of breadth and depth, while retaining a degree of choice for individual learners to study content relevant to their own interests and progression choices. Also, the content may be applied during delivery in a way that is relevant to local employment needs.

The proportion of mandatory content ensures that all learners are following a coherent programme of study and acquiring the knowledge, understanding and skills that will be recognised and valued. Learners are expected to show achievement across mandatory units as detailed in *Section 2*.

BTEC Nationals have always required applied learning that brings together knowledge and understanding (the cognitive domain) with practical and technical skills (the psychomotor domain). This is achieved through learners performing vocational tasks that encourage the development of appropriate vocational behaviours (the affective domain) and transferable skills. Transferable skills are those such as communication, teamwork, research and analysis, which are valued in both higher education and the workplace.

Our approach provides rigour and balance, and promotes the ability to apply learning immediately in new contexts. Further details can be found in *Section 2*.

Centres should ensure that delivery of content is kept up to date. Some of the units within the specification may contain references to legislation, policies, regulations and organisations, which may not be applicable in the country you deliver this qualification in (if teaching outside of England), or which may have gone out-of-date during the lifespan of the specification. In these instances, it is possible to substitute such references with ones that are current and applicable in the country you deliver subject to confirmation by your Standards Verifier.

## Assessment

Assessment is specifically designed to fit the purpose and objective of the qualification. It includes a range of assessment types and styles suited to vocational qualifications in the sector. There are three main forms of assessment that you need to be aware of: external, internal and synoptic.

### Externally-assessed units

Each external assessment for a BTEC National is linked to a specific unit. All of the units developed for external assessment are of 90 or 120 GLH to allow learners to demonstrate breadth and depth of achievement. Each assessment is taken under specified conditions, then marked by Pearson and a grade awarded. Learners are permitted to resit external assessments during their programme. You should refer to our website for current policy information on permitted retakes.

The styles of external assessment used for qualifications in the Applied Science suite are:

- examinations – all learners take the same assessment at the same time, normally with a written outcome
- set tasks – learners take the assessment during a defined window and demonstrate understanding through completion of a vocational task.

Some external assessments include a period of preparation using set information. External assessments are available twice a year. For detailed information on the external assessments please see the table in *Section 2*. For further information on preparing for external assessment see *Section 5*.

## Internally-assessed units

Most units in the sector are internally assessed and subject to external standards verification. This means that you set and assess the assignments that provide the final summative assessment of each unit, using the examples and support that Pearson provides. Before you assess you will need to become an approved centre, if you are not one already. You will need to prepare to assess using the guidance in *Section 6*.

In line with the requirements and guidance for internal assessment, you select the most appropriate assessment styles according to the learning set out in the unit. This ensures that learners are assessed using a variety of styles to help them develop a broad range of transferable skills. Learners could be given opportunities to:

- write up the findings of their own research
- use case studies to explore complex or unfamiliar situations
- carry out projects for which they have choice over the direction and outcomes
- demonstrate practical and technical skills using appropriate equipment, procedures and techniques.

You will make grading decisions based on the requirements and supporting guidance given in the units. Learners may not make repeated submissions of assignment evidence. For further information see *Section 6*.

## Synoptic assessment

Synoptic assessment requires learners to demonstrate that they can identify and use effectively, in an integrated way, an appropriate selection of skills, techniques, concepts, theories and knowledge from across the whole sector as relevant to a key task. BTEC learning has always encouraged learners to apply their learning in realistic contexts using scenarios and realistic activities that will permit learners to draw on and apply their learning. For these qualifications we have formally identified units which contain a synoptic assessment task. Synoptic assessment must take place after the teaching and learning of other mandatory units in order for learners to be able to draw from the full range of content. The synoptic assessment gives learners an opportunity to independently select and apply learning from across their programmes in the completion of a vocational task. Synoptic tasks may be in internally or externally assessed units. The particular units that contain the synoptic tasks for this qualification are shown in the structure in *Section 2*.

## Language of assessment

Assessment of the internal and external units for these qualifications will be available in English. All learner work must be in English. A learner taking the qualifications may be assessed in British or Irish Sign Language where it is permitted for the purpose of reasonable adjustment. For information on reasonable adjustments see *Section 6*.



## Grading for units and qualifications

Achievement in the qualification requires a demonstration of depth of study in each unit, assured acquisition of a range of practical skills required for employment or progression to HE, and successful development of transferable skills. Learners achieving a qualification will have achieved across mandatory units, including external and synoptic assessment.

Units are assessed using a grading scale of Distinction (D), Merit (M), Pass (P), Near Pass (N) and Unclassified (U). The grade of Near Pass is used for externally-assessed units only. All mandatory and optional units contribute proportionately to the overall qualification grade, for example a unit of 120 GLH will contribute double that of a 60 GLH unit.

Qualifications in the suite are graded using a scale of P to D\*, **or** PP to D\*D\*, **or** PPP to D\*D\*D\*. Please see *Section 9* for more details. The relationship between qualification grading scales and unit grades will be subject to regular review as part of Pearson's standards monitoring processes on the basis of learner performance and in consultation with key users of the qualification.

## UCAS Tariff points

The BTEC Nationals attract UCAS points. Please go to the UCAS website for full details of the points allocated.

# 1 Qualification purpose

## Pearson BTEC Level 3 National Diploma in Applied Science

In this section you will find information on the purpose of this qualification and how its design meets that purpose through the qualification objective and structure. We publish a full 'Statement of Purpose' for each qualification on our website. These statements are designed to guide you and potential learners to make the most appropriate choice about the size of qualification suitable at recruitment.

### Who is this qualification for?

The Pearson BTEC Level 3 National Diploma in Applied Science is intended as an Applied General qualification for post-16 learners who want to continue their education through applied learning and who aim to progress to higher education, and ultimately to employment in the applied science sector. The qualification is equivalent in size to two A Levels, and it has been designed as part of a two-year programme, normally alongside a further Level 3 qualification.

Learners who wish to take this qualification will have successfully completed a Level 2 programme of learning with GCSEs or vocational qualifications.

### What does this qualification cover?

The content of this qualification has been developed in consultation with academics to ensure that it supports progression to higher education. Employers and professional bodies have also been involved and consulted to confirm that the content is appropriate and consistent with current practice.

Learners will study six mandatory units:

- Unit 1: Principles and Application of Science I
- Unit 2: Practical Scientific Procedures and Techniques
- Unit 3: Science Investigation Skills
- Unit 4: Laboratory Techniques and their application
- Unit 5: Principles and Applications of Science II
- Unit 6: Investigative Project.

Learners choose two optional units, which have been designed to support progression to the range of sector-related courses in higher education and to link with relevant occupational areas.

Optional units include:

- Unit 8: Physiology of Human Body Systems
- Unit 11: Genetics and Genetic Engineering
- Unit 13: Applications of Inorganic Chemistry
- Unit 15: Electrical Circuits and their Application
- Unit 22: Materials Science
- Unit 23: Forensic Evidence, Collection and Analysis.

This qualification enables learners to acquire substantial cross-sector scientific knowledge and practical scientific skills, including carrying out practical laboratory tasks, planning investigations, collecting, analysing and presenting data, and reviewing and refining the methodology of practical and laboratory-based work.

## What could this qualification lead to?

The requirements of the qualification will mean that learners develop the transferable and higher order skills which are valued by higher education providers and employers.

The qualification carries UCAS points and is recognised by higher education providers as contributing to admission requirements for many relevant courses. Taken on its own, the National Diploma in Applied Science will offer the opportunity to progress to some science-related degree courses. Taken alongside other qualifications, it will prepare learners to progress to a wider range of degree programmes. For example, taken alongside:

- a BTEC Level 3 National Extended Certificate in Health and Social Care to progress to nursing courses
- an A Level in Psychology to progress to psychology courses
- an A Level in Geography to progress to environmental science courses.

Learners should always check the entry requirements for degree programmes with specific higher education providers.

This qualification is primarily designed to support progression to applied science and related employment after further study at university. However, it also supports learners progressing directly to employment, as the transferable knowledge, understanding and skills will give learners an advantage when applying for a range of entry-level industry training programmes and/or Higher Apprenticeships in areas such as laboratory technician, industrial technician, medical technician.

## How does the qualification provide employability skills?

In the BTEC National units there are opportunities during the teaching and learning phase to give learners practice in developing employability skills. Where employability skills are referred to in this specification, we are generally referring to skills in the following three main categories:

- **cognitive and problem-solving skills:** use critical thinking, approach non-routine problems applying expert and creative solutions, use systems and technology
- **interpersonal skills:** communicating, working collaboratively, negotiating and influencing
- **intrapersonal skills:** self-management, adaptability and resilience, self-monitoring and development, self-presentation.

There are also specific requirements in some units for assessment of these skills where relevant. For example, where learners are required to undertake real or simulated activities.

## How does the qualification provide transferable knowledge and skills for higher education?

All BTEC Nationals provide transferable knowledge and skills that prepare learners for progression to university. The transferable skills that universities value include:

- the ability to learn independently
- the ability to research actively and methodically
- being able to give presentations and being active group members.

BTEC learners can also benefit from opportunities for deep learning where they are able to make connections among units and select areas of interest for detailed study. BTEC Nationals provide a vocational context in which learners can develop the knowledge and skills required for particular degree courses, including:

- reading scientific and technical texts
- effective writing
- analytical skills
- practical skills
- preparation for assessment methods used in degrees.

## 2 Structure

### Qualification structure

#### Pearson BTEC Level 3 National Diploma in Applied Science

##### Mandatory units

There are six mandatory units, three internal and three external. Learners must complete and achieve at Near Pass grade or above in all mandatory external units and achieve a Pass or above in the mandatory internal unit in group A. Learners must complete both mandatory units in group B and achieve a pass or above in at least one unit.

##### Optional units

Learners must complete a 2 optional units.

Pearson BTEC Level 3 National Diploma in Applied Science				
Unit number	Unit title	GLH	Type	How assessed
<b>Mandatory group A units – learners complete and achieve all units</b>				
1	Principles and Applications of Science I	90	Mandatory	External
3	Science Investigation Skills	120	Mandatory and Synoptic	External
5	Principles and Applications of Science II	120	Mandatory	External
6	Investigative Project	90	Mandatory and Synoptic	Internal
<b>Mandatory group B units - learners complete all units</b>				
2	Practical Scientific Procedures and Techniques	90	Mandatory	Internal
4	Laboratory Techniques and their Application	90	Mandatory	Internal
<b>Optional units – learners complete 2 units</b>				
8	Physiology of Human Body Systems	60	Optional	Internal
9	Human Regulation and Reproduction	60	Optional	Internal
10	Biological Molecules and Metabolic Pathways	60	Optional	Internal
11	Genetics and Genetic Engineering	60	Optional	Internal
12	Diseases and Infections	60	Optional	Internal
13	Applications of Inorganic Chemistry	60	Optional	Internal
14	Applications of Organic Chemistry	60	Optional	Internal
15	Electrical Circuits and their Application	60	Optional	Internal
16	Astronomy and Space Science	60	Optional	Internal
17	Microbiology and Microbiological Techniques	60	Optional	Internal
18	Industrial Chemical Reactions	60	Optional	Internal
19	Practical Chemical Analysis	60	Optional	Internal
20	Biomedical Science	60	Optional	Internal
21	Medical Physics Applications	60	Optional	Internal

<b>Unit number</b>	<b>Unit title</b>	<b>GLH</b>	<b>Type</b>	<b>How assessed</b>
<b>22</b>	Materials Science	<b>60</b>	<b>Optional</b>	Internal
<b>23</b>	Forensic Evidence, Collection and Analysis	<b>60</b>	<b>Optional</b>	Internal

## External assessment

This is a summary of the type and availability of external assessment, which is of units making up 46% of the total qualification GLH. See *Section 5* and the units and sample assessment materials for more information.

Unit	Type	Availability
<b>Unit 1: Principles and Applications of Science I</b>	<ul style="list-style-type: none"><li>• Written examination set and marked by Pearson.</li><li>• 2 hours.</li><li>• 90 marks.</li></ul>	<b>Jan and May/June First assessment May/June 2017</b>
<b>Unit 3: Science Investigation Skills</b>	<ul style="list-style-type: none"><li>• A task set and marked by Pearson and completed under supervised conditions.</li><li>• Part A and B are taken in a single session timetabled by Pearson.</li><li>• Learners will have 45 minutes to review Part A before they complete Part B.</li><li>• Part B will be one session lasting one hour and 30 minutes.</li><li>• 60 marks.</li></ul>	<b>Jan and May/June First assessment May/June 2017</b>
<b>Unit 5: Principles and Applications of Science II</b>	<ul style="list-style-type: none"><li>• Written examination set and marked by Pearson.</li><li>• 2.5 hours.</li><li>• 120 marks.</li></ul>	<b>Jan and May/June First assessment January 2018</b>

## Synoptic assessment

The mandatory synoptic assessment requires learners to apply learning from across the qualification to the completion of defined vocational tasks.

Within the assessment for *Unit 3*, learners complete a practical investigation which assesses the skills learnt in the unit though the context of the content areas, and allows learners to apply both transferable and specialist knowledge and skills, drawing on the knowledge they will have met in *Unit 1*.

In delivering these units you need to encourage learners to draw on their broader learning so they will be prepared for the assessment.

Within the assessment for *Unit 6*, following a scientific literature search and review, learners produce a realistic plan and carry out an investigative project. They will then prepare an evaluative report that considers project outcomes and the improvements that could be made. The unit will allow learners to apply both transferable and specialist knowledge and skills from across the whole qualification.

In assessing the unit assignments will require learners to select from and apply their learning from across their programme. The unit provides further information.

Learners complete the tasks using knowledge and understanding from their studies of the sector and apply both transferable and specialist knowledge and skills.

## Employer involvement in assessment and delivery

You are encouraged to give learners opportunities to be involved with employers.

See *Section 4* for more information.

## 3 Units

### Understanding your units

The units in this specification set out our expectations of assessment in a way that helps you to prepare your learners for assessment. The units help you to undertake assessment and quality assurance effectively.

Each unit in the specification is set out in a similar way. There are two types of unit format:

- internal units
- external units.

This section explains how the units work. It is important that all teachers, assessors, internal verifiers and other staff responsible for the programme review this section.

#### Internal units

Section	Explanation
<b>Unit number</b>	The number is in a sequence in the sector. Numbers may not be sequential for an individual qualification.
<b>Unit title</b>	This is the formal title that we always use and it appears on certificates.
<b>Level</b>	All units are at Level 3 on the national framework.
<b>Unit type</b>	This shows if the unit is internal or external only. See structure information in <i>Section 2</i> for full details.
<b>GLH</b>	Units may have a GLH value of 120, 90 or 60 GLH. This indicates the numbers of hours of teaching, directed activity and assessment expected. It also shows the weighting of the unit in the final qualification grade.
<b>Unit in brief</b>	A brief formal statement on the content of the unit that is helpful in understanding its role in the qualification. You can use this in summary documents, brochures etc.
<b>Unit introduction</b>	This is designed with learners in mind. It indicates why the unit is important, how learning is structured, and how learning might be applied when progressing to employment or higher education.
<b>Learning aims</b>	These help to define the scope, style and depth of learning of the unit. You can see where learners should be learning standard requirements ('understand') or where they should be actively researching ('investigate'). You can find out more about the verbs we use in learning aims in <i>Appendix 2</i> .
<b>Summary of unit</b>	This new section helps teachers to see at a glance the main content areas against the learning aims and the structure of the assessment. The content areas and structure of assessment are required. The forms of evidence given are suitable to fulfil the requirements.
<b>Content</b>	This section sets out the required teaching content of the unit. Content is compulsory except when shown as 'e.g.'. Learners should be asked to complete summative assessment only after the teaching content for the unit or learning aim(s) has been covered.

Section	Explanation
<b>Assessment criteria</b>	<p>Each learning aim has Pass and Merit criteria. Each assignment has at least one Distinction criterion.</p> <p>A full glossary of terms used is given in <i>Appendix 2</i>. All assessors need to understand our expectations of the terms used.</p> <p>Distinction criteria represent outstanding performance in the unit. Some criteria require learners to draw together learning from across the learning aims.</p>
<b>Essential information for assignments</b>	<p>This shows the maximum number of assignments that may be used for the unit to allow for effective summative assessment, and how the assessment criteria should be used to assess performance.</p>
<b>Further information for teachers and assessors</b>	<p>The section gives you information to support the implementation of assessment. It is important that this is used carefully alongside the assessment criteria.</p>
<b>Resource requirements</b>	<p>Any specific resources that you need to be able to teach and assess are listed in this section. For information on support resources see <i>Section 10</i>.</p>
<b>Essential information for assessment decisions</b>	<p>This information gives guidance for each learning aim or assignment of the expectations for Pass, Merit and Distinction standard. This section contains examples and essential clarification.</p>
<b>Links to other units</b>	<p>This section shows you the main relationship among units. This section can help you to structure your programme and make best use of materials and resources.</p>
<b>Employer involvement</b>	<p>This section gives you information on the units that can be used to give learners involvement with employers. It will help you to identify the kind of involvement that is likely to be successful.</p>



## External units

Section	Explanation
<b>Unit number</b>	The number is in a sequence in the sector. Numbers may not be sequential for an individual qualification.
<b>Unit title</b>	This is the formal title that we always use and it appears on certificates.
<b>Level</b>	All units are at Level 3 on the national framework.
<b>Unit type</b>	This shows if the unit is internal or external only. See structure information in <i>Section 2</i> for full details.
<b>GLH</b>	Units may have a GLH value of 120, 90 or 60 GLH. This indicates the numbers of hours of teaching, directed activity and assessment expected. It also shows the weighting of the unit in the final qualification grade.
<b>Unit in brief</b>	A brief formal statement on the content of the unit.
<b>Unit introduction</b>	This is designed with learners in mind. It indicates why the unit is important, how learning is structured, and how learning might be applied when progressing to employment or higher education.
<b>Summary of assessment</b>	This sets out the type of external assessment used and the way in which it is used to assess achievement.
<b>Assessment outcomes</b>	These show the hierarchy of knowledge, understanding, skills and behaviours that are assessed. Includes information on how this hierarchy relates to command terms in sample assessment materials (SAMs).
<b>Essential content</b>	For external units all the content is obligatory, the depth of content is indicated in the assessment outcomes and sample assessment materials (SAMs). The content will be sampled through the external assessment over time, using the variety of questions or tasks shown.
<b>Grade descriptors</b>	We use grading descriptors when making judgements on grade boundaries. You can use them to understand what we expect to see from learners at particular grades.
<b>Key terms typically used in assessment</b>	These definitions will help you analyse requirements and prepare learners for assessment.
<b>Resources</b>	Any specific resources that you need to be able to teach and assess are listed in this section. For information on support resources see <i>Section 10</i> .
<b>Links to other units</b>	This section shows the main relationship among units. This section can help you to structure your programme and make best use of materials and resources.
<b>Employer involvement</b>	This section gives you information on the units that can be used to give learners involvement with employers. It will help you to identify the kind of involvement that is likely to be successful.



## Index of units

This section contains all the units developed for this qualification. Please refer to *pages 5–6* to check which units are available in all qualifications in the applied science sector.

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# Unit 1: Principles and Applications of Science I

Level: **3**

Unit type: **External**

Guided learning hours: **90**

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## Unit in brief

This unit covers some of the key science concepts in biology, chemistry and physics. Further key science concepts are considered in *Unit 5: Principles and Applications of Science II*.

## Unit introduction

Scientists and technicians working in science and science-related organisations must have a good understanding of core science concepts. A strong grasp of these concepts will enable you to use and apply this knowledge and understanding in vocational contexts when studying other units within this specification.

The topic areas covered in this unit include: animal and plant cells; tissues; atomic structure and bonding; chemical and physical properties of substances related to their uses; waves and their application in communications.

Scientists and technicians working in the chemical industry need to have an understanding of atoms and electronic structure. This allows them to predict how chemical substances will react in the production of a wide range of products – anything from fertilisers in the farming industry to fragrances in the perfume industry. Metals play an important role in the construction industry, in providing the structure to buildings, as well as in electrical wiring and the production of decorative features. So understanding the chemical and physical properties of metals is essential when selecting appropriate building materials.

Medical professionals need to understand the structure and workings of cells. They build on this knowledge to understand how the body stays healthy as well as the symptoms and causes of some diseases. This allows them to diagnose and treat illnesses. The study of bacterial prokaryotic cells gives an understanding of how some other diseases are caused and can be treated.

Scientists and technicians in the food industry also need to understand the structure and function of plant cells to enable them to develop food crops that produce greater yields.

Knowledge of waves is essential in a wide range of industries and organisations. In the communication industry, scientists and technicians apply their knowledge of the electromagnetic spectrum when designing mobile phone and satellite communication, and fibre optics are used to transmit telephone and television signals. Fibre optics are also used in diagnostic tools in medicine.

To complete the assessment task within this unit, you will need to draw on your learning from across your programme. The knowledge and understanding you will learn in this unit will provide a strong basis for you to progress in the science sector and to a variety of science and related programmes such as higher nationals and degrees.

## Summary of assessment

This unit is assessed through an examination worth 90 marks with a total time of 2 hours, undertaken in three timed sessions of 40 minutes for each of Biology, Chemistry and Physics. Learners must take all three parts of the single examination in the same series to be awarded a result.

The paper will include a range of question types, including multiple choice, calculations, short answer and open response. These question types will assess discrete knowledge and understanding of the content in this unit.

The assessment availability is January and May/June each year. The first assessment availability is May/June 2017.

Sample assessment materials will be available to help centres prepare learners for assessment.

## Assessment outcomes

**AO1** Demonstrate knowledge of scientific facts, terms, definitions and scientific formulae

Command words: give, label, name, state

Marks: ranges from 12 to 18 marks

**AO2** Demonstrate understanding of scientific concepts, procedures, processes and techniques and their application

Command words: calculate, compare, discuss, draw, explain, state, write

Marks: ranges from 39 to 45 marks

**AO3** Analyse, interpret and evaluate scientific information to make judgements and reach conclusions

Command words: calculate, comment, compare, complete, describe, discuss, explain, state

Marks: ranges from 18 to 24 marks

**AO4** Make connections, use and integrate different scientific concepts, procedures, processes or techniques

Command words: comment, compare, complete, discuss, explain

Marks: ranges from 9 to 12 marks

## Essential content

The essential content is set out under content areas. Learners must cover all specified content before the assessment.

### A Periodicity and properties of elements

#### A1 Structure and bonding in applications in science

- Understand the electronic structure of atoms:
  - electronic orbitals
  - Aufbau principle
  - Bohr theory.
- Understand ionic bonding:
  - strong electrostatic attraction between oppositely charged ions
  - effects ionic radius and ionic charge have on the strength of ionic bonding
  - formation of ions in terms of electron loss or gain
  - electronic configuration diagrams of cations and anions.
- Understand covalent bonding:
  - strong electrostatic attraction between two nuclei and the shared pair(s) of electrons between them
  - dot and cross diagrams to show electrons in simple covalent molecules, including those with multiple bonds and dative covalent (coordinate) bonds
  - the relationship between bond lengths and bond strengths in covalent bonds
  - tetrahedral basis of organic chemistry.
- Understand metallic bonding:
  - de-localised electrons
  - positive metal ions
  - regular layer structure.
- Understand the following intermolecular forces:
  - van der Waals
  - dipole-dipole
  - hydrogen bonding.
- Understand the following:
  - balanced equations
  - relative atomic mass
  - atomic number and relative molecular mass
  - moles, molar masses and molarities.
- Understand the quantities used in chemical reactions:
  - mass, volume of solution, concentration
  - reacting quantities
  - percentage yields.

**A2 Production and uses of substances in relation to properties**

- Understand the periodic table:
  - Periods 1, 2, 3 and 4
  - groups – s block, p block, d block
  - layout of periodic table in relation to s, p, d notation
  - electronic arrangement of elements using s, p, d notation.
- Understand the physical properties of elements:
  - first ionisation energy
  - reasons for trends in ionisation energy across Periods 2–4 and down groups 1, 2 and 7
  - electron affinity
  - atomic radius
  - ionic radius
  - electronegativity
  - type of bonding in the element
  - trends – melting point and boiling point
  - physical properties of metals – electrical conductivity, thermal conductivity, malleability, ductility.
- Understand the chemical properties of elements:
  - products and reactivity of all Period 2 and 3 elements with oxygen
  - products and reactivity of metals with oxygen, water, dilute hydrochloric acid and dilute sulfuric acid
  - position of metals in the reactivity series in relation to position in the periodic table
  - oxidation
  - reduction
  - variable oxidation states of transition metal ions
  - displacement reactions of metals/halogens
  - uses and applications of substances produced within this learning aim.

**B Structure and functions of cells and tissues****B1 Cell structure and function**

- Know that cell theory is a unifying concept stating that cells are a fundamental unit of structure, function and organisation in all living organisms.
- Understand the ultrastructure and function of organelles in the following cells:
  - prokaryote cells (bacterial cell) – nucleoid, plasmids, 70S ribosomes, capsule, cell wall
  - eukaryotic cells (plant and animal cells) – plasma membrane, cytoplasm, nucleus, nucleolus, endoplasmic reticulum (smooth and rough), Golgi apparatus, vesicles, lysosomes, 80S ribosomes, mitochondria, centriole
  - eukaryotic cells (plant-cell specific) – cell wall, chloroplasts, vacuole, tonoplast, amyloplasts, plasmodesmata, pits.
- Recognise cell organelles from electron micrographs and the use of light microscopes.
- Understand the similarities and differences between plant and animal cell structure and function.
- Understand how to distinguish between gram-positive and gram-negative bacterial cell walls and why each type reacts differently to some antibiotics.
- Calculate magnification and size of cells and organelles from drawings or images.



**B2 Cell specialisation**

Understand cell specialisation in terms of structure and function, to include:

- palisade mesophyll cells in a leaf
- sperm and egg cells in reproduction
- root hair cells in plants
- white blood cells
- red blood cells.

**B3 Tissue structure and function**

- Understand the structure and function of epithelial tissue, to include:
  - squamous as illustrated by the role of alveolar epithelium in gas exchange to include the effect of chronic obstructive pulmonary disease (COPD) in smokers
  - columnar as illustrated by goblet cells and ciliated cells in the lungs to include their role in protecting lungs from pathogens.
- Understand the structure and function of endothelial tissue, as illustrated by blood vessels in the cardiovascular system, including the risk factors that damage endothelial cells and affect the development of atherosclerosis.
- Understand the structure and function of muscular tissue, to include:
  - the microscopic structure of a skeletal muscle fibre
  - structural and physiological differences between fast- and slow-twitch muscle fibres and their relevance in sport.
- Understand the structure and function of nervous tissue, to include:
  - non-myelinated and myelinated neurones
  - the conduction of a nerve impulse (action potential) along an axon, including changes in membrane permeability to sodium and potassium ions and the role of the myelination in saltatory conduction
  - interpretation of graphical displays of a nerve impulse and electrocardiogram (ECG) recordings
  - synaptic structure and the role of neurotransmitters, including acetylcholine
  - how imbalances in certain, naturally occurring brain chemicals can contribute to ill health, including dopamine in Parkinson's disease and serotonin in depression
  - the effects of drugs on synaptic transmission, including the use of L-Dopa in the treatment of Parkinson's disease.

**C Waves in communication****C1 Working with waves**

- Understand the features common to all waves and use the following terms as applied to waves:
  - periodic time
  - speed
  - wavelength
  - frequency
  - amplitude
  - oscillation.
- Graphical representation of wave features.
- Understand the difference between the two main types of wave:
  - transverse
  - longitudinal.
- Understand concepts of displacement, coherence, path difference, phase difference, superposition as applied to diffraction gratings.

- Understand the industrial application of diffraction gratings, to include:
  - emission spectra
  - identifying gases.

- Be able to use the wave equation:

$$v = f\lambda$$

- Understand the concept and applications of stationary waves resonance.

- Musical instruments.

- Be able to use the equation:

$$\text{calculation of speed } v = \sqrt{\frac{T}{\mu}}$$

## C2 Waves in communication

- Understand the principles of fibre optics:

- refractive index  $n = \frac{c}{v} = \frac{\sin i}{\sin r}$

- total internal reflection

- calculation of critical angles at a glass–air interface:

$$\sin c = \frac{1}{n}$$

- Understand the applications of fibre optics in medicine to include endoscopes.

- Understand the applications of fibre optics in communication, to include:

- analogue and digital signals: analogue-to-digital conversion, broadband.

## C3 Use of electromagnetic waves in communication

- Understand that all electromagnetic waves travel with the same speed in a vacuum.

- Be able to use the inverse square law in relation to the intensity of a wave:

$$I = \frac{k}{r^2}$$

- Understand how the regions of the electromagnetic spectrum are grouped according to the frequency.

- Understand how the applications of electromagnetic waves in communications are related to frequency, including:

- satellite communication

- mobile phones

- Bluetooth®

- infrared

- Wi-Fi.

## Grade descriptors

To achieve a grade learners are expected to demonstrate these attributes across the essential content of the unit. The principle of best fit will apply in awarding grades.

### Level 3 Pass

Learners will be able to recall, select and apply scientific knowledge and understanding to vocational and realistic situations. They will be able to use scientific terminology and concepts in given situations, and to use given information and apply appropriate mathematical and technical skills in context. Learners will be able to interpret and analyse information in order to make valid judgements.

### Level 3 Distinction

Learners will be able to integrate relevant scientific knowledge and understanding from different areas to demonstrate a deeper understanding of how these apply to vocational and realistic situations. They will be able to use scientific terminology and concepts, communicating consistently and effectively in given situations. They will be able to select relevant information and apply appropriate mathematical and technical skills to justify decisions or solve problems in context. Learners will be able to interpret and analyse information in order to make valid judgements that are supported by evidence, with awareness of limitations.

## Key terms typically used in assessment

The following table shows the key terms that will be used consistently by Pearson in our assessments to ensure learners are rewarded for demonstrating the necessary skills.

Please note: the list below will not necessarily be used in every paper/session and is provided for guidance only. Only a single command word will be used per item.

Command or term	Definition
Add/label	Learners label or add to a stimulus material given in the question, for example labelling a diagram or adding units to a table.
Assess	Learners give careful consideration to all the factors or events that apply and identify which are the most important or relevant. Make a judgement on the importance of something and come to a conclusion where needed.
Calculate	Learners obtain a numerical answer, showing relevant working. If the answer has a unit, this must be included.
Comment on	Learners synthesise a number of variables from data/ information to form a judgement. More than two factors need to be synthesised.
Compare	Learners look for the similarities and differences of two (or more) things. Should not require the drawing of a conclusion. Answer must relate to both (or all) things mentioned in the question. The answer must include at least one similarity and one difference.
Complete	Learners complete a table/diagram.
Criticise	Learners inspect a set of data, an experimental plan or a scientific statement and consider the elements. Look at the merits and/or faults of the information presented and back up judgements made.
Deduce	Learners draw/reach conclusion(s) from the information provided.

Command or term	Definition
Derive	Learners combine two or more equations or principles to develop a new equation.
Describe	Learners give an account of something. Statements in the response need to be developed as they are often linked but do not need to include a justification or reason.
Determine	Learners' answers must have an element that is quantitative from the stimulus provided, or must show how the answer can be reached quantitatively. To gain maximum marks there must be a quantitative element to the answer.
Devise	Learners plan or invent a procedure from existing principles/ideas.
Discuss	Learners identify the issue/situation/problem/argument that is being assessed in the question. Explore all aspects of an issue/situation/problem/argument. Investigate the issue/situation, etc. by reasoning or argument.
Draw	Learners produce a diagram, either using a ruler or using freehand.
Evaluate	Learners review information then bring it together to form a conclusion, drawing on evidence, including strengths, weaknesses, alternative actions, relevant data or information. Come to a supported judgement of a subject's qualities and relation to its context.
Explain	Learners' explanations require a justification/ exemplification of a point. The answer must contain some element of reasoning/justification – this can include mathematical explanations.
Give/state/name	These generally require recall of one or more pieces of information.
Give a reason why	When a statement has been made and the requirement is only to give the reasons why.
Identify	Usually requires some key information to be selected from a given stimulus/resource.
Plot	Learners produce a graph by marking points accurately on a grid from data that is provided and then drawing a line of best fit through these points. A suitable scale and appropriately labelled axes must be included if these are not provided in the question.
Predict	Learners give an expected result.
Show that	Learners prove that a numerical figure is as stated in the question. The answer must be to at least one more significant figure than the numerical figure in the question.
Sketch	Learners produce a freehand drawing. For a graph this would need a line and labelled axes with important features indicated. The axes are not scaled.

<b>Command or term</b>	<b>Definition</b>
State and justify/identify and justify	When a selection is made and a justification has to be given for the selection.
State what is meant by	When the meaning of a term is expected but there are different ways in which this meaning can be described.
Write	When the question asks for an equation.

## Links to other units

This assessment for this unit should draw on knowledge, understanding and skills developed from:

- Unit 2 Practical Scientific Procedures and Techniques.

## Employer involvement

Centres may involve employers in the delivery of this unit if there are local opportunities. There is no specific guidance related to this unit.

# Unit 2: Practical Scientific Procedures and Techniques

Level: **3**

Unit type: **Internal**

Guided learning hours: **90**

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## Unit in brief

Learners will be introduced to quantitative laboratory techniques, calibration, chromatography, calorimetry and laboratory safety, which are relevant to the chemical and life science industries.

## Unit introduction

This unit introduces you to standard laboratory equipment and techniques, including titration, colorimetry, calorimetry, chromatography, calibration procedures and laboratory safety. Through the practical tasks in the unit, you will develop proficiency in the quantitative analytical techniques of titration and colorimetry, including learning to calculate the concentration of solutions. You will use measurement of temperature to study cooling curves and be introduced to paper and thin-layer chromatography (TLC). You will also have the opportunity to calibrate equipment and will be encouraged to be aware of the safety aspects of given laboratory procedures and techniques.

While you develop your practical competence, the discussion and analysis of group results will allow you to understand your progress in relation to that of others and also to gain an understanding of the reliability, repeatability and reproducibility of various procedures and techniques. You will have the opportunity to use problem-solving skills when you undertake calorimetry work. There is scope throughout the unit to reflect on the skills you have gained and how you may develop further. .

The fundamental knowledge, practical skills, transferable skills – for example, organisation, self-assessment and problem-solving, and the ability to interpret data – all developed in this unit will give you confidence when you undertake the more complex practical techniques involved in higher education science courses such as biochemistry, chemistry, forensic science and environmental science.

The experience you gain will be invaluable when you begin your career as a trainee laboratory technician in industries such as contract analysis, oil, biopharmaceuticals, water treatment, and polymers. Employers in these industries will appreciate your ability to follow written scientific procedures and your desire to ensure accuracy by using techniques correctly and by checking that equipment – for example, pipettes, balances, pH meters and thermometers – is calibrated correctly and that appropriate standard calibration documentation has been completed.

## Learning aims

In this unit you will:

- A** Undertake titration and colorimetry to determine the concentration of solutions
- B** Undertake calorimetry to study cooling curves
- C** Undertake chromatographic techniques to identify components in mixtures
- D** Review personal development of scientific skills for laboratory work.

## Summary of unit

Learning aim	Key content areas	Recommended assessment approach
<b>A</b> Undertake titration and colorimetry to determine the concentration of solutions	<p><b>A1</b> Laboratory equipment and its calibration</p> <p><b>A2</b> Preparation and standardisation of solutions using titration</p> <p><b>A3</b> Colorimetry</p>	<p>Pro formas of results for checking the calibration of a pipette and balance(s) and calibration of a pH meter.</p> <p>A report on the use of <math>\text{Na}_2\text{CO}_3</math> to standardise HCl, used in turn to standardise NaOH. pH curve from the titration plus a differential plot.</p> <p>Results, calculations and calibration graph for the determination of the concentration of a coloured solution using colorimetry.</p> <p>Explanations of how the accuracy, precision and safety of the quantitative techniques may be optimised.</p> <p>Observation checklist, completed by the teacher, including safety.</p>
<b>B</b> Undertake calorimetry to study cooling curves	<p><b>B1</b> Thermometers</p> <p><b>B2</b> Cooling curves</p>	<p>Results from checking the calibration of at least two types of thermometer.</p> <p>A table of time/temperature data and a graph of temperature against time for a substance cooling.</p> <p>Calculations of the rate of cooling at points on the graph.</p> <p>An analysis of how the rate of cooling is related to intermolecular forces and the state of the substance.</p> <p>A report evaluating the accuracy of the cooling curve experiment.</p> <p>An observation report with a checklist, completed by the teacher, including safety.</p>
<b>C</b> Undertake chromatographic techniques to identify components in mixtures	<p><b>C1</b> Chromatographic techniques</p> <p><b>C2</b> Application of chromatography</p> <p><b>C3</b> Interpretation of a chromatogram</p>	<p>Results from the paper chromatography and TLC of extracted plant pigments from paper chromatography of amino acids.</p> <p>An explanation of the principles behind the chromatographic separations.</p> <p>Suggestions for improvements to the chromatographic procedures carried out and full justification of these suggestions.</p> <p>An observation report with a checklist, completed by the teacher, including safety.</p>
<b>D</b> Review personal development of scientific skills for laboratory work	<p><b>D1</b> Personal responsibility</p> <p><b>D2</b> Interpersonal skills</p> <p><b>D3</b> Professional practice</p>	<p>A presentation or report that focuses on the evaluation of learners' performance and skill development across all scientific procedures and techniques carried out in learning aims A, B and C.</p>



## Content

### Learning aim A: Undertake titration and colorimetry to determine the concentration of solutions

#### A1 Laboratory equipment and its calibration

Equipment and glassware used in titration and colorimetry and the importance and processes involved in calibration of measuring equipment.

- Use of pH meters and probes:
  - calibration according to the manufacturer's instructions.
- Use of balances and weighing:
  - electronic balances – rough balances (two decimal places), analytical balances (four decimal places)
  - checking calibration with certified weights
  - measurement of mass using increasingly accurate balances
  - suitable containers for weighing liquids and solids
  - density of water at different temperatures.
- Safe use of volumetric glassware:
  - bulb, graduated, automated and teat pipettes
  - burettes
  - glass and plastic filter funnels
  - volumetric flasks
  - accurate dilution
  - use of water as a standard for calibrating volumetric glassware.

#### A2 Preparation and standardisation of solutions using titration

Processes involved in the preparation and standardisation of solutions using titration.

- Accurate determination of the end-point of titrations from:
  - the colour change of a suitable indicator
  - plots of pH versus volume
  - $\Delta\text{pH}/\Delta\text{volume}$  versus volume.
- Calculation of concentrations:
  - use of molecular mass from periodic table.
- Use of primary and secondary titrimetric standards.

#### A3 Colorimetry

Understanding and practical application of colorimetry techniques.

- Selection and use of a colorimeter or visible spectrometer – selection of filter (colorimeter) or fixed wavelength (spectrometer).
- Measurement and use of absorbance readings.
- Use of Beer-Lambert law to determine the concentration of a transition metal ion solution.
- Accurate dilution of stock solutions to prepare a range of calibration standards with absorbance in the range 0 to 1.
- Use of blank solutions.
- Calibration plot.
- Determination of unknown solution concentration from reading from graph (graph paper) or from the equation of a linear trend line through the origin (Microsoft Excel).

**Learning aim B: Undertake calorimetry to study cooling curves****B1 Thermometers**

Types of thermometer, appropriate use and practical application of measurements of heat.

- The relationship between temperature and heat energy.
- Types of thermometer and how they are used to gain accurate readings:
  - electronic thermometers/temperature probes
  - liquid-filled thermometers.
- Checking the calibration of thermometers by using ice and boiling water.
- Accuracy of thermometers and temperature probes at different temperatures.

**B2 Cooling curves**

Construction and interpretation of cooling curves:

- temperature as a function of time
- rate of cooling from the gradient of the tangent to the cooling curve
- determination of melting point from the shape of a curve for a substance freezing
- super cooling
- shape of the curve and rate of cooling in relation to intermolecular forces and the state (solid or liquid) of the substance.

**Learning aim C: Undertake chromatographic techniques to identify components in mixtures****C1 Chromatographic techniques**

Theory, equipment and procedures used in chromatography.

- Terminology:
  - mobile and stationary phases
  - adsorption.
- Principles of paper chromatography.
- Principles of thin-layer chromatography (TLC):
  - nature of a TLC plate – glass, metal or plastic sheet with solid adsorbent layer.
- Use of capillary tubes to apply mixtures to paper or TLC plates.
- Choice of developing solvent and vessel.
- Preparative methods for samples:
  - solvent extraction
  - filtration
  - concentration by evaporation.
- The use of locating agents.

**C2 Application of chromatography**

- Separation of components of a mixture, to include plant pigments extracted from leaves/herbs with propanone (paper chromatography and TLC).
- Identification of unknown mixtures and pure substances using chromatography, to include amino acids (paper chromatography).
- Awareness of other types of chromatography – e.g. gas chromatography, ion-exchange chromatography – and that procedures and chromatogram interpretations are very different.

**C3 Interpretation of a chromatogram**

- Polarity of molecules/intermolecular forces in relation to solubility in the mobile phase.
- Polarity of molecules/intermolecular forces in relation to retention of molecules in the stationary phase.
- Size of molecules in relation to solubility and mobility.
- Calculation of R<sub>f</sub> value.
- Interpretation of chromatograms in terms of the number of substances present and the R<sub>f</sub> values of components.
- Awareness of common problems in technique resulting in difficulty interpreting a chromatogram, e.g. overloading samples, disturbing plate/paper during development or contamination of plate/paper.

**Learning aim D: Review personal development of scientific skills for laboratory work****D1 Personal responsibility**

Understanding of the personal responsibilities that must be accepted for successful work in science.

- Work to appropriate standards and protocols.
- Application of safe working practices.
- Accept responsibility for the quality of own work.
- Take responsibility for completing tasks and procedures as well as using judgements within defined parameters.

**D2 Interpersonal skills**

Understanding and development of skills for effective and efficient working with others:

- communication and co-operation in the scientific working environment
- give and receive constructive feedback
- behaviour for safe and efficient working in science.

**D3 Professional practice**

Understanding and personal development of standard practices applicable to working as a professional scientist:

- recognise problems and apply appropriate scientific methods to identify causes and achieve solutions
- identify, organise and use resources effectively to complete tasks
- maintain and enhance competence.

## Assessment criteria

Pass	Merit	Distinction
<b>Learning aim A: Undertake titration and colorimetry to determine the concentration of solutions</b>		<b>A.D1</b> Evaluate the accuracy of procedures and techniques used in titration and colorimetry in relation to outcomes and suggest improvements.
<b>A.P1</b> Correctly prepare and standardise solutions for titration and colorimetry. <b>A.P2</b> Investigate the concentration of unknown solutions, using procedures and techniques in titration and colorimetry.	<b>A.M1</b> Demonstrate skilful application of procedures and techniques in titration and colorimetry to accurately determine the concentration of solutions.	
<b>Learning aim B: Undertake calorimetry to study cooling curves</b>		<b>B.D2</b> Evaluate the accuracy of practical work in calorimetry in relation to the analysis of the cooling curve.
<b>B.P3</b> Correctly obtain data using different equipment to construct cooling curves. <b>B.P4</b> Correctly determine the rate of cooling of substances using cooling curves.	<b>B.M2</b> Analyse the rate of cooling of substances from your data using cooling curves to draw valid conclusions.	
<b>Learning aim C: Undertake chromatographic techniques to identify components in mixtures</b>		<b>C.D3</b> Evaluate the chromatographic techniques used in relation to outcomes and suggest improvements.
<b>C.P5</b> Correctly use chromatographic techniques to produce chromatograms. <b>C.P6</b> Explain the use of chromatographic techniques to separate mixtures.	<b>C.M3</b> Analyse own chromatograms and relate the factors that affect the separation of mixtures to the quality of results obtained.	
<b>Learning aim D: Review personal development of scientific skills for laboratory work</b>		<b>D.D4</b> Evaluate scientific skills developed in terms of potential for future progression.
<b>D.P7</b> Summarise key personal competencies developed in relation to scientific skills undertaken.	<b>D.M4</b> Analyse skills developed and suggest improvements to own practice.	

## Essential information for assignments

The recommended structure of assessment is shown in the unit summary along with suitable forms of evidence. *Section 6* gives information on setting assignments and there is further information on our website.

There is a maximum number of four summative assignments for this unit. The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.P2, A.M1, A.D1)

Learning aim: B (B.P3, B.P4, B.M2, B.D2)

Learning aim: C (C.P5, C.P6, C.M3, C.D3)

Learning aim: D (D.P7, D.M4, D.D4)

## Further information for teachers and assessors

### Resource requirements

For this unit, learners must have access to:

- a well-equipped laboratory with a fume cupboard
- accurate balances
- a range of volumetric glassware
- pH meters, thermometers and temperature probes (access to data-logging software is useful but not essential)
- colorimeter or visible spectrometer
- chromatography paper, TLC slides
- a range of suitable chemicals, dependent on specific practical work that centres choose to utilise.

### Essential information for assessment decisions

#### Learning aim A

**For distinction standard,** learners will interpret outcomes of their quantitative analytical procedures and techniques to make sound judgements on the accuracy of them. They will place the accuracy of their results in the context of those obtained by other learners in a meaningful and quantitative way. Learners will be able to coherently discuss problems/issues with the quantitative procedures and techniques used and develop a strong rationale for suggestions made to improve accuracy and precision in order to obtain reliable and valid outcomes (or for justifying the appropriate steps already taken should no problems be identified).

Learners will provide sound discussion of inherent hazards and risks associated with the analytical techniques and procedures, for example justifying why certain aspects are carried out in a particular way on safety grounds.

**For merit standard,** learners will undertake quantitative analytical procedures and techniques with minimal supervision, and perform to a high degree of accuracy and precision in order to obtain reliable and valid outcomes, with consideration for health and safety. Learners will demonstrate skill and fluency in a number of areas, such as: calibrating pipettes transferring solids, measuring volumes, mixing solutions, carrying out titrations and making the dilutions for colorimetry standards. They will be fully prepared in terms of equipment, reference material and consumables before attempting each step.

**For pass standard,** learners will follow instructions to safely undertake titration and colorimetry, although they may need to refer frequently to the instructions. These must be performed correctly to obtain reliable and valid outcomes. Learners will correctly carry out calculations of concentration.

For titration, learners will check the calibration of equipment used to ensure the validity of outcomes obtained (for example the calibration of a pipette, balances and a pH meter using buffer solutions). It is expected that learners will be assessed making a solution by weighing a solid, making the solution to volume and shaking to ensure that it mixes thoroughly. They could use a primary standard acid/base in a titration to standardise sodium hydroxide/hydrochloric acid prepared by the learner. Learners must also safely and correctly calibrate and use a colorimeter or visible spectrometer to determine the concentration of a coloured solution.

## Learning aim B

**For distinction standard,** learners will interpret outcomes of their calorimetry to make sound judgements on accuracy. Learners will be able to use appropriate mathematical terminology (for example rapid increase, decrease, approximately constant, etc.) to describe the patterns and trends in the shapes of cooling curves. They will be able to use the cooling curve of a substance to evaluate how close their values for the melting points are to literature and to class values, explaining where specific errors or problems with the given method or equipment may have led to inaccuracy. Learners could, for example, discuss the way in which the substance was cooled and the resulting changes to the curve. Learners will explain why it may be necessary to make changes to procedures in order to reduce levels of uncertainty.

**For merit standard,** learners will demonstrate selection of an appropriate amount of solid; selection of a suitable vessel for heating the solid, setting up the equipment to enable heating and cooling of the vessel in an appropriate way and monitoring temperature as a function of time in a safe way.

Learners will demonstrate numerical skills in graph plotting when constructing their cooling curve. These must include selecting the most appropriate scale, using appropriate labels including units, and drawing a smooth, best-fit curve through the points. By drawing tangents at appropriate points and finding their gradients, learners will correctly determine the rate of cooling near the start, end and where the rate appears to have changed dramatically in between. They will draw valid conclusions linking the rate of cooling to what is happening at a molecular level in terms of the positions and velocity of molecules and the forces between them. They will be able to explain which part of the graph corresponds to, for example, the melting point (freezing temperature).

**For pass standard,** learners will safely check the calibration of a given thermometer, following instructions. This could be done by using ice and boiling water. Learners will also explore the accuracy of the temperature measurements obtained from thermometers and other equipment by comparing their readings in water that is being heated. Learners will use a table of their own design for recording their readings. Learners will demonstrate key practical competencies in calorimetry, including being able to set up a vessel containing a solid, heating it to above its melting point, cooling it and measuring its temperature as a function of time, following a standard procedure.

Learners will plot graphs for a substance undergoing freezing. Learners might not select the most appropriate scale but will label axes correctly and draw a smooth curve through the points. They will accurately determine the rate of cooling near the start, demonstrating the ability to draw a tangent to the curve and find its gradient.

## Learning aim C

**For distinction standard,** learners will articulate strong links between outcomes and techniques used in order to give a rationale for specific improvements that could be made to the chromatographic techniques. They will articulate what would happen if a particular change were to be made. They will demonstrate awareness that some chromatograms may show the spots rising at an angle or have spots that are too big or smeared out rather than being distinct.

**For merit standard,** learners will demonstrate safe working practices and a high level of proficiency when carrying out paper- and thin-layer chromatography (TLC) with minimal supervision. They will produce chromatograms showing clear separation of spots, repeating the separations if they are not satisfied with the quality of the separation obtained. Learners will also comment on the suitability of the techniques for separation.

Learners will use appropriately calculated  $R_f$  values and consider factors that influence separation to justify conclusions drawn about the identification of components in a mixture (for example the polarity of the components of the mixtures and the polarity of the solvents and effect of the size of a molecule on its mobility).

**For pass standard,** learners will follow instructions, demonstrating safe working practices and a good level of ability when carrying out paper and TLC. Learners will comment on the suitability of the techniques for separation and the chromatogram produced for each technique (TLC and paper chromatography). At this standard, the chromatograms may not produce spots showing an optimum degree of separation (for example the spots may be too large and lacking in distinction). They will determine  $R_f$  values using paper chromatograms, using these to correctly identify components in a mixture.

### Learning aim D

**For distinction standard,** learners will draw upon all areas of practical work carried out to critically reflect on strengths and weaknesses of their own performance and skill development drawing on feedback, for example from peers, teachers and industry. Drawing on others' feedback is crucial for developing balanced progression goals.

**For merit standard,** learners will need to make judgements on their skill development and level in relation to their peer group. They will need to recognise the improvements that need to be made and how they will take steps to achieve them.

**For pass standard,** learners will identify areas of scientific skills developed in relation to the learning aims. They should draw on scientific skills they have previously acquired and use them to illustrate the transferability and development of skills.

### Links to other units

This unit links to:

- Unit 1: Principles and Applications of Science I
- Unit 3: Science Investigation Skills
- Unit 4: Laboratory Techniques and their Application
- Unit 19: Practical Chemical Analysis.

This unit also links to a wide range of optional units available across the qualification.

### Employer involvement

Centres may involve employers in the delivery of this unit if there are local opportunities. It would be beneficial for an industry representative to explain the importance of the routine calibration of equipment in ensuring the reliability of results. A visit to a local laboratory would reinforce the importance of calibration of equipment and health and safety. Even if the local organisations that use science only operate on a small scale, their representatives will be able to reinforce the importance of the transferable skills this unit develops.



## Unit 3: Science Investigation Skills

Level: **3**

Unit type: **External**

Guided learning hours: **120**

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### Unit in brief

Learners will cover the stages involved and the skills needed in planning a scientific investigation: how to record, interpret, draw scientific conclusions and evaluate.

### Unit introduction

Advancement in science and technology has produced great benefits for society. This advancement depends on research and investigative approaches in science and technology. In research, development, analytical and industrial laboratories, laboratory technicians and scientists are employed to safely carry out practical investigations, or follow prescribed laboratory procedures. They repeat measurements to obtain consistent, reliable results. They use investigative skills, including planning, recording and interpreting data, analysing and evaluating findings in order to test a hypothesis to inform further research and development.

In this unit, you will develop the essential skills underpinning practical scientific investigations. As well as drawing on *Unit 1* and *Unit 2*, these skills will be delivered through subject themes ranging from enzymes and diffusion to electrical circuits. The subject themes provide different contexts for the development of the investigative skills. To complete the assessment task within this unit, you will need to draw on your learning from across your programme.

Science investigative skills will help you in many scientific or enquiry-based learning courses in higher education, as well as prepare you for employment in a science-related industry.

### Summary of assessment

This unit will be assessed through a written task (Part B) worth 60 marks. The task is set and marked by Pearson and will be completed in one sitting, within a supervised assessment session timetabled by Pearson.

The assessment task will assess learners' ability to plan, record, process, analyse and evaluate scientific findings, using secondary information/data from scientific investigations related to the unit content.

In order to complete the written task in Part B, learners will be provided with Part A. Part A will outline the method/materials used to generate results/observations from a practical investigation.

Learners will have 45 minutes to review Part A before they complete Part B. Part B will be one session lasting one hour and 30 minutes. Both Part A and B will be under supervised conditions.

Part A and B are taken in a single session timetabled by Pearson.

The assessment availability is in January and May/June.

Sample assessment materials will be available to help centres prepare learners for the assessment.

## Assessment outcomes

**AO1** Demonstrate knowledge and understanding of scientific concepts, procedures, processes and techniques and their application in a practical investigative context

**AO2** Interpret and analyse qualitative and quantitative scientific information to make reasoned judgements and draw conclusions based on evidence in a practical investigative context

**AO3** Evaluate practical investigative procedures used and their effect on the qualitative and quantitative scientific information obtained to make reasoned judgements

**AO4** Be able to make connections between different scientific concepts, procedures, processes and techniques to make a hypothesis and write a plan for a practical investigation

## Essential content

The essential content is set out under content areas. Learners must cover all specified content before the assessment.

### A Planning a scientific investigation

#### A1 Developing a hypothesis for an investigation

- Be able to formulate a hypothesis or a null hypothesis based on relevant scientific ideas.

#### A2 Selection of appropriate equipment, techniques and standard procedures

- Be able to select and justify the use of equipment/techniques/standard procedures for quantitative and/or qualitative investigations.

#### A3 Health and safety associated with the investigation

- Understand risks and hazards associated with the investigation.

#### A4 Variables in the investigation

- Independent.
- Dependent.
- Control.

#### A5 Method for data collection and analysis

- Be able to produce a clear, logically ordered method to obtain results.
- Be able to select relevant measurements and the range of measurements to be recorded.
- Understand the importance of obtaining data accurately/reliably and to appropriate levels of precision.
- Understand how variables can be controlled/measured/monitored.
- Understand how the data/information can be analysed.

### B Data collection, processing and analysis/interpretation

#### B1 Collection of quantitative/qualitative data

- Be able to collect data accurately/reliably and to appropriate levels of precision.
- Be able to tabulate data in a clear and logical format using correct headings with units where appropriate.
- Be able to identify anomalous data and take appropriate action.
- Be able to recognise when it is appropriate to take repeats.
- Be able to make qualitative observations and draw inferences.

#### B2 Processing data

- Be able to carry out relevant calculations where appropriate, involving:
  - mean and standard deviation
  - use and interpretation of error bars
  - measuring gradients of a line and/or curve
  - use of statistical tests, including t-test, chi-squared and correlation analysis
  - use of formulae
  - transposition of formulae
  - conversion of units
  - use of standard form
  - percentage error of measuring equipment.
- Be able to display data in an appropriate format, including:
  - choosing an appropriate graph/chart/tables
  - correct plotting/labelling/scales.

## **C Drawing conclusions and evaluation**

### **C1 Interpretation/analysis of data**

- Be able to identify trends/patterns in data.
- Be able to compare primary and secondary data.
- Be able to use data to draw conclusions that are valid and relevant to the purpose of the investigation.
- Interpretation of statistical tests using tables of critical values and a 5% significance level, with reference to the null hypothesis.

### **C2 Evaluation**

- Be able to make any recommendations for improvements to the investigation.
- Be able to explain anomalous data.
- Be able to determine quantitative and discuss qualitative sources of error.
- Be able to discuss evidence of the reliability of the data collected during the investigation.
- Be able to identify strengths and weaknesses within method/techniques/standard procedures/equipment used.
- Be able to suggest improvements to an investigation.

## **D Enzymes in action**

### **D1 Protein structure**

- Peptide linkage.
- Active sites.
- Denaturation.

### **D2 Enzymes as biological catalysts in chemical reactions**

- Collision theory.
- Formation of enzyme-substrate complex.
- Specificity of enzymes.
- Lowering of activation energy.
- Importance of measuring initial rates of reaction.

### **D3 Factors that can affect enzyme activity**

- Temperature.
- pH.
- Substrate and enzyme concentration.

## **E Diffusion of molecules**

### **E1 Factors affecting the rate of diffusion**

- Concentration gradient.
- Shape and size of molecules.
- Temperature.
- Diffusion distance.
- Surface area – surface area to volume ratio.
- Energy of molecules.
- Membranes and barriers.

### **E2 Arrangement and movement of molecules**

- Random movement of molecules in liquids and gases.
- Little movement of molecules in solids.
- Diffusion down a concentration gradient until dynamic equilibrium is reached.

## **F Plants and their environment**

### **F1 Factors that can affect plant growth and/or distribution**

- Human effects – trampling, pollution, deforestation.
- Soil pH and aeration.
- Light intensity – shaded and unshaded areas.
- Temperature.
- Presence of water – moisture and rainfall.
- Mineral ions.
- Competition – intraspecific and interspecific.

### **F2 Sampling techniques**

- Understand the importance of random sampling in collecting reliable and valid data for analysis.
- Select appropriate ecological sampling techniques to investigate the effect of abiotic factors on plant populations, including:
  - transects
  - quadrats (open and gridded)
  - point frames.

### **F3 Sampling sizes**

- Select sample sizes for investigation with regards to practical constraints and the need to collect sufficient data to make valid conclusions.

## **G Energy content of fuels**

### **G1 Fuels**

- Alcohols – methanol, ethanol, propanol, butanol, pentanol.
- Foods – carbohydrates, lipids, protein.
- Hydrocarbons – petrol, paraffin, wax.

### **G2 Hazards associated with fuels**

- Flammability – risk of explosion.
- Toxicity – harmful effects of products of incomplete combustion.
- Pollution from sulfur impurities.

### **G3 Units of energy**

- Define – joules, kilojoules, calories, kilocalories.
- Heat capacity of water (will be given if required).
- Calculate heat energy supplied by a fuel to water using:
  - $\text{heat energy} = \text{mass of water} \times \text{specific heat capacity of water} \times \text{temperature rise of water}$ .
- Calculate heat energy released from a fuel in  $\text{kJ mol}^{-1}$ .

## H Electrical circuits

### H1 Use of electrical components in series and parallel circuits

- Cells, batteries, power packs.
- Ammeter.
- Voltmeter.
- Lamps.
- Resistors – thermistors, LDRs.
- Diodes – photodiodes, LEDs.

### H2 Equations

- Power = voltage  $\times$  current ( $P = I \times V$ ).
- Voltage = current  $\times$  resistance ( $V = I \times R$ )
- Power =  $\frac{\text{work done}}{\text{time}}$  ( $P = \frac{E}{t}$ )
- Energy = voltage  $\times$  current  $\times$  time ( $E = V \times I \times t$ ).

### H3 Energy usage

- Consider different domestic appliances to calculate energy usage.
- Relate fuse size to current.
- Energy transferred = power in kilowatts  $\times$  time in hours ( $kWh = kW \times h$ ).

## Grade descriptors

To achieve a grade a learner is expected to demonstrate these attributes across the essential content of the unit. The principle of best fit will apply in awarding grades.

### Level 3 Pass

Learners will demonstrate a sound knowledge and understanding of scientific concepts, procedures, processes and techniques and their application within a practical context. Learners will interpret and analyse secondary data, leading to reasoned judgements on the qualitative and quantitative data collected during an investigation. They will be able to draw links between different scientific concepts, procedures, processes and techniques to make a hypothesis and plan an investigation. Learners will be able to make evaluative judgements on scientific data, processes and procedures that make reference to scientific reasoning.

### Level 3 Distinction

Learners will demonstrate a thorough understanding of how scientific concepts, procedures, processes and techniques can be integrated and applied within a practical context. They will interpret, analyse and evaluate secondary data to support judgements and conclusions drawn. Learners will use and integrate knowledge and understanding of scientific concepts, procedures, processes and techniques to make a hypothesis and plan an investigation that is fully supported by scientific reasoning. Learners will be able to provide rationalised evaluative judgements on scientific data, processes and procedures that are fully supported by scientific reasoning.

## Key terms typically used in assessment

The following table shows the key terms that will be used consistently by Pearson in our assessments to ensure students are rewarded for demonstrating the necessary skills.

Please note: the list below will not necessarily be used in every paper/session and is provided for guidance only.

Only a single command word will be used per item.

Command or term	Definition
Add/label	Learners label or add to a stimulus material given in the question, for example labelling a diagram or adding units to a table.
Assess	Learners give careful consideration to all the factors or events that apply and identify which are the most important or relevant. Make a judgement on the importance of something, and come to a conclusion where needed.
Calculate	Learners obtain a numerical answer, showing relevant working. If the answer has a unit, this must be included.
Comment on	Learners synthesise a number of variables from data/information to form a judgement. More than two factors need to be synthesised.
Compare	Learners look for the similarities and differences of two (or more) things. Should not require the drawing of a conclusion. Answer must relate to both (or all) things mentioned in the question. The answer must include at least one similarity and one difference.
Complete	Learners complete a table/diagram.
Convert	Relates to unit conversion, for example g to kg.
Deduce	Learners draw/reach conclusion(s) from the information provided.

Command or term	Definition
Derive	Learners combine two or more equations or principles to develop a new equation.
Describe	Learners give an account of something. Statements in the response need to be developed as they are often linked but do not need to include a justification or reason.
Determine	Learners' answers must have an element which is quantitative from the stimulus provided, or must show how the answer can be reached quantitatively. To gain maximum marks there must be a quantitative element to the answer.
Discuss	Learners identify the issue/situation/problem/argument that is being assessed in the question. Explore all aspects of an issue/situation/problem argument. Investigate the issue/situation etc. by reasoning or argument.
Draw	Learners produce a diagram, either using a ruler or using freehand.
Estimate	Learners give a numerical value expected based on data given.
Evaluate	Learners review information then bring it together to form a conclusion, drawing on evidence including strengths, weaknesses, alternative actions, relevant data or information. Come to a supported judgement of a subject's qualities and relation to its context.
Explain	Learners' explanations require a justification/exemplification of a point. The answer must contain some element of reasoning/justification, this can include mathematical explanations.
Give/state/name	These generally require recall of one or more pieces of information.
Give a reason why	When a statement has been made and the requirement is only to give the reasons why.
Identify	Usually requires some key information to be selected from a given stimulus/resource.
Plot	Learners produce a graph by marking points accurately on a grid from data that is provided and then drawing a line of best fit through these points. A suitable scale and appropriately labelled axes must be included if these are not provided in the question.
Predict	Learners give an expected result.
Record	Specifically relates to devising a results table.
Show that	Learners prove that a numerical figure is as stated in the question. The answer must be to at least one more significant figure than the numerical figure in the question.
Sketch	Learners produce a freehand drawing. For a graph this would need a line and labelled axis with important features indicated. The axes are not scaled.
State and justify/identify and justify	When a selection is made and a justification has to be given for the selection.
State what is meant by	When the meaning of a term is expected but there are different ways in which this meaning can be described.
Write	When the question asks for an equation.



## Links to other units

This assessment for this unit should draw on knowledge, understanding and skills developed from:

- Unit 1 Principles and Applications of Science
- Unit 2 Practical Scientific Procedures and Techniques
- Unit 4 Laboratory Techniques and their Application
- Unit 5 Principles and Applications of Science II
- Unit 6 Investigative Project.

## Employer involvement

Centres may involve employers in the delivery of this unit if there are local opportunities. There is no specific guidance related to this unit.



# Unit 4: Laboratory Techniques and their Application

Level: **3**

Unit type: **Internal**

Guided learning hours: **90**

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## Unit in brief

This unit covers the importance of health and safety in work place laboratories, how data is stored and communicated and how organic liquids and solids are made and tested industrially.

## Unit introduction

In this unit, you will investigate a scientific organisation to gain an understanding of how it operates. You will investigate health and safety practices in the organisation's laboratories and consider related primary and secondary legislation. You will also have the opportunity to compare the approach taken to hazards and risk management in different part of the organisation, for example production, the warehouse, the office. It is important to realise that, whether you progress to employment in the science industry or to higher education in science, you will have to be aware of the relevant hazards and to follow the practices that have been developed for your safety.

You will gain a valuable insight into the operation of the pharmaceutical and bulk chemistry industries by making and testing two organic compounds – a liquid and a solid – exploring how industrial production differs from the process that you carry out in the laboratory. You will also investigate the different methods for testing the purity of the products.

Management of data/information is becoming increasingly sophisticated. You will investigate how data/information within the organisation is stored, used and communicated. You will learn about the procedures used for recording laboratory information that ensure it is sufficiently detailed, accessible and traceable. Large amounts of data are available for others to use for research purposes, for example by organisations interested in DNA sequencing or in healthcare. You will explore how these data may be used and consider the benefits and issues associated with accessing and with making large quantities of data available for research.

Not only will this unit give you some understanding of the workplace environment you may enter after finishing this course or after completing a scientific higher education programme, it will also allow you to develop an appreciation of how laboratory preparation and testing of compounds may be scaled up by industry, and of how data is managed within the organisation.

## Learning aims

In this unit you will:

- A** Understand the importance of health and safety in scientific organisations
- B** Explore manufacturing techniques and testing methods for an organic liquid
- C** Explore manufacturing techniques and testing methods for an organic solid
- D** Understand how scientific information may be stored and communicated in a workplace laboratory.

## Summary of unit

Learning aim	Key content areas	Recommended assessment approach
<b>A</b> Understand the importance of health and safety in scientific organisations	<b>A1</b> Application of health and safety legislation in scientific organisations <b>A2</b> Hazards in scientific organisations	A report describing health and safety legislation relevant to an organisation, describing the hazards and discussing aspects of health and safety management.
<b>B</b> Explore manufacturing techniques and testing methods for an organic liquid	<b>B1</b> Manufacturing techniques <b>B2</b> Testing methods and techniques	A report containing: <ul style="list-style-type: none"> <li>• notes and results from making and testing an organic liquid</li> <li>• a description of the principles behind the preparative methods and tests used</li> <li>• analysis of ways to improve yield and purity and the reliability of testing methods as a guide to purity</li> <li>• an explanation of the principles behind the industrial manufacture and testing of the liquid</li> <li>• an observation report by the teacher of making and testing the liquid safely.</li> </ul>
<b>C</b> Explore manufacturing techniques and testing methods for an organic solid	<b>C1</b> Manufacturing techniques <b>C2</b> Industrial manufacturing techniques <b>C3</b> Estimation of purity	A report containing: <ul style="list-style-type: none"> <li>• notes and results from making and testing an organic solid</li> <li>• a description of the principles of preparative methods and tests used</li> <li>• analysis of ways to improve yield and purity and of the reliability of testing methods as a guide to purity</li> <li>• an explanation of the principles behind the industrial manufacture and solid</li> <li>• an observation report by teacher of making and testing the solid safely.</li> </ul>
<b>D</b> Understand how scientific information may be stored and communicated in a workplace laboratory	<b>D1</b> Systems for managing laboratory information <b>D2</b> Communicating information in a scientific organisation <b>D3</b> Use of informatics for storage and retrieval of scientific information	A report containing: <ul style="list-style-type: none"> <li>• a description of the information stored and used in the laboratory</li> <li>• a description of how useful information can be obtained from large data sets</li> <li>• analysis of the communication channels in the organisation</li> <li>• evaluation of the benefits and issues involved in making large volumes of data available to others.</li> </ul>

## Content

### Learning aim A: Understand the importance of health and safety in scientific organisations

#### A1 Application of health and safety legislation in scientific organisations

- Health and safety at work legislation, including:
  - management of health and safety
  - personal protective equipment (PPE)
  - use and control of hazardous substances
  - manual handling operations
  - display screen , classification, labelling and packaging regulations
  - reporting of injuries, diseases and dangerous occurrences.
- Health and safety policy or health, safety and environmental policy – scrutiny of examples from the workplace.
- Consequences of not complying with health and safety legislation.

#### A2 Hazards in a scientific organisation

- Control of Major Accident Hazards (COMAH) sites.
- Explosive atmospheres.
- Electrical hazards.
- Working at height.
- Lone working.
- Vehicles.
- Sensitisers.
- Noise.
- Working environments in scientific settings:
  - laboratories
  - educational settings.

### Learning aim B: Explore manufacturing techniques and testing methods for an organic liquid

#### B1 Manufacturing techniques

- Reflux:
  - principles
  - equipment in the laboratory and in industry.
- Distillation:
  - simple and fractional
  - laboratory distillation equipment
  - distillation towers used in industry.
- Solvent extraction:
  - liquid to liquid.
- Use of chemicals to remove impurities:
  - anhydrous sodium carbonate to react with unreacted acid
  - anhydrous calcium chloride to remove water
  - molecular sieves to remove water and other impurities (depending on pore size)
  - addition of water to remove impurities soluble in water.
- Manufacture of either ethyl ethanoate or 3-methylbut-1-yl ethanoate (banana oil) – one method to be selected:
  - laboratory scale – from ethanol and ethanoic acid (for ethyl ethanoate)
  - industrial scale – from ethanol and ethanoic acid (for ethyl ethanoate)
  - other commercial methods.

**B2 Testing methods and techniques**

- Measurement of boiling point:
  - relation of boiling point of pure substances to intermolecular forces
  - measurement of boiling point with distillation apparatus
  - Siwoloboff method for small quantities
  - reliability of boiling point as a measure of purity.
- Infrared spectroscopy:
  - comparison of infrared spectrum with that of a pure sample.
- Other methods used in industry:
  - high-performance liquid chromatography (HPLC)
  - gas chromatography (GC).

**Learning aim C: Explore manufacturing techniques and testing methods for an organic solid****C1 Manufacturing techniques**

- Precipitation crystallisation and recrystallisation:
  - terms relating to saturated solutions and supersaturated solutions
  - influence of temperature on solubility
  - influence of polarity of solvent on solubility
  - crystallisation – supersaturation, nucleation, growth
  - recrystallisation used as a means of purifying solids, particularly organic solids – choice of solvent for recrystallization, the minimum amount of solvent is used, influence of rate of cooling on size of crystals and presence of impurities.
- Filtration:
  - gravity filtration: fluted and non-fluted filter paper
  - hot filtration
  - vacuum filtration using Büchner funnels, Hirsch funnels and sintered glass crucibles.
- Evaporation and drying:
  - evaporation from a crystallisation dish or other suitable container
  - oven drying
  - use of a desiccator
  - use of chemical drying agents to remove water from a solution in an organic solvent
  - distillation
  - rotary evaporation and the effect of reduced pressure.

**C2 Industrial manufacturing techniques**

- Spray drying.
- Freeze drying.
- Use of a filter press.
- Manufacture of aspirin or paracetamol:
  - laboratory scale
  - industrial scale.

**C3 Estimation of purity**

- Assessment of the appearance of crystals as an indicator of purity.
- Measurement of melting point:
  - simple cooling curves
  - design of melting-point apparatus
  - choice of thermometer with an appropriate range
  - use of glass melting-point tubes
  - techniques for filling tubes
  - presence of an impurity lowering the melting point
  - identifying a substance by the mixed-melting-point technique
  - use of standard substances (benzoic acid)
  - commercial melting point apparatus
  - reliability of melting-point and mixed-melting-point measurements as an indicator of purity.
- Thin-layer chromatography (TLC) using a locating agent.
- Other methods used in industry:
  - infrared spectroscopy.

**Learning aim D: Understand how scientific information may be stored and communicated in a workplace laboratory****D1 Systems for managing laboratory information**

- The need for traceability:
  - signatures or unique computer logins.
- Records associated with laboratory work:
  - booking in a sample – record of origin of the sample
  - unique sample identification number
  - records relating to the analysis – readings/weights etc. on computer, sheets or in a notebook
  - results sheet (sheet or computer or notebook)
  - report of analysis/certificate of analysis (paper or electronic)
  - reporting in a format that meets the customer's needs by a scientific organisation.
- Laboratory information management system (LIMS).

**D2 Communicating information in a scientific organisation**

- Types of information used in organisations:
  - customer details
  - product details
  - manufacturing data
  - warehousing data
  - standard operating procedures – for all departments
  - sample details
  - results of analysis of raw materials and products
  - maintenance records – showing when equipment was serviced or repaired
  - safety data
  - environmental records
  - ways of communicating data, including company intranet, documents, email, website.
- Channels of communication:
  - in departments
  - between departments
  - with external customers
  - with regulatory bodies
  - with the wider scientific community – to share research data.

### **D3 Use of informatics for storage and retrieval of scientific information**

- Examples of science data stored in large databases:
  - DNA sequencing
  - healthcare records
  - data relating to population surveys (human/animal/plant)
  - fingerprints.
- Examples of uses of information from large databases:
  - personalised healthcare treatment
  - checking what research has already been done
  - evaluating the quality of existing data
  - genetic engineering.
- Advantages of storing and retrieving large quantities of data:
  - access to a much larger data set to inform conclusions
  - access to other relevant information and research.
- Issues associated with bioinformatics:
  - confidentiality
  - ethical issues.
- The need to use appropriate software effectively.



## Assessment criteria

Pass	Merit	Distinction
<b>Learning aim A: Understand the importance of health and safety in scientific organisations</b>		
<p><b>A.P1</b> Explain how health and safety measures in a scientific organisation comply with legislation.</p> <p><b>A.P2</b> Describe the potential hazards relevant to different scientific working environments.</p>	<p><b>A.M1</b> Compare the health and safety measures taken in relation to legislation for different scientific working environments, referencing potential hazards.</p>	<p><b>A.D1</b> Evaluate the measures taken for different working environments to ensure high standards of health and safety that comply with legislation.</p>
<b>Learning aim B: Explore the manufacturing techniques and testing methods for an organic liquid</b>		
<p><b>B.P3</b> Correctly prepare and test the purity of an organic liquid and draw conclusions.</p> <p><b>B.P4</b> Describe the industrial manufacture and testing of an organic liquid.</p>	<p><b>B.M2</b> Demonstrate skilful application of techniques in preparing and testing the purity of an organic liquid and draw detailed conclusions.</p> <p><b>B.M3</b> Compare the laboratory and industrial manufacture and testing of an organic liquid.</p>	<p><b>B.D2</b> Analyse the factors affecting the yield and purity of an organic liquid in the laboratory and their relevance to its industrial manufacture.</p>
<b>Learning aim C: Explore manufacturing techniques and testing methods for an organic solid</b>		
<p><b>C.P5</b> Correctly prepare and test the purity of an organic solids and draw conclusions.</p> <p><b>C.P6</b> Describe the industrial manufacture and testing of an organic solid.</p>	<p><b>C.M4</b> Demonstrate skilful application of techniques in preparing and testing the purity of an organic solid and draw detailed conclusions.</p> <p><b>C.M5</b> Compare the laboratory and industrial manufacture and testing of an organic solid.</p>	<p><b>C.D3</b> Analyse the factors affecting the yield and purity of an organic solid in the laboratory and their relevance to its industrial manufacture.</p>
<b>Learning aim D: Understand how scientific information may be stored and communicated in a workplace laboratory</b>		
<p><b>D.P7</b> Explain how scientific information in a workplace laboratory is recorded and processed to meet the needs of the customer and to ensure traceability.</p> <p><b>D.P8</b> Explain how useful scientific information is obtained from large data sets and the potential issues and benefits.</p>	<p><b>D.M6</b> Analyse the differences in the storage and communication of scientific information in different workplace laboratories.</p>	<p><b>D.D4</b> Evaluate the challenges to organisations in making available large volumes of scientific information.</p>

## Essential information for assignments

The recommended structure of assessment is shown in the unit summary along with suitable forms of evidence. *Section 6* gives information on setting assignments and there is further information on our website.

There is a maximum number of four summative assignments for this unit. The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.P2, A.M1, A.D1)

Learning aim: B (B.P3, B.P4, B.M2, B.M3, B.D2)

Learning aim: C (C.P5, C.P6, C.M4, C.M5, C.D3)

Learning aim: D (D.P7, D.P8, D.M6, D.D4)

## Further information for teachers and assessors

### Resource requirements

For this unit, learners must have access to:

- a well-equipped laboratory with a fume cupboard
- vacuum filtration and sufficient sinks and power sources to allow reflux and distillation to be carried out
- Quickfit™ apparatus for reflux and distillation
- melting-point apparatus
- an infrared spectrometer or specimen infrared spectra
- examples of health and safety policies.

### Essential information for assessment decisions

#### Learning aim A

**For distinction standard,** learners will explain why following the organisation's specific health and safety management system improves the standard of health and safety and allows the company to comply with legislation. They will evaluate the measures taken for two work environments, and one of these could include the science laboratory in an educational setting or two departments in a scientific organisation. The benefits to employees and to the company of following the systems should be clear. Learners will show an awareness of different safety constraints being in place. Learners will recognise that hazards in the working environments chosen may be different, although there will be commonality too.

**For merit standard,** learners will compare specific measures taken in two working environments in order to keep its workforce safe and to comply with legislation. One of these could include the science laboratory in an educational setting or two departments in a scientific organisation. Some measures may be part of the management system that applies to the whole site – for example having a health and safety policy/committee, health and safety audits, risk assessment, use of standard procedures and training employees how to follow procedures. Differences may include procedures for wearing specific PPE for dealing with spillages, specific substances used, quantities of substances used, danger from vehicles, the extent of training on how to lift things, designated walkways in warehouses, permit to work systems, lone working arrangements.

**For pass standard,** learners will identify a specific science-based organisation. They will describe the main activities of the organisation and why specific pieces of legislation are relevant to that organisation. The list of relevant legislation described does not need to be exhaustive. Learners will also identify two different scientific working environments – for example, laboratory and production or a laboratory in an educational setting – and describe the main hazards associated with each environment. At this standard, learners will give a limited description of some hazards common to both environments in addition to hazards specific to the environments.

#### Learning aim B

**For distinction standard,** learners will analyse the factors to give thorough explanations of how they affect the yield and purity of an organic liquid. This should be in the context of the practical work that they have carried out rather than for the industrial process. However, they must explain how those factors will be relevant in the industrial context. Learners should analyse whether boiling point measurement and infrared spectroscopy are effective ways to assess whether the liquid is pure and comment on the reliability of the test methods used. Learners will also conclude using research, whether any of the methods used industrially are more reliable.

**For merit standard,** learners will demonstrate skilful application of techniques and procedures to prepare and test their organic liquid. Learners will independently assemble equipment safely. This could be knowing how certain equipment should be clamped securely without causing any strain on the set-up and also consider correct positioning of the equipment used. Learners will draw detailed scientific conclusions about the purity of their samples from the tests carried out and provide explanations based on the principles behind the techniques to support their conclusions.

Learners will research how the liquid is made industrially and will compare the similarities and differences in the equipment and techniques used to manufacture and test the liquid on an industrial scale.

**For pass standard,** learners will correctly and competently follow given techniques and procedures to prepare and test their organic liquid. Learners should use the techniques of reflux and distillation, and add chemicals to purify the liquid they have made. Making the organic liquid will involve assembling Quickfit apparatus in reflux and distillation configurations. It is expected that, at pass standard, learners will be given support to assemble the equipment associated with these techniques safely.

Learners will draw simple conclusions about the purity of the samples based on the tests carried out.

Learners will research the industrial production and testing of the liquid and describe the scale, equipment, testing and the raw materials used to produce the liquid. The information should be in the learners' own words and all reference sources should be acknowledged.

### Learning aim C

**For distinction standard,** learners will analyse the factors to give thorough explanations of how they affect the yield and purity of an organic solid prepared by reaction and by extraction. This should be in the context of the practical work that they have carried out rather than in the industrial process. However, learners must analyse how those factors will be relevant in the industrial context to ensure scalability. Learners will comment on the reliability of the techniques used in terms of whether melting-point measurement, mixed-melting-point measurement and thin-layer chromatography (TLC) are effective ways to assess whether the solid is pure and explain the effectiveness of alternative testing methods used industrially.

**For merit standard,** learners will demonstrate skilful application of techniques and procedures to prepare and test their organic solid. Learners will independently assemble equipment safely. Learners will be able to draw detailed scientific conclusions about how pure the samples are based on the tests that been carried out. Learners will reference their sources of information and explain the principles behind the techniques to support their conclusions.

Learners will research the industrial production and testing of an organic solid and compare the similarities and differences in terms of the scale, the equipment, the testing and the raw materials used to produce the organic solid, with the techniques and methods used to prepare and test their sample.

**For pass standard,** learners will correctly and competently follow given techniques and procedures to prepare and test their organic solid. Learners will use the techniques of vacuum filtration, filtration through filter paper, solvent extraction and recrystallisation. They will measure the melting point of the organic solid prepared from reaction and extraction, and carry out a mixed-melting-point measurement on the two samples, using a pure sample as a comparison. It is expected that at pass standard learners will be given support to assemble the equipment associated with these techniques safely. Learners will draw simple conclusions about the purity of the samples based on the tests carried out.

Learners will research the industrial production and testing of the solid and describe the scale, equipment, testing and the raw materials used to produce the solid. The information should be in learners' own words and all reference sources should be acknowledged.

## Learning aim D

**For distinction standard,** learners will evaluate the benefits of and issues with storing large quantities of information so that they can be retrieved and used. Learners should explain the benefits gained from pooling and sharing a specific type of information. Learners should contrast those benefits with the issues involved in organising information so that it may be retrieved and shared. They should include the ethical and bioethical considerations associated with storage of information that may be made available to a third party. Learners will be able to evaluate how scientific information is stored and communicated in different working environments.

**For merit standard,** learners will analyse how different workplace laboratories (these could be within an organisation or in different organisations) communicate and why and how they may communicate with external customers or regulatory bodies.

Learners could, for example, focus on the communication associated with the manufacture, testing and distribution of a single product, including communication with one body (customer or regulator) external to the company. Alternatively, they could focus on the development and manufacture of a new product, for which their sales team thinks there is a need. They should analyse the sort of information communicated, why it is needed and how that information may be shared between different departments.

Learners could comment on whether the way information communicated is fit for purpose and how it may be improved.

**For pass standard,** learners will investigate a workplace laboratory and gather information about the day-to-day recording systems used by the laboratory technicians as they generate routine data on a day-to-day basis. They should know whether paper worksheets, laboratory notebooks or computer forms are used to record data relevant to analysis. Learners should explain what they know about how the information is processed and made traceable, for example by using signatures or by analysts having a computer login unique to them.

Learners will understand the process of analysis in an analytical laboratory (from booking in samples through to producing a certificate of analysis) or the process of carrying out industrial development project work (from planning the project through to producing the report). Learners must use this understanding to explain how the information collected is transformed into documents that are useful to the customer (external or internal).

Learners must research and explain a specific example of one way in which useful scientific information is obtained, for example in healthcare. This does not need to be in the context of the organisation(s) investigated.

## Links to other units

This unit links to:

- Unit 2: Practical Scientific Procedures and Techniques
- Unit 18: Industrial Chemical Reactions
- Unit 19: Practical Chemical Analysis.

## Employer involvement

For this unit, learners must have access to one or more scientific organisations to investigate, for example organisations involved in manufacturing, contract analysis or providing a technical service such as water treatment. Ideally, learners should have the opportunity to visit and communicate with the organisation, but the unit could be successfully supported by the provision of case study material from the organisation. The organisation should have at least one laboratory with an established laboratory information and management system (paper based or electronic).

Visits to, or speakers from, manufacturing industry will be invaluable when learners are researching health and safety practices in the laboratory and elsewhere in the organisation. Visits or speakers will also provide insight into data-management systems. Suitable companies could come from the following list of industries: pharmaceuticals, biopharmaceuticals, metals, printed circuits, bulk chemicals, paints and coatings, agrochemicals, food and drink, refractories, nuclear fuel or reprocessing, water treatment, polymers, textiles. A speaker from the local NHS trust may explain how the organisation uses large data sets.

# Unit 5: Principles and Applications of Science II

Level: **3**

Unit type: **External**

Guided learning hours: **120**

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## Unit in brief

This unit builds on and extends the range of key science concepts in biology, chemistry and physics that were covered in *Unit 1: Principles and Applications of Science I*.

## Unit introduction

It is important that scientists and laboratory technicians are able to use and apply key science concepts to work efficiently and effectively in science and science-related organisations. This unit builds on and extends the range of key science concepts that you covered in *Unit 1: Principles and Applications of Science I*. A strong grasp of these concepts will enable you to use and apply this knowledge and understanding in vocational contexts when studying other units in this specification.

This unit includes: properties, uses and production of some inorganic compounds; structures, reactions and properties of commercially important organic compounds; enthalpy changes; the cardiovascular system; ventilation and gas exchange in the lungs; urinary system structure and function; cell transport mechanisms; thermal physics; physical properties of materials; and fluids in motion.

It is essential, for example that chemists understand how the uses of chemical substances relate to their physical and chemical properties, as does their method of production and extraction. Scientists and technicians working in a range of industries, such as the medical or plastics industries, need a good working knowledge of the structure of organic chemicals and their physical and chemical properties.

Knowledge of the energetics of chemical reactions is necessary for scientists working in industry in order to ensure safe, efficient processes are used in the production of chemical substances.

In the medical and pharmaceutical industries, it is important for scientists and technicians to have a good knowledge and understanding of the working of the human body and body systems and apply this knowledge in preventing disease. They must also have an understanding of how diseases are diagnosed and treated.

Scientists and engineers need a good understanding of the properties and behaviour of different materials to ensure they use materials that are fit for purpose. When designing machines and engines, it is important to know how the materials will behave under different conditions and forces. They must understand how energy is transferred in order to make efficient machines and engines. For example, engineers would need to understand how a spring will behave in a car suspension system, or how heat is transferred in a refrigeration unit.

The knowledge and understanding you gain in this unit will give you a strong basis for progression in the applied science sector and to a variety of science and related programmes, such as higher nationals and degrees.

## Summary of assessment

This unit is assessed through an examination worth 120 marks with a total time of 2.5 hours, undertaken in three timed sessions of 50 minutes for each of Biology, Chemistry and Physics. Learners must take all three parts of the single examination in the same series to be awarded a result.

The paper will include a range of question types, including multiple choice, calculations, short answer and open response. These questions will assess discrete knowledge and understanding of the content in this unit.

The assessment availability is January and May/June each year. The first assessment availability is January 2018.

Sample assessment materials will be available to help centres prepare learners for assessment.

## Assessment outcomes

**AO1** Demonstrate knowledge of scientific facts, terms, definitions and scientific formulae

Command words: describe, draw, explain, identify, name, state

Marks: ranges from 18 to 24 marks

**AO2** Demonstrate understanding of scientific concepts, procedures, processes and techniques and their application

Command words: calculate, describe, draw, explain, give, show, state

Marks: ranges from 51 to 60 marks

**AO3** Analyse, interpret and evaluate scientific information to make judgements and reach conclusions

Command words: analyse, comment, describe, explain, give, state

Marks: ranges from 18 to 24 marks

**AO4** Make connections, use and integrate different scientific concepts, procedures, processes or techniques

Command words: calculate, comment, explain

Marks: ranges from 12 to 15 marks



## Essential content

The essential content is set out under content areas. Learners must cover all specified content before the assessment.

### A Properties and uses of substances

#### A1 Relating properties to uses and production of substances

- Understand the chemical properties of substances:
  - amphoteric character of alumina
  - basic character of metal oxides and hydroxides
  - ease of electrolysis.
- Understand the uses of substances:
  - $\text{Ca}(\text{OH})_2$  in acidic effluent treatment
  - transition metals, transition metal oxides and transition metal complexes as catalysts
    - vanadium (V) oxide as catalyst in the contact process, iron as a catalyst in the Haber process
  - alumina in refractories.
- Understand purification, extraction and manufacture of:
  - alumina from bauxite
  - titanium from its ore
  - aluminium from alumina, Hall–Hérault
  - electrolysis of brine to produce sodium hydroxide, hydrogen and chlorine, diaphragm cell and membrane cell.
- Understand how to relate the properties of substances to their production and uses:
  - comparison of production methods in relation to properties
  - choice of a substance for use in relation to its properties.

#### A2 Structures, reactions and properties of commercially important organic compounds

Understand the following:

- straight-chain, branched and cyclic alkanes and alkenes, including isomers
- general formulae of alkanes and alkenes
- International Union of Pure and Applied Chemistry (IUPAC) nomenclature
- structure representations, full (displayed) structural formulae showing all the bonds, shortened structural formulae
- 3D representations using wedge/dashed line diagrams, skeletal formulae
- symmetric and asymmetric alkenes
- sigma and pi-bonding in alkanes and alkenes
- hybridisation
- bond angles, lengths and strengths in alkanes, alkenes, benzene
- increase in boiling point with chain length and intermolecular forces of attraction
- mechanisms of hydrocarbon reactions
- free radical substitution in alkanes
- electrophilic addition of water, halogens, hydrogen halides and sulfuric acid in alkenes
- stability of carbocations
- reactions of commercial importance:
  - use of free radical polymerisation of alkenes and hydration of ethene
  - cracking of hydrocarbons
  - combustion of alkanes.

**A3 Energy changes in industry**

- Know the Kelvin scale of temperature.
- Know the definition of enthalpy change,  $\Delta H = \Delta U + p\Delta V$ , also called 'change in heat content'.
- Know the standard conditions:
  - $1 \times 10^5$  Pa (100 kPa)
  - 298 K
  - per mole ( $\text{mol}^{-1}$ ).
- Understand enthalpy change under standard conditions,  $\Delta H^\circ$
- Know the units of standard enthalpy change  $\text{kJ mol}^{-1}$ .
- Understand the system and surroundings.
- Understand the sign convention.
- Understand exothermic and endothermic reactions and processes.
- Understand reaction profiles.
- Know the definitions of a range of standard enthalpy changes related to reactions in A1 and A2:
  - combustion
  - formation
  - hydration
  - interpretation of the size and sign of values
  - literature values.
- Understand the measurement of enthalpy changes:
  - specific heat capacity of water
  - enthalpy change in water in contact with a reaction
  - heat  $Q = mc\Delta t$
- Calculate enthalpy changes from supplied data.

**B Organs and systems****B1 The cardiovascular system**

- Understand the structure and function of the heart, to include:
  - atria
  - ventricles
  - septum
  - valves – semi-lunar, tricuspid, bicuspid
  - vena cava
  - pulmonary vein
  - pulmonary artery
  - aorta
  - myogenic muscle
  - sinoatrial node (SAN)
  - atrioventricular node (AVN)
  - Purkinje fibres
  - bundle of His
  - be able to calculate cardiac output.
- Understand the characteristic features of blood vessels and pressure changes, to include:
  - arteries – elastic, small lumen, thick muscle, high pressure
  - veins – large lumen, valves, thin walled, low pressure
  - capillaries – link arteries and veins, one cell thick, site of diffusion
  - blood transfusion and the ABO rhesus system.

- Understand the cardiac cycle, to include:
  - atrial systole
  - ventricular systole
  - cardiac diastole
  - role of major blood vessels – vena cava, pulmonary vein, pulmonary artery, aorta and coronary artery
  - opening and closing of the heart valves.
- Understand the use of electrocardiograms (ECG), to include:
  - significance of PQRST points on an ECG trace
  - identification of arrhythmias – tachycardia, bradycardia, ventricular fibrillation, sinus arrhythmia, flat line.
- Understand how factors can increase the risk of cardiovascular disease (CVD), to include:
  - genetics
  - age
  - gender
  - diet
  - high blood pressure
  - smoking
  - inactivity.
- Investigate the effect of caffeine on heart rate in *Daphnia*.
- Understand the benefits and risks of treatments for CVD, including:
  - antihypertensives
  - statins
  - transplantation and immunosuppressants.

## **B2 Ventilation and gas exchange in the lungs**

- Understand the structure of the human lung and overall ventilation system, to include:
  - trachea
  - bronchi
  - bronchioles
  - alveoli
  - capillary network
  - intercostal muscles
  - diaphragm
  - role of pleural membranes.
- Understand the mechanics of ventilation of the lungs, to include:
  - inspiration and expiration
  - action of intercostal muscles
  - action of the diaphragm
  - changes in the volume of thorax
  - changes in air pressure and movement
  - the use of a ventilator to assist breathing.
- Understand the principles that relate to efficient gas exchange in the human lung:
  - proximity of alveoli to capillary network
  - one-cell-thick capillaries
  - alveolar large surface area
  - moisture
  - diffusion gradients
  - provision of oxygen for respiration and removal of carbon dioxide for efficient production of adenosine triphosphate (ATP) during cellular respiration.

- Understand the importance of spirometer readings of lung volumes, to include:
  - tidal volume
  - inspiratory reserve volume
  - residual volume
  - expiratory reserve volume
  - vital capacity
  - total lung capacity.
- Understand the importance of the methods used to measure lung function for respiratory conditions, to include:
  - peak expiratory flow
  - forced vital capacity.
- Understand the effects of exercise on the following using data from spirometer traces, to include:
  - tidal volume
  - breathing rate
  - respiratory minute ventilation
  - oxygen consumption.

### **B3 Urinary system structure and function**

- Understand the roles of the kidney in:
  - excretion
  - osmoregulation.
- Know the function of the urinary system, to include:
  - ureter
  - bladder
  - renal artery and vein.
- Understand the structure and function of a kidney nephron, to include:
  - glomerulus and its role in ultrafiltration
  - Bowman's capsule
  - proximal convoluted tubule and its role in selective reabsorption of glucose
  - distal convoluted tubule
  - collecting duct
  - loop of Henle
  - osmoregulation and the role of anti-diuretic hormone (ADH)
  - electrolyte balance, blood pressure and the role of the renin-angiotensin-aldosterone mechanism.
- Understand how the kidney is involved in water, electrolyte and acid base balances.
- Understand how to treat kidney disease, to include:
  - dialysis
  - transplantation.

### **B4 Cell transport mechanisms**

- Understand the structure of the cell surface membrane with reference to the fluid mosaic model.
- Understand the methods used to transport molecules through cell membranes, to include:
  - passive transport brought about by diffusion, facilitated diffusion (through carrier proteins and protein channels) and osmosis (consideration of water potential is not required)
  - active transport, including the role of ATP as an immediate source of energy
  - the processes of endocytosis and exocytosis in the transport of large molecules through the formation of vesicles.
- Understand how surface area to volume ratio affects transport of molecules in living organisms.

## C Thermal physics, materials and fluids

### C1 Thermal physics in domestic and industrial applications

- Be able to use the following quantities and units:
  - power, watt (W), kilowatt (kW), megawatt (MW), gigawatt (GW)
  - convert °C to K
  - pressure (Pascals (Pa), Newton per metre squared (Nm<sup>-2</sup>)).
- Know the following definitions:
  - work done as energy transferred
  - work done as force × distance moved in direction of force ( $W = F \times \Delta x$ )
  - work done by a gas as pressure × change in volume of gas ( $W = p \times \Delta V$ )
- Be able to calculate efficiency using the relationships:
  - efficiency = useful energy output / total energy input
  - for heat engines:
 
$$\text{efficiency} = 1 - \frac{Q_{out}}{Q_{in}}$$
  - Maximum theoretical efficiency =  $1 - \frac{T_C}{T_H}$
- Understand the following concepts:
  - law of conservation of energy
  - ideal gas equation  $pV = NkT$
  - internal energy ( $U$ ), first law of thermodynamics ( $Q = \Delta U + W$ )
  - isothermal and adiabatic processes
  - idealised engine cycles
  - second law of thermodynamics
  - heat engines, refrigerators and heat pumps
  - maximum theoretical coefficient of performance (COP).
- Understand the changes of state of substances used in domestic and industrial processes:
  - transfer of energy producing temperature change or changes of state, thermal capacity, thermal equilibrium
  - specific heat capacity from ( $\Delta Q = mc\Delta T$ )
  - specific latent heat from ( $\Delta Q = \Delta mL$ ), fusion, vapourisation, condensation.

### C2 Materials in domestic and industrial applications

- Understand the following concepts and apply them in domestic and industrial applications:
  - elasticity
  - stress-strain curves
  - elastic limit
  - strength
  - yield point
  - plastic deformation
  - creep
  - fatigue
  - ductility
  - brittleness
  - malleability
  - elastic hysteresis.

- Be able to use the following quantities and units:
  - density  $\text{kgm}^{-3}$
  - tensile/compressive stress (Newton per metre squared ( $\text{Nm}^{-2}$ ))
  - tensile/compressive strain (no units)
  - Young's modulus (Newton per metre squared ( $\text{Nm}^{-2}$ )).
- Understand the following definitions:
  - Density  $\rho = \frac{m}{v}$
  - tensile/compressive stress =  $\frac{F}{A}$
  - tensile/compressive strain =  $\frac{\Delta x}{L}$
  - Young's modulus  $E = \frac{\text{stress}}{\text{strain}}$
  - Hooke's law  $F = k\Delta x$
  - work done in stretching/compressing a wire/spring,  
Elastic strain energy,  $\Delta E(el) = \frac{1}{2} F\Delta x = \frac{1}{2} k(\Delta x)^2$

### C3 Fluids in motion

Understand the following concepts and apply them in industrial and domestic situations:

- fluid flow patterns, streamline and turbulent flow
- viscosity
- viscous drag
- mass of fluid flow per second for all points along a pipe or stream tube is constant
- non-Newtonian fluid flow
- rate of fluid flow and pressure
- Bernoulli's principle.

## Grade descriptors

To achieve a grade, learners are expected to demonstrate these attributes across the essential content of the unit. The principle of best fit will apply in awarding grades.

### Level 3 Pass

Learners will be able to recall, select and apply scientific knowledge and understanding to vocational and realistic situations. They will be able to use scientific terminology and concepts in given situations, and use given information and apply appropriate mathematical and technical skills in context. Learners will be able to interpret and analyse information in order to make valid judgements.

### Level 3 Distinction

Learners will be able to integrate relevant scientific knowledge and understanding from different areas to demonstrate a deeper understanding of how these apply to vocational and realistic situations. They will be able to use scientific terminology and concepts, communicating consistently and effectively in given situations. They will be able to select relevant information and apply appropriate mathematical and technical skills to justify decisions or solve problems in context. Learners will be able to interpret and analyse information in order to make valid judgements that are supported by evidence, with awareness of limitations.

## Key terms typically used in assessment

The following table shows the key terms that will be used consistently by Pearson in our assessments to ensure learners are rewarded for demonstrating the necessary skills.

Please note: the list below will not necessarily be used in every paper/session and is provided for guidance only.

Command or term	Definition
Add/label	Requires the addition of labelling to a stimulus material given in the question, for example labelling a diagram or adding units to a table.
Assess	Learners give careful consideration to all the factors or events that apply and identify which are the most important or relevant. Make a judgement on the importance of something and come to a conclusion where needed.
Calculate	Learners obtain a numerical answer, showing relevant working. If the answer has a unit, this must be included.
Comment on	Requires the synthesis of a number of variables from data/information to form a judgement. More than two factors need to be synthesised.
Compare	Learners look for the similarities and differences of two (or more) things. Should not require the drawing of a conclusion. Answer must relate to both (or all) things mentioned in the question. The answer must include at least one similarity and one difference.
Complete	Requires the completion of a table/diagram.

Command or term	Definition
Criticise	Learners inspect a set of data, an experimental plan or a scientific statement and consider the elements. Look at the merits and/or faults of the information presented and back up judgements made.
Deduce	Learners draw/reach conclusion(s) from the information provided.
Derive	Learners combine two or more equations or principles to develop a new equation.
Describe	Learners give an account of something. Statements in the response need to be developed as they are often linked but do not need to include a justification or reason.
Determine	The answer must have an element that is quantitative from the stimulus provided, or must show how the answer can be reached quantitatively. To gain maximum marks there must be a quantitative element to the answer.
Devise	Learners plan or invent a procedure from existing principles/ideas.
Discuss	Learners identify the issue/situation/ problem/argument that is being assessed within the question. Explore all aspects of an issue/situation/problem/argument. Investigate the issue/situation, etc. by reasoning or argument.
Draw	Learners produce a diagram either using a ruler or using freehand.
Evaluate	Learners review information, then bring it together to form a conclusion, drawing on evidence, including strengths, weaknesses, alternative actions, relevant data or information. Come to a supported judgement of a subject's qualities and relation to its context.
Explain	An explanation requires a justification/ exemplification of a point. The answer must contain some element of reasoning/justification – this can include mathematical explanations.
Give/state/name	These generally require recall of one or more pieces of information.
Give a reason why	When a statement has been made and the requirement is only to give the reasons why.



<b>Command or term</b>	<b>Definition</b>
Identify	Usually requires some key information to be selected from a given stimulus/resource.
Plot	Learners produce a graph by marking points accurately on a grid from data that is provided and then drawing a line of best fit through these points. A suitable scale and appropriately labelled axes must be included if these are not provided in the question.
Predict	Learners give an expected result.
Show that	Learners prove that a numerical figure is as stated in the question. The answer must be to at least one more significant figure than the numerical figure in the question.
Sketch	Learners produce a freehand drawing. For a graph this would need a line and labelled axes with important features indicated. The axes are not scaled.
State and justify/identify and justify	When a selection is made and a justification has to be given for the selection.
State what is meant by	When the meaning of a term is expected but there are different ways in which this meaning can be described.
Write	When the question asks for an equation.

## Links to other units

This unit, alongside *Unit 1: Principles and Applications of Science I*, covers some of the core science concepts in biology, chemistry and physics.

This unit also links to a wide range of optional units available across the qualification.

## Employer involvement

Centres may involve employers in the delivery of this unit if there are local opportunities. There is no specific guidance related to this unit.

# Unit 6: Investigative Project

Level: **3**

Unit type: **Internal**

Guided learning hours: **90**

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## Unit in brief

This unit enables learners to gain an understanding and the skills required to undertake an investigative project.

## Unit introduction

In this unit, you will carry out an investigative project that you have chosen in collaboration with your teacher.

You will choose one topic area that interests you and this will form the basis of your investigative project. You will carry out a scientific literature search and review, considering the project's aims and objectives, then produce a realistic plan and carry out the project safely using your scientific investigation skills, project management skills and what you have learnt from the other units. Finally, you will prepare an evaluative report that will consider the project outcomes and suggest amendments that may have improved those outcomes. To complete the assessment task for within this unit, you will need to draw on your learning from across your programme.

Completing an investigative project is an excellent way for you to develop an understanding of the science-related workplace. The skills developed in this unit will be of considerable benefit for progression to higher education in a variety of science and science-related courses and to employment in the science or applied science sector.

## Learning aims

In this unit you will:

- A** Undertake a literature search and review to produce an investigative project proposal
- B** Produce a plan for an investigative project based on the proposal
- C** Safely undertake the project, collecting, analysing and presenting the results
- D** Review the investigative project using correct scientific principles.

## Summary of unit

Learning aim	Key content areas	Recommended assessment approach
<b>A</b> Undertake a literature search and review to produce an investigative project proposal	<b>A1</b> Literature review <b>A2</b> Investigative project proposal	Present a project plan proposal supported by a logbook.
<b>B</b> Produce a plan for an investigative project based on the proposal	<b>B1</b> Schedule <b>B2</b> Plan <b>B3</b> Health and safety and ethical considerations	Present a project plan proposal supported by a logbook.
<b>C</b> Safely undertake the project, collecting, analysing and presenting the results	<b>C1</b> Experimental procedures and techniques <b>C2</b> Collect, collate and analyse data <b>C3</b> Data presentation	Present an evaluative report of the final project outcomes. Outcomes could then be presented to a class and observation sheets could also be used to assess element of self-reflection. Alternatively, this could be an additional written piece alongside the report.
<b>D</b> Review the investigative project using correct scientific principles	<b>D1</b> Scientific report for the investigative project <b>D2</b> Scientific evaluation of findings <b>D3</b> Skill development within project work	

## Content

### Learning aim A: Undertake a literature search and review to produce an investigative project proposal

Learners must select a relevant area of study linked to chemistry, physics or biology, or a combination of different fields.

#### A1 Literature review

- Identification of criteria, e.g. how many sources, what is the oldest date that will be looked at, which types of source will be excluded.
- Nature of study, which could include field work, laboratory-based work, sports facility, workshop.
- Sources of information:
  - identification and location of relevant and reliable sources of information, e.g. journal articles, textbooks, websites
  - extraction – how to obtain the information from libraries, resource centres, organisations, government organisations, charities
  - recognising and using protocol for referencing of information sources, to include use of the Harvard referencing system.

#### A2 Investigative project proposal

- Rationale for area of study – suitable for interest/based on literature review.
- Background.
- Hypothesis.
- Aims and objectives.
- Identification of potential limitations of the project, e.g. implications for resources, time constraints, use of facilities.

### Learning aim B: Produce a plan for an investigative project based on the proposal

#### B1 Schedule

Timeline for the project, to include:

- start date
- completion date
- milestones.

#### B2 Plan

- Relevant methods for processes/procedures.
- Use of resources, e.g. participants, equipment and instrumentation, materials.
- Contingency planning and remedial actions, e.g. extra resources, schedule revision.

#### B3 Health and safety and ethical considerations

- Identification of hazards, personal protective equipment (PPE) and control of substances hazardous to health (COSHH) regulations current requirements, health and safety legislation.
- Risk assessment, including type of hazard, level of risk, prevention and minimising of hazards.
- Ethical considerations, e.g. obtaining consent, maintaining confidentiality.

**Learning aim C: Undertake the project, collecting, analysing and presenting the results****C1 Experimental procedures and techniques**

- Assembly of relevant equipment and materials.
- Adhering to health and safety risk analysis, and PPE and COSHH requirements during practical investigation.
- Skills of transferring, handling and using equipment and materials.
- Use of equipment, instruments, sensors and techniques for taking measurements.
- Observation skills.
- Adhering to relevant legislation:
  - Good Laboratory Practice (GLP)
  - Good Manufacturing Practice (GMP)
  - Good Clinical Practice (GCP).

**C2 Collect, collate and analyse data**

- Recording results with, accuracy, integrity, precision.
- Maintenance of working laboratory logbooks and record keeping.
- Organisation of practical data in class intervals, tallying.
- Methods and uses of data processing and analysis, e.g. standard deviation, student's t-test, chi-square test.
- Correct units of experimental quantities used.
- Assessment of experimental accuracy, reliability and precision.
- Validation of method and results:
  - fitness for purpose of methods used
  - repeatability
  - sources and magnitudes of errors in readings taken.

**C3 Data presentation**

- Range of appropriate data presentation used.
- Choice of data presentation explained.
- Correct presentation of chosen data format explained.

**Learning aim D: Review the investigative project using correct scientific principles****D1 Scientific report for the investigative project**

- Correct scientific principles:
  - structure and format
  - use of correct scientific terminology
  - past tense, including third person.
- References and bibliography:
  - correctly written
  - included in appendix
  - correct use of the Harvard referencing system.

**D2 Scientific evaluation of findings**

- Evaluation of statistical results.
- Conclusions drawn from primary and secondary data using scientific principles.
- Limitations of investigative project and areas for improvement.
- Assessment of information sources used and relevance to investigation experimental and literature investigations.
- Evaluation of proof, or otherwise, of hypothesis stated.
- Recommendations for further research.

**D3 Skill development within project work**

- Time management and organisation.
- Adhering to and following appropriate standards and protocols.
- Taking responsibility for completing tasks/procedures.
- Making judgements within defined parameters.
- Application of safe working practice.
- Give and receive constructive feedback.
- Identify, organise and use resources effectively to complete tasks.
- Utilising channels of communication.
- Resourceful and using initiative.

## Assessment criteria

Pass	Merit	Distinction
<b>Learning aim A: Undertake a literature search and review to produce an investigative project proposal</b>		<b>A.D1</b> Evaluate the different methods of investigation considered for the investigative project proposal, justifying the hypothesis chosen.
<b>A.P1</b> Carry out a literature search and review into a chosen scientific area. <b>A.P2</b> Produce an appropriate project proposal for an investigative project proposal, to include hypothesis.	<b>A.M1</b> Analyse a literature search and discuss its relevance to inform the investigative project proposal. <b>A.M2</b> Produce a project proposal for a scientific investigation, to include hypothesis and potential limitations.	
<b>Learning aim B: Produce a plan for an investigative project based on the proposal</b>		<b>B.D2</b> Analyse the effectiveness of the working plan, justifying changes made.
<b>B.P3</b> Produce a realistic working plan for the project, including health and safety and risk assessments.	<b>B.M3</b> Produce a realistic working plan for the project, including health and safety and risk assessments and contingency planning.	
<b>Learning aim C: Safely undertake the project, collecting, analysing and presenting the results</b>		<b>CD.D3</b> Evaluate the conclusions of the investigative project and its practical aspects, discussing limitations, improvements and recommendations for further study. <b>CD.D4</b> Evaluate the skills developed in the investigative project undertaken and suggest areas for improvement.
<b>C.P4</b> Demonstrate practical skills to assemble relevant apparatus/equipment and materials, and carry out the project using safe working practices. <b>C.P5</b> Accurately collect, analyse and present the results obtained.	<b>C.M4</b> Justify the choice of experimental and data-analysis techniques used as a means of increasing accuracy, reliability and validity.	
<b>Learning aim D: Review the investigative project using correct scientific principles</b>		
<b>D.P6</b> Produce a report using findings, scientific terminology and protocol appropriately and drawing conclusions. <b>D.P7</b> Summarise skills developed in the investigative project undertaken.	<b>D.M5</b> Produce a report using findings, correct scientific terminology, protocol and formatting and drawing valid conclusions. <b>D.M6</b> Discuss the importance of skills developed in the investigative project undertaken to achieve aims.	



## Essential information for assignments

The recommended structure of assessment is shown in the unit summary along with suitable forms of evidence. *Section 6* gives information on setting assignments and there is further information on our website.

There is a maximum number of three summative assignments for this unit. The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.P2, A.M1, A.M2, A.D1)

Learning aim: B (B.P3, B.M3, B.D2)

Learning aims: C and D (C.P4, C.P5, D.P6, D.P7, C.M4, D.M5, D.M6, CD.D3, CD.D4)

## Further information for teachers and assessors

### Resource requirements

For this unit, learners must have access to:

- a well-equipped laboratory (and maybe a fume cupboard or access to suitable environments to carry out field work)
- materials/equipment and/or laboratory instruments/sensors that will enable them to carry out practical work
- appropriate science and maths software packages to help them present their data in the most appropriate way.

### Essential information for assessment decisions

#### Learning aim A

**For distinction standard**, learners will show that they have considered in detail, more than one appropriate investigative method of approach to tackling the hypothesis and explain why their chosen approach is suitable. Once they have established their plan, they will justify their choice of project and the hypothesis they are going to test. Learners will justify their method of approach to the method used in their project proposal, using evidence from their literature review.

**For merit standard**, learners will show that they can use the material to help them plan their work and indicate its relevance to the investigative work they have in mind. Teachers should look for evidence of the search material being analysed. It is expected that this analysis will influence learners' hypothesis and the research project proposal. Learners will include any potential limitations of the project proposal, such as the accuracy of any graduated apparatus or limitations of instruments/sensors.

**For pass standard**, learners will be informed that when they are carrying out their search on the scientific topic, they are expected to give a comprehensive bibliography and list of references using a standard protocol, such as the Harvard system. Teachers should also look for the use of more than one source in order to confirm statements made by learners. They should review the information they have gathered and ensure confirmation of information from different sources. This information will be used to form the basis of their project proposal. Learners will produce an appropriate research project proposal for an investigation.

#### Learning aim B

**For distinction standard**, learners will reflect on their working plan and justify any changes made, such as a change in their timeline that affects milestones or internal/external factors requiring different equipment/instrumentation.

**For merit standard**, learners will include contingency planning (for example if they did not have enough time to complete the experiment or if a sensor/instrument stopped working).

**For pass standard**, learners will produce a realistic working plan taking into account possible constraints. Teachers will be able to follow the information and carry out the experiment without reference to learners. The relevant health and safety and risk assessments will be carried out for practical experiments and adhered to.

## Learning aims C and D

**For distinction standard,** learners will review the information they have obtained from their search and practical work, and decide on its validity, reliability and accuracy, and whether the original hypothesis has been met. They will include an evaluation of alternative experimental approaches, the modification or rewriting of their hypothesis and the strengths and weaknesses if alternative approaches were used. Learners will also evaluate the effectiveness of their choice of statistical methods or graphs/calculations and the validity and usefulness of their research data, as well as considering how their experimental data compares to any published information and discussing the limitations of their project. Learners will draw on all areas of project work carried out to critically reflect on the strengths and weaknesses of their own performance and skill development, drawing on feedback. Learners will demonstrate how self-reflection and feedback (which could be through collaborative working) has aided their project work, and also suggest areas for improvement and the steps necessary to achieve them.

**For merit standard,** learners will have previously run through the experimental and data analysis techniques they are using with their teacher and justified their choice. Teachers can question learners about the experimental techniques used, but there must be evidence for this so that it can be assessed and verified. Learners may refine their experimental techniques after discussion with their teacher, but this must also be recorded in some way so that it can be assessed and verified. Whatever approach is taken, learners will record their review, evaluate the effectiveness of experimental procedures and suggest how these could be improved.

Learners will demonstrate accuracy in their observational skills, recording the results in an appropriate format, including noting approximations, decimal point accuracy, etc. Learners will justify, for example, why an approximation was used or why only two decimal points were recorded.

Learners will be in a position to support (or not) their original hypothesis and justify their opinion based on both their collected primary data and any researched secondary data. Learners will be able to succinctly interpret their statistical data and draw valid conclusions from this.

Learners will need to explain how specific skills developed within their project have enabled them to meet project aims. Learners may demonstrate limited awareness of areas of improvement and the steps to achieve them.

**For pass standard,** learners will be observed assembling the apparatus/equipment effectively and efficiently, and selecting the correct materials before carrying out the experiment safely. Teachers should regularly check the laboratory logbook and diary of each learner and sign and date the section seen.

Learners will use the results of their experiment, stating if their original objectives or hypothesis has been met and making appropriate conclusions from statistical data, as well as drawing together scientific using correct principles.

Learners will produce their report in the correct scientific format and in a formal manner, using the information and data they have collected throughout the project. The report will be written using accepted scientific terminology and protocol, such as impersonal, third party and past tense. The presentation can be made to a group or to their project teacher.

Learners will outline the key skills developed in their investigative project and may identify areas of improvement.

### Links to other units

This assessment for this unit should draw on knowledge, understanding and skills developed from:

- Unit 1 Principles and Applications of Science
- Unit 2 Practical Scientific Procedures and Techniques
- Unit 3 Science Investigation Skills
- Unit 4 Laboratory Techniques and their Application
- Unit 5 Principles and Applications of Science II.

### Employer involvement

Centres may involve employers in the delivery of this unit if there are local opportunities. There is no specific guidance related to this unit.

# Unit 8: Physiology of Human Body Systems

Level: **3**

Unit type: **Internal**

Guided learning hours: **60**

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## Unit in brief

Learners will focus on the physiological make up of three human body systems (musculoskeletal, lymphatic and digestive), how the systems function and what occurs during dysfunction.

## Unit introduction

The human body is a complex mix of organs and organ systems. Knowledge of how they function to maintain human life is an essential part of the study of human physiology. In this unit, you will focus on three body systems: musculoskeletal, lymphatic and digestive. You will examine each of the systems as a functioning unit, identifying their structure and function. By exploring the anatomy of these systems, through experimentation and use of simulations, you will develop your knowledge and understanding of their role in the human body.

You will also give attention to understanding the implications of what happens when the systems fail to work properly and the available treatments. The unit will be of particular interest if you are interested in sport, body-building and maintaining a healthy body.

An understanding of the fundamental systems that make up the human body is a key requirement if you wish to progress to study health and care-related programmes or biomedical sciences in further education and at university. It is an essential requirement for a career in sport- and health-related disciplines, for example physiotherapist, sport trainer and exercise physiologist.

## Learning aims

In this unit you will:

- A** Understand the impact of disorders of the musculoskeletal system and their associated corrective treatments
- B** Understand the impact of disorders on the physiology of the lymphatic system and the associated corrective treatments
- C** Explore the physiology of the digestive system and the use of corrective treatments for dietary-related diseases.

## Summary of unit

Learning aim	Key content areas	Recommended assessment approach
<p><b>A</b> Understand the impact of disorders of the musculoskeletal system and their associated corrective treatments</p>	<p><b>A1</b> Structure of the musculoskeletal system</p> <p><b>A2</b> Function of the musculoskeletal system</p> <p><b>A3</b> Health matters and treatments related to the musculoskeletal system</p>	<p>Learners would use information gained from research, visits, dissections/videos, models and simulations to produce an illustrated report explaining and analysing the structure and function of the musculoskeletal system.</p> <p>An evaluation of a related disorder/dysfunction of the system and associated treatments must be included.</p>
<p><b>B</b> Understand the impact of disorders on the physiology of the lymphatic system and the associated corrective treatments</p>	<p><b>B1</b> Structure of the lymphatic system</p> <p><b>B2</b> Function of the lymphatic system</p> <p><b>B3</b> Health matters and treatments related to the lymphatic system</p>	<p>Research work using the internet and TV documentaries to help learners to create a presentation that describes and explains the structure and function of the lymphatic system in promoting a healthy body.</p> <p>An evaluative case study of the effect of a disorder/dysfunction of the system and possible treatments must be included.</p>
<p><b>C</b> Explore the physiology of the digestive system and the use of corrective treatments for dietary-related diseases</p>	<p><b>C1</b> Structure of the digestive system</p> <p><b>C2</b> Function of the digestive system</p> <p><b>C3</b> Health matters and treatments related to the digestive system</p>	<p>A lab book/record of investigations modelling the functioning of the various parts of the digestive system. Photographs and information from the investigations will be used to create an information leaflet that explains the role and location of organs and evaluates dietary disorder in the system and possible treatments.</p> <p>Observation records of practical work undertaken to assess the nutrient content of food will be required. Evidence and conclusions from the investigations will be incorporated into the information leaflet.</p>

## Content

### Learning aim A: Understand the impact of disorders of the musculoskeletal system and their associated corrective treatments

#### A1 Structure of the musculoskeletal system

Structure and identification of major bones, muscles, joints and supporting apparatus by visual examination of diagrams or models and manipulative means in living subjects as appropriate.

- Axial skeleton, to include:
  - cranium, mandible and maxilla
  - vertebral column (cervical, thoracic and lumbar vertebrae, sacrum and coccyx, intervertebral discs)
  - ribs and sternum.
- Appendicular skeleton, to include:
  - limb bones (humerus, radius, ulna; femur, patella, tibia, fibula)
  - wrist, hand and digit bones (carpals, metacarpals, phalanges)
  - ankle, foot and digit bones (tarsals, metatarsals, phalanges, calcaneus)
  - shoulder girdle (scapula, clavicle)
  - pelvic girdle (ilium, pubis, ischium).
- Bone types: long bones, short bones, flat bones, irregular bones, sesamoid bones.
- Bone composition: periosteum, spongy/compact bone, bone marrow, mineral use.
- Identification of the major joint types and where they exist in the human body – gliding, condyloid, saddle, socket, ball and socket, pivot, hinge.
- Classification of joints: fibrous, cartilaginous, synovial.
- Composition and location of ligaments and tendons.
- Major muscle groups.
- Structure of muscle fibres.

#### A2 Function of the musculoskeletal system

Functions of each part of the musculoskeletal system and how each contributes to the effective functioning of the whole system.

- Skeletal functions: support, protection, attachment for skeletal muscle, storing minerals, producing blood cells, maintaining mineral homeostasis.
- Muscle: the role of ligaments, tendons, skeletal muscle, smooth muscle, process of muscle contraction, fast- and slow-twitch fibres.
- Movement due to interaction of muscles, bones, joints and attachment apparatus: flexion/extension, adduction/abduction, internal/external, rotation, circumduction.

#### A3 Health matters and treatments related to the musculoskeletal system

The causes, symptoms and common treatments involved in common disorders or dysfunction in the musculoskeletal system.

- Disorders to include: forms of arthritis; hip dysplasia; hypermobility; bone fracture and dislocation; repetitive strain injury (RSI); muscle, ligament and tendon trauma.
- Treatments for musculoskeletal disorders (including physiological reasoning behind the treatment), to include: physiotherapy; arthroscopy; joint replacement therapy; rest, ice, compression, elevation (RICE); splinting and casting.

## **Learning aim B: Understand the impact of disorders on the physiology of the lymphatic system and the associated corrective treatments**

### **B1 Structure of the lymphatic system**

Composition and location of component parts:

- spleen, thymus gland, tonsils, lymph glands, lymph vessels
- major lymph nodes – axillary, abdominal, inguinal, popliteal, supraclavicular
- presence of valves.

### **B2 Function of the lymphatic system**

Location, processes, structures involved and importance of each function:

- formation and transport of lymphocytes and lymph
- removal of interstitial fluid from tissues
- maintenance of hydrostatic pressure
- absorption of fats from the digestive system.

### **B3 Health matters and treatments related to the lymphatic system**

Symptoms, treatment and physiological reasoning behind treatment for disruption or dysfunction of the lymphatic system, to include:

- lymphadenitis
- lymphedema
- Hodgkin's lymphoma.

## **Learning aim C: Explore the physiology of the digestive system and the use of corrective treatments for dietary-related diseases**

### **C1 Structure of the digestive system**

Location and structural features of the following parts of the digestive system and associated organs:

- mouth, pharynx, oesophagus, stomach, small intestine (duodenum, jejunum, ileum), large intestine, rectum, anus
- associated organs: pancreas, liver, gall bladder.

### **C2 Function of the digestive system**

- Processes involved in digestion, absorption and assimilation of nutrients:
  - mechanical and chemical digestion
  - action of enzymes (protease, amylase, lipase, hydrolysis and assimilation)
  - sites of nutrient absorption, active transport, diffusion.
- Chemical tests for the presence of macro-nutrients found in foods: starch, proteins, lipids, reducing and non-reducing sugars, vitamin C content.

### **C3 Health matters and treatments related to the digestive system**

- Dietary sources and importance of macronutrients and micronutrients including symptoms of deficiencies – fibre, lipids, protein, water, carbohydrates, vitamins (A, B, C, D) and minerals (iron, magnesium and iodine).
- Digestive system diseases and physiological reasoning behind treatments, e.g. coeliac disease, irritable bowel syndrome, colitis.



## Assessment criteria

Pass	Merit	Distinction
<b>Learning aim A: Understand the impact of disorders of the musculoskeletal system and their associated corrective treatments</b>		
<b>A.P1</b> Explain the functional role of the musculoskeletal system in the human body. <b>A.P2</b> Describe the effect of disorder of muscles and joints and possible corrective treatment(s).	<b>A.M1</b> Compare how disorders of the musculoskeletal system can affect how muscles bring about movement of joints and the role of corrective treatment(s).	<b>A.D1</b> Evaluate the effect of corrective treatment(s) associated with a musculoskeletal disorder.
<b>Learning aim B: Understand the impact of disorders on the physiology of the lymphatic system and the associated corrective treatments</b>		
<b>B.P3</b> Describe the gross anatomy and function of the organs of the lymphatic system. <b>B.P4</b> Describe the effect of a disorder on the lymphatic system and possible corrective treatment(s).	<b>B.M2</b> Explain the physiological reasoning for corrective treatment(s) associated with a disorder of the lymphatic system.	<b>B.D2</b> Evaluate the effect of corrective treatment(s) for a disorder of the lymphatic system.
<b>Learning aim C: Explore the physiology of the digestive system and the use of corrective treatments for dietary related diseases</b>		
<b>C.P5</b> Explain the role and location of organs involved in digestion. <b>C.P6</b> Correctly carry out investigations to establish sources and importance of key nutrients for a balanced diet. <b>C.P7</b> Describe the symptoms of nutrient deficiency as a result of dietary-related disease.	<b>C.M3</b> Analyse the role of digestive enzymes on nutrient uptake in each part of the digestive system. <b>C.M4</b> Explain the use of corrective treatment(s) for nutrient deficiency.	<b>C.D3</b> Evaluate the effect of dietary disease and corrective treatment(s) on human health.

## Essential information for assignments

The recommended structure of assessment is shown in the unit summary along with suitable forms of evidence. *Section 6* gives information on setting assignments and there is further information on our website.

There is a maximum number of three summative assignments for this unit. The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.P2, A.M1, A.D1)

Learning aim: B (B.P3, B.P4, B.M2, B.D2)

Learning aim: C (C.P5, C.P6, C.P7, C.M3, C.M4, C.D3)

## Further information for teachers and assessors

### Resource requirements

For this unit, learners must have access to:

- a well-equipped laboratory
- IT resources, which could be used as a reference point.

### Essential information for assessment decisions

It is expected that where possible, investigative work will be carried out in this unit. Health and safety considerations are paramount, and teachers must ensure that the necessary risk assessments are carried out and communicated to their learners. Refer to CLEAPSS and/or your centre's health and safety regulations if in doubt about any of the investigative work that has been suggested.

It is understood that specific groups of learners or teachers for ethical, religious or other reasons may feel that they are not able to undertake dissection work as part of the unit. If practical dissection is not carried out, it is expected that suitable alternatives will be available. This is to enable learners to fully understand the anatomy and physiology of the body systems studied in the unit content. Alternatives to dissection could be documentaries of dissections/operations, computer-generated simulations and model making.

## Learning aim A

**For distinction standard,** learners will research disorders/dysfunctions of the musculoskeletal system. Learners will reach conclusions based on referenced evidence they have produced from research on the impact on health of one named disorder/dysfunction and its corrective treatment(s). A visit from or to a physiotherapist would aid understanding and help create a vocational context.

Learners will provide a detailed evaluation demonstrating in-depth, scientific knowledge of the anatomy and physiology of the effects of the condition, including major bones, muscle (groups), joints and movement at the joints. Learners will then establish how the disorder impacts the normal functioning/movement in the human body.

Learners will evaluate how the work of the medical professional uses corrective mechanisms and treatments in order to improve the functioning of the skeleton and its physical, physiological and social impact on human health. Learners will also explain the limitation of the corrective treatment(s) used.

**For merit standard,** learners must provide a detailed comparison of three disorders affecting different aspects of the musculoskeletal system and how normal movement is affected. Learners must use the correct scientific and technical terms to clearly outline the type of joint, muscle movement at the joint, muscle attachment and the groups of muscles that are involved in bringing about normal movement. They must also explain the importance of the movement to the normal functioning of the human body and how each disorder differs in terms of its effect on normal function. When comparing corrective treatments for each disorder, learners must consider scientific rationale for using that particular treatment over others.

Access to dissection of a small mammal, chicken bones/joints, or models of skeletons and joints and use of simulations would develop and aid learners' understanding. The use of referenced diagrams or photographs to help learners to produce an analytical report on muscles, joints and associated movement should be encouraged. Correct use of scientific terms must be included in the report.

**For pass standard,** learners will explain how the structure of the human skeleton, muscles and joints form an essential system in the functioning of the human body by providing support, protection, movement and storage/production of minerals and blood cells. Learners will identify and name six major joints in the human musculoskeletal system and fully explain the importance of their structure and role in the human body in terms of normal movement. Learners will name one disorder of musculoskeletal system and outline how it impacts normal function of the human body. Learners will reference specific muscles or muscle groups and joints affected by the disorder and give an overview of the corrective treatment(s) associated with it.

## Learning aim B

**For distinction standard,** learners must base their evaluation on one named disorder. They will analyse the effect of the disease on the lymphatic system, the normal functioning of which will be explicitly explained. The implications of the disease on the health status of an individual suffering from the disorder will be addressed within the context of a patient case study. Learners will evaluate the physiological basis of any treatment and discuss the impact of this on the restoration of normal lymphatic function. This will include benefits and problems faced by medical professionals when using corrective treatments. They will use correct scientific terminology throughout.

**For merit standard,** learners will demonstrate detailed understanding of the anatomy and function of the lymphatic system, using correct scientific terminology to explain the rationale for use of corrective treatment for the effects of a named disorder of the lymphatic system. Learners will give detailed explanations of the disorder affecting the normal functioning of the lymphatic system and the associated corrective treatment.

**For pass standard,** learners must describe the gross anatomy of the organs and associated structures that form the lymphatic system. Learners must label (for themselves) each structure of the lymphatic system and describe, in brief, the role it plays in the system. Learners will describe how lymph is formed and its role in the health of the body.

Learners will also briefly describe a named disorder and its effect on the normal function of the lymphatic system, including the symptoms present in the human body and give an overview of the corrective treatment(s) associated with the disorder.

### Learning aim C

**For distinction standard,** learners will research dietary-related disorders of the digestive system. Learners must choose a named digestive system-related disease that affects the normal functioning of the body. They must explain how the named disease affects the system using correct biological terminology. Learners must also consider the effects on the person that is suffering from the disease and how medical intervention seeks to treat the effects of disease. Evaluations must also cover the implications to the health status of the individual and compare this with the healthy functioning of the digestive system.

**For merit standard,** learners must analyse the mode of action of digestive enzymes as applied to each of the macronutrients listed in the unit content. This will include named enzymes, the location of enzyme secretion, the location of enzyme action (if different), substrates and products of each nutrient broken down with enzymatic assistance. This will be linked to the analysis of nutrients in foods.

Learners will need to consider how nutrient deficiency can be tackled in terms of corrective treatments. They must explain the corrective treatment for the deficiency of two nutrients and how they may relieve the symptoms described.

**For pass standard,** learners must perform analytical tests to identify the nutrients present in dietary sources of macronutrients as listed in the unit content, they must also give detailed descriptions of nutrient-deficiency symptoms. Learners must describe the gross anatomy of the different areas of the digestive system as listed in the unit content. Learners should label each of the areas of the digestive system and describe, in brief, the role of the component labelled. Learners could use photographs from the dissection to label or complete a dissection. This would help provide the context necessary to help generate the understanding required.

### Links to other units

This unit links to:

- Unit 1: Principles and Applications of Science I
- Unit 5: Principles and Applications of Science II
- Unit 9: Human Regulation and Reproduction
- Unit 10: Biological Molecules and Metabolic Pathways
- Unit 11: Genetics and Genetic Engineering
- Unit 12: Diseases and Infections.

### Employer involvement

University sports science departments may be able to provide support and guidance and access to models of joints and a skeleton. Physiotherapy departments may be able to offer information and access to examples of replacement joints and exercises that will assist in treatment and recovery from musculoskeletal dysfunction.

GP Surgeries may have specialist nurses who might be available to visit and provide information about management of digestive system disorders, such as coeliac disease, irritable bowel syndrome and colitis.



# Unit 9: Human Regulation and Reproduction

Level: **3**

Unit type: **Internal**

Guided learning hours: **60**

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## Unit in brief

This unit will give learners an understanding of how in the internal body environment is regulated and controlled within set parameters to enable key bodily process to take place.

## Unit introduction

The human body is a complex organisation of systems that each needs to be controlled within a well-defined range of parameters. This unit will help your understanding of the key homeostatic principles that help provide this stable body environment. There have been many advances in human fertility in recent years, and there are opportunities to consider these and the hormonal control of the reproductive system. Fertility treatments will also be considered.

You will investigate the interrelationship and nervous control of the cardiovascular and respiratory systems, the homeostatic mechanisms in the body and the hormonal control of the reproductive system.

Knowledge of the mechanisms by which the body regulates systems within narrow parameters is an essential part of health and medical science-related occupations and other allied roles, including sport science and fitness, clinical science and veterinary science. Progression to higher education to study reproductive technologies or animal breeding leading to degree level is possible. It is equally possible to gain access to science technician or apprenticeships career pathways.

## Learning aims

In this unit you will:

- A** Understand the interrelationship and nervous control of the cardiovascular and respiratory systems
- B** Understand the homeostatic mechanisms used by the human body
- C** Understand the role of hormones in the regulation and control of the reproductive system.

## Summary of unit

Learning aim	Key content areas	Recommended assessment approach
<b>A</b> Understand the interrelationship and nervous control of the cardiovascular and respiratory systems	<b>A1</b> Nervous system organisation <b>A2</b> Cardiovascular and respiratory system regulation and control	A report looking at how the organisation and function of the human nervous system, along with the importance of coordinating the cardiovascular and respiratory systems.
<b>B</b> Understand the homeostatic mechanisms used by the human body	<b>B1</b> Feedback and control <b>B2</b> Glands and organs <b>B3</b> Homeostatic mechanisms <b>B4</b> Impact of an imbalance	A presentation on the mechanisms used to maintain homeostasis and the importance of normal homeostatic function.
<b>C</b> Understand the role of hormones in the regulation and control of the reproductive system	<b>C1</b> Structure and function of reproductive anatomy <b>C2</b> Reproductive processes	Learners put together a series of informative leaflets on the control of fertility.



## Content

### Learning aim A: Understand the interrelationship and nervous control of the cardiovascular and respiratory systems

Structure, function and processes involved in the nervous control of the cardiovascular and respiratory systems.

#### A1 Nervous system organisation

- Components of the central and peripheral nervous systems.
- Neuron and glial cells, to include a comparison of myelinated and unmyelinated neurons.
- Transmission of action potentials and saltatory conduction, including interpretation of graphs.
- Transmission at synapses, neuromuscular junctions and neuroglandular junctions.
- Neurotransmitters.
- Stimuli detection by receptor cells and sense organs.
- Roles and regulation of the autonomic nervous system divisions (sympathetic and parasympathetic), to include different neurotransmitters, e.g. acetylcholine and dopamine.
- Stages in and role of voluntary and non-voluntary reflexes and reactions, to include afferent and efferent pathways and the role of interneurons.
- Neurological disorders, e.g. Parkinson's disease, multiple sclerosis.

#### A2 Cardiovascular and respiratory system regulation and control

- How changes in concentrations of oxygen and carbon dioxide come about.
- Role of chemoreceptors and baroreceptors.
- Gaseous exchange at tissues and alveoli.
- Autonomic nervous system; sympathetic and parasympathetic pathways.
- Role of medulla oblongata in coordination.
- Elasticity of blood vessels related to function.
- Control of heart rate – role and action of:
  - sinoatrial and atrioventricular nodes
  - Bundle of His
  - Purkinje fibres.
- Control of inspiration, expiration and rate of ventilation:
  - changes in contraction and relaxation of diaphragm and intercostal muscles
  - relative air pressure changes.

### Learning aim B: Understand the homeostatic mechanisms used by the human body

Processes, organs and hormones involved in maintaining the internal environment.

#### B1 Feedback and control

Positive and negative feedback loops, to include the part played by:

- set point
- receptors
- coordinator(s)
- effectors.

#### B2 Glands and organs

Location, nature and hormone secretion from:

- exocrine glands, e.g. sweat glands, Brunner's glands
- endocrine glands, to include hypothalamus, pituitary gland, thyroid and parathyroid
- endocrine and exocrine organs, e.g. pancreas, liver.

**B3 Homeostatic mechanisms**

Stages involved in the regulation of:

- water (osmoregulation), to include roles of:
  - antidiuretic hormone (ADH), atrial natriuretic peptide (ANP), angiotensinogen, aldosterone
  - hypothalamus, pituitary gland
  - kidney nephron (endothelial cells)
  - Cl<sup>-</sup>, Na<sup>+</sup>, K<sup>+</sup> ions
- blood glucose, to include roles of:
  - secretion of insulin and glucagon by beta and alpha cells in the Islets of Langerhans
  - glycogen, glucose, glycogenesis, glycogenolysis, gluconeogenesis
- temperature, to include roles of:
  - vasodilation and vasoconstriction of arterioles leading to surface capillaries
  - pili erector muscles
  - sweat production
  - shivering.

**B4 Impact of an imbalance**

- Conditions caused by an imbalance of a homeostatic mechanism, to include effects on normal functioning and potential management strategies, e.g. dehydration, hyperglycaemia, hypoglycaemia, diabetes, hypothermia, hyperthermia, syndrome of inappropriate antidiuretic hormone (SIADH).

**Learning aim C: Understand the role of hormones in the regulation and control of the reproductive system****C1 Structure and function of reproductive anatomy**

- Female reproductive system: ovary, fallopian tube (oviduct), uterus, uterine horn, fimbriae, endometrium, cervix, vagina, labia.
- Male reproductive system: epididymis, seminal vesicle, Cowper's gland, prostate gland, testes, penis, scrotum, vas deferens, erectile tissue.

**C2 Reproductive processes**

- Stages in the following, to include the interactions of hormones (to include progesterone, oestrogen, testosterone, FSH and LH as appropriate). Timescales for each should be referenced and links made to effects on fertility.
- Gamete development and release; infertility causes and identification in these stages:
  - oogenesis from oogonia; formation of primary, secondary and Graafian follicles; ovulation; formation and role of corpus luteum
  - normal/abnormal morphology of oocytes; ovulation disorders
  - spermatogenesis from spermatogonia, formation of primary and secondary spermatocytes and spermatids, spermiation, role of Sertoli and Leydig cells
  - normal/abnormal morphology and abundance of sperm.
- Hormonal changes in the menstrual cycle.
- Processes leading to conception, how infertility can come about in these stages and potential treatments for assisting fertility:
  - wafting of ova through fallopian tubes, semen delivery, fertilisation (including role of acrosome in penetration of the zona pellucida), implantation
  - erectile dysfunction, antisperm antibodies, effects of menopause, hypo/hyperthyroidism
  - sperm donation, artificial insemination (AI); in vitro fertilisation (IVF); hormone replacement therapy; induction of ovulation.
- Contraceptive methods: oral, injection and implanted use of hormones to prevent pregnancy.

## Assessment criteria

Pass	Merit	Distinction
<b>Learning aim A: Understand the interrelationship and nervous control of the cardiovascular and respiratory systems</b>		<b>A.D1</b> Assess the role of the nervous system in coordinating the cardiovascular and respiratory systems.
<b>A.P1</b> Describe the organisation and function of the nervous system in relation to cardiovascular and respiratory requirements.	<b>A.M1</b> Explain how nervous impulses are initiated, transmitted and coordinated in the control of the cardiovascular and respiratory systems.	
<b>Learning aim B: Understand the homeostatic mechanisms used by the human body</b>		<b>B.D2</b> Analyse the impact of homeostatic dysfunction on the human body.
<b>B.P2</b> Describe how homeostatic mechanisms maintain normal function.	<b>B.M2</b> Explain the role of hormones in homeostatic mechanisms.	
<b>Learning aim C: Understand the role of hormones in the regulation and control of the reproductive system</b>		<b>C.D3</b> Evaluate how conception may be prevented and promoted.
<b>C.P3</b> Describe the structure and function of reproductive anatomy. <b>C.P4</b> Describe how hormones are involved in gamete development and conception.	<b>C.M3</b> Explain how the regulation of male and female reproductive systems can affect human reproductive health.	

## Essential information for assignments

The recommended structure of assessment is shown in the unit summary along with suitable forms of evidence. *Section 6* gives information on setting assignments and there is further information on our website.

There is a maximum number of three summative assignments for this unit and the relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.M1, A.D1)

Learning aim: B (B.P2, B.M2, B.D2)

Learning aim: C (C.P3, C.P4, C.M3, C.D3)

## Further information for teachers and assessors

### Resource requirements

For this unit, learners must have access to a well-equipped laboratory.

For learning aim C, learners could assess the motility and morphology of porcine semen under a microscope. This practical activity will help learners to engage with the material on the causes of infertility in the male.

It would be an advantage for learners to use digital cameras to take photographs of their experimental work. This will help them to engage with the material they produce and supplement their reports.

### Essential information for assessment decisions

It is assumed that, where possible, investigative work will be carried out in this unit. Health and safety considerations are paramount. Teachers must ensure that the necessary risk assessments are carried out and communicated to their learners. Refer to CLEAPSS and/or your own centre's health and safety regulations if in doubt about any of the investigative work that has been suggested.

### Learning aim A

**For distinction standard,** learners will assess the nervous control of the cardiovascular and respiratory systems in maintaining a constant body environment. Learners need to consider the causes of changes, how they are detected internally and the interrelated stimulation of nervous pathways that bring about corrective measures for normal function. They will do this with reference to two neurological disorders affecting the central nervous or cardiovascular and respiratory systems.

**For merit standard,** learners must explain the initiation and transmission of nervous impulses in relation to the cardiovascular and respiratory systems. They will use correct terminology throughout with reference to voluntary and non-voluntary stimulation and control of the systems. They will examine synaptic transmission in the parasympathetic and sympathetic nervous pathways. Learners must demonstrate an understanding of the importance of coordination of the cardiovascular and respiratory systems, in relation to changes to carbon dioxide and oxygen concentration in the blood.

**For pass standard,** learners will provide a clear identification of human nervous system organisation and function, describing the basic structure of sensory and motor neurons and their role in transmitting information for involuntary control of heart rate and ventilation. They will label and use relevant diagrams to illustrate their work.

### Learning aim B

**For distinction standard,** learners will give a well-developed and detailed consideration of the interrelation of homeostatic mechanisms and the potential effects each system has on the others. They will examine a number of dysfunctions in each of the homeostatic mechanisms, explaining their impact on human health, potential methods to correct the dysfunction and the homeostatic consequences of these treatments.

**For merit standard,** learners must include a developed explanation of the role of hormones in homeostatic mechanisms described in the unit content. There must be thorough consideration of the secretion of different hormones and their mode of action on target organs, including the responses of those organs. Learners will devise detailed, annotated feedback diagrams to illustrate points made.

**For pass standard,** learners are to describe the body's requirement to maintain a constant internal environment (homeostasis) by both internal and external factors and how feedback systems maintain this for the mechanisms described in the unit content. They will demonstrate an awareness of the potential impact on human health when mechanisms fail to engage. Learners will use terminology in the correct context.

## Learning aim C

**For distinction standard**, learners must present a detailed account of the processes of gamete development and conception. They will explain at least four different methods of hormonal control, both in preventing conception taking place and in managing infertility. Learners must provide a description of the method and the impact it has on the reproductive system of the male or female in order to prevent or promote conception. They will show well-developed lines of reasoning and use correct terminology with skill.

**For merit standard**, learners will give a coherent account of the normal regulation of the male and female reproductive system, explaining how infertility can develop as result of physiological or morphological changes. At least four examples of infertility relating to issues such as meiosis during gametogenesis, obstruction of the male/female tubules, hormonal control of egg/sperm development, hormonal regulation and control of endometrium and implantation, development of zygote, erectile dysfunction and antisperm antibodies should all be researched and presented in evidence submitted by the learner.

**For pass standard**, learners must identify the name, location and structure of each part of the male and female reproductive anatomy, using diagrams they independently label. A description of the function of each part will also be given.

Learners are required to describe the action of hormones that are released during the production of sperm and ova and leading to conception. Learners are required to correctly annotate diagrams/graphs of the menstrual cycle, gametogenesis and processes leading to conception.

## Links to other units

This unit links to:

- Unit 1: Principles and Applications of Science I
- Unit 5: Principles and Applications of Science II
- Unit 8: Physiology of Human Body Systems.

## Employer involvement

Centres may involve employers in the delivery of this unit if there are local opportunities. An internet search may reveal a relatively local fertility clinic, which may be able to provide a visiting speaker to provide information relating to reasons for infertility and possible treatment options. Local gyms and universities or further education colleges may be able to accept visits from learners to use monitoring equipment to measure the effects of exercise on the cardiovascular and respiratory systems. An endocrinologist may be available from the local hospital to discuss with learners the work they do and the importance of the endocrine system and effects of imbalance within it.

# Unit 10: Biological Molecules and Metabolic Pathways

Level: **3**

Unit type: **Internal**

Guided learning hours: **60**

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## Unit in brief

This unit covers biological molecules and the metabolic pathways involved in chemical reactions to enable organisms to function normally.

## Unit introduction

In this unit, you will study some of the chemical processes in living organisms. Biological molecules and metabolic pathways play a crucial role both in society and in various industries, such as health, chemical and environmental sciences. Examples of the importance of this field of study include improvements in the efficiency of photosynthesis to increase crop yields, the bioremediation of polluted soils, the development of new feed-stocks and the production of biofuels.

Water is a fundamental molecule involved in the biochemical processes that take place in living organisms. Due to its unique structure and properties, the water molecule gives organisms the ability to live and thrive in challenging conditions. The unit looks at the structure and functions of water and other molecules, including carbohydrates, proteins and fats, involved in a variety of biochemical systems and metabolic pathways. You will study the biochemical basis of systems within the body, and look at respiratory systems in humans and photosynthetic systems in plants. You will also investigate metabolic chemical pathways and understand how some substances can affect the metabolic pathways in living organisms.

You will develop practical skills when investigating the effect of physical activity on respiration and during your practical work on photosynthesis. This practical work, which will be assessed, is aimed at developing your practical competences so you have skills required by employers.

Biological molecules and metabolic pathways are an area of science that overlaps and underpins many other branches of science such as pharmacology, physiology, microbiology and clinical chemistry. This unit will also support progression to higher education in biochemistry, biomedical science and bioinformatics-related courses.

## Learning aims

In this unit you will:

- A** Understand the structure and function of biological molecules and their importance in maintaining biochemical processes
- B** Explore the effect of activity on respiration in humans and factors that can affect respiratory pathways
- C** Explore the factors that can affect the pathways and the rate of photosynthesis in plants.

## Summary of unit

Learning aim	Key content areas	Recommended assessment approach
<p><b>A</b> Understand the structure and function of biological molecules and their importance in maintaining biochemical processes</p>	<p><b>A1</b> Water  <b>A2</b> Carbohydrates  <b>A3</b> Proteins and nucleic acids  <b>A4</b> Lipids  <b>A5</b> Disruption of biochemical processes in living organisms</p>	<p>A report or a visual display with explanations, that include:</p> <ul style="list-style-type: none"> <li>the molecular structure of proteins and the basic biochemical properties they show</li> <li>links between molecular structure, their properties and role and importance in the human body, including the effect of disruption to biochemical processes in humans and plants.</li> </ul>
<p><b>B</b> Explore the effect of activity on respiration in humans and factors that can affect respiratory pathways</p>	<p><b>B1</b> Respiration  <b>B2</b> Effect of activity on respiration  <b>B3</b> Effect of activity on requirements for oxygen and output of CO<sub>2</sub></p>	<p>A portfolio of evidence to include:</p> <ul style="list-style-type: none"> <li>practical work and results, which can be recorded in lab notebooks, signed off by the teacher/observer</li> <li>record of analysis, conclusions, evaluation and any research work can be by a written essay, diagrams, flow charts.</li> </ul>
<p><b>C</b> Explore the factors that can affect the pathways and the rate of photosynthesis in plants</p>	<p><b>C1</b> Pathways in photosynthesis  <b>C2</b> Factors that can affect the pathways in photosynthesis</p>	<p>A portfolio of evidence, to include:</p> <ul style="list-style-type: none"> <li>practical work and results, which can be recorded in lab notebooks, signed off by the teacher/observer</li> <li>record of analysis, conclusions, evaluation and any research work can be by a written essay, diagrams, flow charts.</li> </ul>



## Content

### Learning aim A: Understand the structure and function of biological molecules and their importance in maintaining biochemical processes

#### A1 Water

- Structure:
  - contains hydrogen (H) and oxygen (O) atoms
  - structural and chemical formulae.
- Bonding:
  - in water molecule (covalent bonding)
  - between water molecules (hydrogen bonding).
- Importance:
  - as a solvent
  - medium for chemical reactions
  - pH regulation
  - electrolyte balance
  - temperature regulator
  - cohesion-tension in transpiration.

#### A2 Carbohydrates

- Structure and features:
  - contain carbon (C), hydrogen and oxygen atoms
  - monosaccharides, e.g.  $\alpha$  and  $\beta$  glucose, galactose, fructose, ribose and deoxyribose
  - disaccharides, e.g. lactose, maltose and sucrose
  - polysaccharides, e.g. amylose, amylopectin, cellulose
  - use of iodine and Benedicts' solution as tests for presence of carbohydrates.
- Importance:
  - energy production
  - energy storage
  - structural/building
  - lipid metabolism
  - prevention of protein breakdown for energy in animals.

#### A3 Proteins and nucleic acids

Structural features:

- proteins:
  - primary structure, including peptide links to give polypeptides
  - secondary structure, including  $\alpha$ -helices and  $\beta$ -pleated sheets
  - tertiary structure, to include ionic interaction, hydrogen bonding, sulphur bridges and van der Waal's forces
  - quaternary structure, e.g. haemoglobin
  - classification as globular or fibrous
  - use of Biuret solution as a test for presence of protein

- nucleic acids:
  - nucleotide structure (deoxyribose or ribose, phosphate and purine or pyrimidine base)
  - polynucleotide structure with bonds made through condensation reactions
  - formation of the DNA double helix through complementary base pairing
  - importance of proteins and nucleic acids
  - enzymes that control metabolism
  - as neurotransmitters
  - antibodies
  - hormones
  - for transport of other components
  - body tissue growth and repair
  - muscle contraction in animals (actin and myosin interaction: detailed knowledge of the sliding filament theory not required)
  - blood clotting in animals
  - role of nucleic acids in coding for genes and controlling gene expression.

#### **A4 Lipids**

Structure:

- carbon, hydrogen and oxygen in fats, oils and waxes
- saturated and unsaturated fats, and formation of diglycerides and triglycerides via esterification reactions
- use of emulsion tests to identify presence of lipids
- importance of lipids in animals:
  - energy sources
  - insulation and organ protection in animals
  - phospholipids in membranes
  - production of vitamins.

#### **A5 Disruption of biochemical processes in living organisms**

The causes and effects of disruption to biochemical processes, to include:

- porphyria
- lactose intolerance
- diabetes mellitus
- cystic fibrosis
- exposure to carcinogens
- interference in plant growth regulators, e.g. delaying or promoting fruit ripening using the effects of ethene and gibberellins; disruption of auxin transport; use of synthetic auxin.

### **Learning aim B: Explore the effect of activity on respiration in humans and factors that can affect respiratory pathways**

#### **B1 Respiration**

- Adenosine triphosphate (ATP) as the universal energy currency.
- Stages and locations of aerobic and anaerobic respiratory pathways
- Glycolysis: conversion of monosaccharides to pyruvate; production of lactic acid in anaerobic respiration and ethanol in yeast.
- Link reaction.
- Krebs cycle:
  - conversion of molecules in the cycle from citric acid to oxaloacetate
  - carbon dioxide (CO<sub>2</sub>) production.

- Electron transport chain in ATP production:
  - reduction of coenzymes
  - cytochrome system and ATP synthase
  - importance of oxygen as final electron acceptor and nicotinamide adenine dinucleotide (NAD) as hydrogen acceptor.

### **B2 Effect of activity on requirements for oxygen and output of CO<sub>2</sub>**

- Recovery rates after exercise as measured by breathing rate.
- Short-term anaerobic respiration leading to oxygen debt.
- Effect of exercise on carbon dioxide output; potential damaging effects of excess CO<sub>2</sub> and lactic acid; bicarbonate buffering system of blood.

### **B3 Factors that can affect respiration**

The causes and effects of the following on the ability of individuals to carry out processes leading to efficient respiration.

- Cigarettes:
  - inhalation of toxins
  - tar
  - nicotine.
- Drugs:
  - ketamine
  - cocaine interferes with how the brain processes chemicals.
- Pollutants:
  - asbestos
  - oxidants causing inflammation and metabolic damage to the cells.
- Disease, e.g. asthma.

## **Learning aim C: Explore the factors that can affect the pathways and the rate of photosynthesis in plants**

### **C1 Pathways in photosynthesis**

- Light-dependent reaction:
  - stages in and location of photophosphorylation, including role of coenzymes, and photolysis
  - light energy converted to chemical energy held in ATP.
- Light-independent reaction:
  - stages in and location of the Calvin cycle
  - role of ribulose biphosphate (RuBP) and ribulose biphosphate carboxylase (RuBisCO)
  - production of glucose.

### **C2 Factors that can affect the pathways in photosynthesis**

- Requirements for photosynthetic organisms, including sources and control of limiting factors, e.g. light intensity, CO<sub>2</sub> concentration, temperature, water.
- Role of photosynthetic pigments (chlorophylls and carotenoids) in absorbing different wavelengths of light.

## Assessment criteria

Pass	Merit	Distinction
<b>Learning aim A: Understand the structure and function of biological molecules and their importance in maintaining biochemical processes</b>		<b>A.D1</b> Evaluate the effects of disruption of biochemical processes in living organisms.
<b>A.P1</b> Explain the structure of biological molecules in living organisms.	<b>A.M1</b> Explain the links between the structure and function of biological molecules and their role in living organisms.	
<b>Learning aim B: Explore the effect of activity on respiration in humans and factors that can affect respiratory pathways</b>		<b>B.D2</b> Evaluate the effects of harmful substances on the efficiency of respiration.
<b>B.P2</b> Explain the stages involved in the human respiratory pathway.	<b>B.M2</b> Analyse primary and secondary data to explain the effect of activity on respiration.	
<b>B.P3</b> Carry out an investigation involving the effect of activity on respiration in humans. <b>B.P4</b> Describe factors that can affect respiration.	<b>B.M3</b> Explain the harmful effects of factors on respiration.	
<b>Learning aim C: Explore the factors that can affect the pathways and the rate of photosynthesis in plants</b>		<b>C.D3</b> Evaluate the effect of factors on photosynthetic efficiency.
<b>C.P5</b> Explain the stages involved in photosynthesis in plants. <b>C.P6</b> Carry out an investigation into a factor that affects the rate of photosynthesis.	<b>C.M4</b> Analyse primary and secondary data to explain the outcomes of an investigation into a factor that affects the rate of photosynthesis.	

## Essential information for assignments

The recommended structure of assessment is shown in the unit summary along with suitable forms of evidence. *Section 6* gives information on setting assignments and there is further information on our website.

There is a maximum number of three summative assignments for this unit. The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.M1, A.D1)

Learning aim: B (B.P2, B.P3, B.P4, B.M2, B.M3, B.D2)

Learning aim: C (C.P5, C.P6, C.M4, C.D3)

## Further information for teachers and assessors

### Resource requirements

For this unit, learners must have access to a well-equipped laboratory in order to carry out practical work to support learning. This unit is based on practicals, with research and tutorials backing up the outcomes from practical work.

### Essential information for assessment decisions

#### Learning aim A

**For distinction standard**, learners must present a detailed evaluation of the effects caused by disruption of biological molecules. This would include details of the structures of the biological molecules related to their function and importance in the human body. This provides the basis for analysing what happens if there is a disruption to the structure or function, leading to major changes in normal biochemical processes. Learners will identify where these are intentionally disrupted for human benefit. They will use scientific terminology with skill and with a lack of fundamental errors.

**For merit standard**, learners must show their understanding of how the elements carbon (C), hydrogen (H) and oxygen (O) are the fundamental building blocks of biological molecules. Learners will demonstrate understanding that different carbohydrates, lipids and proteins are formed from the original elements of C, H, O. This must be extended to include how the addition of elements such as nitrogen, phosphorus and sometimes sulphur changes the structure and properties of the biological molecules. Using chemical diagrams, learners can show the CHO ratio in carbohydrates to other molecules. They should explore side group structure and function found in proteins. They can use diagrams to compare the structure of nucleic acids as a five-carbon sugar (pentose) with a phosphate group and nitrogenous bases, and how RNA and DNA have different functions in the body. Learners must give detailed explanations of how structure of biological molecules is linked to function and the role in the human body. They will use scientific terminology accurately in many cases.

**For pass standard**, learners must demonstrate their knowledge of the structure of biological molecules in living organisms, for example learners must show how simple sugars combine to form disaccharides and polysaccharides. They will show a similar understanding of other biological molecules such as proteins and lipids. Learners will use relevant scientific terminology, although there may be errors.

#### Learning aim B

**For distinction standard**, learners must research factors (chemicals in cigarettes, drugs, pollutants and disease) and how they affect metabolic pathways in terms of how efficiently aerobic respiration can proceed. For example, the inhibitory effect of pesticides on enzyme reactions as part of neural conduction or pollutant particles preventing normal respiratory function, could be researched and evaluated. Learners will extend their analysis of primary and secondary data to help in their evaluation and in drawing conclusions. They must cite references.

**For merit standard**, learners are expected to analyse and relate primary data from their investigations into effects of activity on respiration to secondary data. This may have been researched or be given to them by the teacher. They must use the analysis of primary and secondary data to form valid and detailed conclusions about their investigation. Learners must use the evidence obtained to link changes in respiration rates to the type of activity undertaken.

Learners are expected to explain how two named examples of factors, from the unit content, can disrupt the respiratory pathways. For example, they could explain how oxidants inhaled as the result of a polluted atmosphere can overload the body's normal metabolism, causing inflammation and cell damage.

**For pass standard,** learners must explain how the chemical stages in the human respiratory pathways are related and significant in energy release. Learners will use scientific terminology accurately in their explanations of the stages involved in respiratory pathways and demonstrate a clear understanding of the importance of each stage.

Learners will demonstrate the ability to carry out investigative work relating to effect of activity on respiration, in a competent and safe manner and in accordance to any health and safety instructions. Outline methods can be given and must be adapted by the learner to allow valid and authentic evidence to be generated. Anomalous results must be identified and, if possible, explained. Learners should be encouraged to repeat practical work to help eliminate errors and check the validity of results.

An observation sheet must be completed and submitted to validate the practical. It is good practice to encourage learners to use a laboratory notebook, which should be checked regularly by the teacher. This will help make learners aware of the importance of logbooks as a record of practical work being carried out. They must give clear, objective accounts of how factors affect respiration. These accounts could cover the breadth of the unit content in less detail, or cover three factors each in greater detail.

### Learning aim C

**For distinction standard,** learners must demonstrate knowledge of optimum levels of the factors affecting the rate of photosynthesis. They must consider alterations to levels of these factors and the effect on photosynthetic efficiency, and the commercial importance and relevance of this. For instance, they could consider a conclusion about the relevance, in terms of yield and production costs, of increasing levels of light or carbon dioxide in a greenhouse. Learners will be expected to use their understanding of the main stages in photosynthesis when drawing their conclusions from the analysis of primary and secondary data.

**For merit standard,** learners must draw accurate conclusions from an investigation into factors affecting the rate of photosynthesis and will refer to the stage in photosynthesis affected. It is expected that light intensity, carbon dioxide levels or temperature will have been investigated. In order to draw valid conclusions, learners must analyse their own data (primary) from their investigation along with secondary data, which may have been researched or given to them by the teacher. Learners will need to consider in their analysis of the data any difference between their results and those from published material.

**For pass standard,** learners must describe the chemical stages in photosynthesis and give clear details of the stages in photosynthesis. Accurate scientific terminology must be used in the explanations of the importance of each stage of the process.

Learners can follow given methods to competently and safely carry out investigative work into factors affecting the rate of photosynthesis. Different factors should be investigated by different learners and results collated for analysis. Anomalous results should be identified and discussed, and repeats carried out where possible. An observation record is required to validate the practical work carried out. Use of laboratory logbooks by learners, monitored by teachers, should be encouraged.

### Links to other units

This unit links to:

- Unit 2: Practical Scientific Procedures and Techniques
- Unit 8: Physiology of Human Body Systems
- Unit 9: Human Regulation and Reproduction
- Unit 11: Genetics and Genetic Engineering
- Unit 20: Biomedical Science.

### Employer involvement

Centres may involve employers in the delivery of this unit if there are local opportunities. There is no specific guidance related to this unit.





# Unit 11: Genetics and Genetic Engineering

Level: **3**

Unit type: **Internal**

Guided learning hours: **60**

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## Unit in brief

Learners will study the basis of life itself. They will gain an understanding of the structure of DNA, cell division and the principles of Mendelian genetics and variation.

## Unit introduction

Massive advances in DNA technology over the last 30 years have driven genetics forward at an extraordinary rate, creating enormous potential for future applications. This unit will allow you to develop a deeper practical and theoretical knowledge and understanding of genetics, and modern genetic engineering techniques and their uses. This may be of particular interest to learners wishing to follow a career in forensic science or research. There are often media reports of medical advances, for instance, growing replacement body parts for transplantation, and advances in treatments for life-threatening and debilitating diseases. There will be opportunities to follow up some of these reports and to extend your knowledge and understanding of what might be possible in the future.

You will investigate the mechanisms of cell division and carry out research to explain how the behaviour of chromosomes during cell division relates to variation. There will be an opportunity to demonstrate and expand your knowledge of genetics and variation, to include how genes control the characteristics of living organisms by synthesising proteins using nucleic acids as a code. The principles of Mendelian genetics will be used to outline and explain patterns of inheritance and how this can influence variation and evolution. You will explore modern genetic techniques and their uses and have the opportunity to extract and work with DNA.

This unit will provide a basis for progression in the fields of medical, veterinary science, agricultural, industrial or forensic science. Multiple pathways for career development are available. These may be through higher education courses, university, or by direct entry to these fields as science technicians or on apprenticeship schemes.

## Learning aims

In this unit you will:

- A** Understand the structure and function of nucleic acids in order to describe gene expression and the process of protein synthesis
- B** Explore how the process of cell division in eukaryotic cells contributes to genetic variation
- C** Explore the principles of inheritance and their application in predicting genetic traits
- D** Explore basic DNA techniques and the use of genetic engineering technologies.

## Summary of unit

Learning aim	Key content areas	Recommended assessment approach
<p><b>A</b> Understand the structure and function of nucleic acids in order to describe gene expression and the process of protein synthesis</p>	<p><b>A1</b> Nucleic acids  <b>A2</b> The basis of the genetic code  <b>A3</b> Protein synthesis</p>	<p>A portfolio of evidence to include:</p> <ul style="list-style-type: none"> <li>• photographic evidence of DNA models learners make</li> <li>• a leaflet/report explaining the structure of nucleic acids and how they code for protein synthesis</li> <li>• annotated diagrams of the stages of protein synthesis, how and where the stages occur and analysis of the impact of possible errors.</li> </ul>
<p><b>B</b> Explore how the process of cell division in eukaryotic cells contributes to genetic variation</p>	<p><b>B1</b> Human chromosome  <b>B2</b> Cell division and its role in variation  <b>B3</b> Practical demonstration of slide preparation of dividing cells</p>	<p>A portfolio of evidence to include:</p> <ul style="list-style-type: none"> <li>• a leaflet on the structure and function of human chromosomes</li> <li>• an observation record of microscope slide preparation of mitosis and meiosis</li> <li>• annotated diagrams identifying the stages in mitosis and meiosis</li> <li>• a report explaining and evaluating how the behaviour of the chromosomes during meiosis leads to variation.</li> </ul>
<p><b>C</b> Explore the principles of inheritance and their application in predicting genetic traits</p>	<p><b>C1</b> Principles of classical genetics  <b>C2</b> Further genetics</p>	<p>A portfolio of evidence to include:</p> <ul style="list-style-type: none"> <li>• an observation record to validate the practical work carried out on <i>Drosophila</i></li> <li>• statistical analysis of the patterns of inheritance ratios from practical work</li> <li>• genetic diagrams and a report using appropriate terminology to predict and describe the results of genetic crosses.</li> </ul>
<p><b>D</b> Explore basic DNA techniques and the use of genetic engineering technologies</p>	<p><b>D1</b> DNA extraction  <b>D2</b> Gel electrophoresis  <b>D3</b> DNA amplification  <b>D4</b> Transformation of cells  <b>D5</b> Uses of genetic engineering</p>	<p>A portfolio of evidence to include:</p> <ul style="list-style-type: none"> <li>• a brief report on practical techniques carried out and their applications in industry and medicine</li> <li>• observation records to validate the practical work</li> <li>• a report on how restriction enzymes and electrophoresis work with an explanation of stem cell therapies and their uses.</li> </ul>

## Content

### Learning aim A: Understand the structure and function of nucleic acids in order to describe gene expression and the process of protein synthesis

#### A1 Nucleic acids

Nucleotide structure, function and location of the following:

- DNA, to include stages and enzymes involved in DNA replication
- RNA, to include mRNA, tRNA, rRNA, siRNA.

#### A2 The basis of the genetic code

Definitions of the following and their importance in gene expression:

- triplet codes
- codon
- anticodon
- degenerate code
- non-overlapping.

#### A3 Protein synthesis

- Major stages involved in each stage (including location) and the effect of mutations on the end products.
- Transcription, to include introns, exons and splicing.
- Amino acid activation.
- Translation.
- Mutagenic agents, e.g. irradiation, chemical mutagens.
- Types of genetic mutations – missense, nonsense, silent, insertion, deletion, duplication, frameshift.

### Learning aim B: Explore how the process of cell division in eukaryotic cells contributes to genetic variation

#### B1 Human chromosomes

The formation and structure of chromosomes, linked to their function:

- centromere
- chromatids
- autosomes
- sex chromosomes
- chromosome number and karyotyping
- homologous and non-homologous chromosomes.

#### B2 Cell division and its role in variation

- Stages of the cell cycle, to include cellular activities at each stage and the checkpoints involved in progressing from one stage to the next. Learners should be able to identify the stage a cell is in from given micrographs or specimens, describe the position of chromosomes and the events that take place within each stage of cell division.
- The cell cycle: G1, S phase, G2, division cytokinesis.
- The stages of mitosis, to include the similarities and differences between mitosis in animal and plant cells – interphase, prophase, metaphase, anaphase, telophase.
- The stages of meiosis in the production of gametes:
  - interphase, prophase I, metaphase I, anaphase I, telophase I, cytokinesis, interkinesis, prophase II, metaphase II, anaphase II, telophase II, cytokinesis.
- The role of centrioles (microtubule-organising centre).
- Haploid, diploid.
- Sex determination.

**B3 Practical demonstration of slide preparation of dividing cells**

- Equipment and techniques involved in the preparation of slides for examination using light microscopy.
- Mitosis, e.g. root tip squash.
- Meiosis, e.g. lily anther squash.

**Learning aim C: Explore the principles of inheritance and their application in predicting genetic traits****C1 Principles of classical genetics**

- Inheritance of straightforward phenotypic traits in animals and plants, their predicted proportions and statistical analysis of phenotypic outcomes.
- The differences and complexities involved in continuous and discontinuous variation.
- Mendel's laws of inheritance: segregation and independent assortment.
- Practical investigation of mono and dihybrid phenotypic ratios.
- Use of Punnett squares and other genetic diagrams, to include use of the terms allele, genotype, phenotype, heterozygous, homozygous, carrier, affected/sufferer, non-affected/non-sufferer.
- Interpretation of Mendelian ratios from practical investigations.
- Chi-squared test.

**C2 Further genetics**

Description of genetic interaction, phenotypic traits and reasoned prediction of inheritance of the following:

- single gene disorders, e.g. Huntington's disease, sickle cell anaemia, cystic fibrosis
- incomplete dominance/blending, e.g. Tay Sachs disease and co-dominance, e.g. blood groups
- sex linkage, e.g. colour blindness, haemophilia.
- chromosome mutation, e.g. Down's syndrome, Turner syndrome.
- epistasis, e.g. albinism.

**Learning aim D: Explore basic DNA techniques and the use of genetic engineering technologies**

Principles and practical application (where appropriate) of the techniques, equipment and consumables in each of the following:

**D1 DNA extraction**

- Genomic and plasmid DNA extraction.

**D2 Gel electrophoresis**

- Use of restriction enzymes.
- Principles of electrophoresis.

**D3 DNA amplification**

- Polymerase chain reaction (PCR).
- Purpose of utilising PCR to amplify DNA:
  - DNA fingerprinting
  - cancer diagnosis
  - tissue typing
  - preimplantation genetic diagnosis/screening.

**D4 Transformation of cells**

- Use of vectors.
- Plasmids.
- Use of marker genes.
- DNA ligase.
- Screening to identify transformed cells.

**D5 Uses of genetic engineering**

- Genetically modified (GM) crops.
- Diagnostic tests and gene therapy.
- Pharming.
- Genetic screening including preimplantation genetic diagnosis (PGD).
- Stem cell therapies, e.g. Parkinson's disease, macular degeneration, spinal cord injuries.
- Xenotransplantation.

## Assessment criteria

Pass	Merit	Distinction
<b>Learning aim A: Understand the structure and function of nucleic acids in order to describe gene expression and the process of protein synthesis</b>		<b>A.D1</b> Assess the impact of error in the stages of protein synthesis.
<b>A.P1</b> Explain the structure and function of DNA and various nucleic acids.	<b>A.M1</b> Discuss the functional role of nucleic acids in DNA in the stages of protein synthesis.	
<b>Learning aim B: Explore how the process of cell division in eukaryotic cells contributes to genetic variation</b>		<b>B.D2</b> Evaluate how the behaviour of the chromosomes leads to variation.
<b>B.P2</b> Prepare microscopic slides to observe and draw the stages of mitosis and meiosis.	<b>B.M2</b> Demonstrate skilful preparation of microscopic slides to observe and draw the stages of mitosis and meiosis.	
<b>B.P3</b> Explain the structure and function of human chromosomes.	<b>B.M3</b> Discuss the behaviour of the chromosomes during the cell cycle stages of mitosis and meiosis.	
<b>Learning aim C: Explore the principles of inheritance and their application in predicting genetic traits</b>		<b>C.D3</b> Make valid predictions on patterns of monohybrid and dihybrid inheritance and variation using principles of inheritance.
<b>C.P4</b> Carry out investigations to collect and record data for mono and dihybrid phenotypic ratios.	<b>C.M4</b> Analyse data to explain the correlation between observed pattern of monohybrid and dihybrid inheritance.	
<b>C.P5</b> Explain genetic crosses between non-affected, affected and carriers of genetic conditions.	<b>C.M5</b> Apply Mendel's laws of inheritance to the results of genetic crosses.	
<b>Learning aim D: Explore basic DNA techniques and the use of genetic engineering technologies</b>		<b>D.D4</b> Evaluate possible future uses of genetic engineering technologies.
<b>D.P6</b> Extract, separate and amplify DNA.	<b>D.M6</b> Analyse the uses of genetic engineering technologies in industry and medicine.	
<b>D.P7</b> Explain the use of genetic engineering technologies in industry and medicine.		

## Essential information for assignments

The recommended structure of assessment is shown in the unit summary along with suitable forms of evidence. *Section 6* gives information on setting assignments and there is further information on our website.

There is a maximum number of four summative assignments for this unit. The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.M1, A.D1)

Learning aim: B (B.P2, B.P3, B.M2, B.M3, B.D2)

Learning aim: C (C.P4, C.P5, C.M4, C.M5, C.D3)

Learning aim: D (D.P6, D.P7, D.M6, D.D4)

## Further information for teachers and assessors

### Resource requirements

For this unit, learners must have access to:

- a well-equipped laboratory
- commercially prepared materials/kits, which can be purchased to facilitate growing of *Drosophila* and for extracting DNA, gel electrophoresis, cell transformation and polymerase chain reactions.

### Essential information for assessment decisions

#### Learning aim A

**For distinction standard**, learners will demonstrate a thorough understanding of the structure and function of DNA in relation to the stages of protein synthesis, with specific and accurate use of scientific terminology. Learners will make relevant links between possible errors that may occur during the different stages of protein synthesis, including transcription, translation and the cause and effect of mutations in DNA. They must also assess the impact of these errors to the end products of protein synthesis, which will be illustrated with examples.

**For merit standard**, learners will clearly use their knowledge of the genetic code to discuss the functional role of nucleic acids in protein synthesis. Learners will discuss the locations of each stage in protein synthesis and how the genetic code allows proteins to be synthesised with minimal errors taking place.

**For pass standard**, learners must explain the structure and main features of each nucleic acid listed in the unit content. Photographic evidence can be submitted and annotated if more kinaesthetic assessment tools are used, such as model making.

#### Learning aim B

**For distinction standard**, learners will use the information from their practical work and discussion on meiosis and mitosis to evaluate the significance of chromosomal behaviour during cell division. Arguments must be provided for and against the behaviour of independent assortment and crossing over leading to variation within an organism.

**For merit standard**, learners will skilfully prepare three microscope slides of squash preparations to show mitosis and meiosis, without guidance during assessment. They must use their slide preparations to produce diagrams to identify a minimum of four stages of mitosis and four stages of meiosis. The diagrams must demonstrate good practice – have a title, be drawn in pencil, have clear outlines (not sketched), no heavy shading, indicate the field of view, magnification and scale. Accurate labelling should be evident. Observation records will be required to validate the level of expertise demonstrated by the learner. Learners will provide a detailed discussion demonstrating an understanding of the behaviour of the chromosomes during mitosis and meiosis in each stage of cell division. Supplementary evidence using prepared slides and photomicrographs, provided and referenced by the learner, can be used to ensure all the required stages listed in the unit content can be identified.

**For pass standard**, learners will correctly prepare three microscope slides to allow them to observe, draw and label a minimum of four stages of mitosis and four stages of meiosis. Learners will follow instructions to prepare the material and apply a stain/fixer, if appropriate, having had an opportunity to practice the skills during teaching and learning. They should demonstrate good technique in applying a cover slip to ensure exclusion of air.

Learners must handle the microscope safely, set it up independently and be able to manoeuvre the slide(s) to obtain a field of view under different magnifications. Good technique includes the use of a pencil and statement of the magnification used for the drawing(s) submitted. Photomicrographs and diagrams sourced and referenced by the learners could be used to aid the explanation of the structure of human chromosomes. Detailed statements are required which demonstrate understanding of how/why the structure relates to the function of the chromosomes.



### Learning aim C

**For distinction standard,** learners must demonstrate the ability to make valid predictions and analyse the outcomes of examples of monohybrid and dihybrid crosses between non-affected, affected and carriers of particular disorders and independent and linked genes. Learners must provide evidence of one disorder for monohybrid and one for dihybrid. Learners will use both their own data from investigations and use case studies to allow access to this criterion. Learners must include an explanation of why the observed ratio for each example is not exactly as would be expected.

**For merit standard,** learners will use the data from practical work they have carried out and effectively apply the chi-squared test to analyse the correlation between the observed and expected phenotypic results. An outcome from the statistical test is required, identifying if the ratios obtained are statistically significant or due to chance. Learners must then apply and use Mendel's laws of independent assortment and segregation to analyse the results of the genetic crosses, and explicitly state conclusions.

**For pass standard,** learners must follow instructions in a competent manner to obtain valid and reliable data from an investigation into monohybrid and dihybrid inheritance. An individual observation sheet will be required to validate their level of competency. Sufficient data to carry out a chi-squared analysis must be collected. Results can be shared/collated between individuals/groups of learners. Spreadsheets can be used. Use of simulations prior to starting the assignment will provide a good basis for the learners to carry out their own practical work and statistical analysis. Learners must produce their own write up to include the data from their investigations. Competent completion of the task will be characterised by adherence to the instructions, a very low error rate and the gaining of results close to that expected by the tutor in the context of the investigation.

Learners must accurately construct genetic diagrams representative of genetic conditions and explain the relationship between the genotypic and phenotypic ratios. The correct terminology will be applied throughout. The evidence submitted does not have to be solely related to humans.

### Learning aim D

**For distinction standard,** learners will research the strengths and weaknesses, advantages and disadvantages of the genetic technologies explored in the relevant unit content. All sources consulted will be accurately referenced. They must use the research to support their own views, speculating in an informed manner about future uses of generic engineering technologies. They must provide counterarguments of the reliability and validity of the use of the technologies.

**For merit standard,** learners will analyse the use of genetic technologies in relation to industry and/or medicine. The analysis will take into account the reasons and science behind the technologies, benefits to the relevant sector of industry or medicine, and include an appreciation of efficacy and cost. This may be achieved effectively through the detailed examination of one real-life example for each technology.

**For pass standard,** learners will need to provide a laboratory record of how they have competently carried out three separate experiments: DNA extraction (chromosomes or plasmids), PCR and gel electrophoresis. An observation record is required to validate the competency of learners' participation in practical work, characterised by methodical preparation and avoidance of sample contamination. Learners will explain the genetic engineering technologies as listed in the unit content in terms of their relevance to industry and medicine, in addition to the basic principles behind how the technologies work.

## Links to other units

This unit links to:

- Unit 1: Principles and Applications of Science I
- Unit 3: Science Investigation Skills
- Unit 10: Biological Molecules and Metabolic Pathways
- Unit 12: Diseases and Infections
- Unit 17: Microbiology and Microbiological Techniques.

## Employer involvement

Centres could approach a local university to try to arrange visits for learners to allow them to view commercial equipment used for extracting and carrying out genetic engineering techniques as well as the more advanced techniques not possible in centres' laboratories.

It may be possible to arrange visits from research scientists to give talks about their current research projects. A visit to a crop research faculty or a visit from scientists or technicians working there could enhance learner knowledge and understanding of the genetic research being undertaken and possible future developments.

Agricultural and horticultural colleges may be able to accommodate visits from learners to see how genetics has led to improved varieties of plants and animals.

A visit to an industrial state-of-the-art laboratory is recommended to help the learners appreciate the sophistication of the modern-day high-tech laboratories compared with the basic equipment available in many educational laboratories.

# Unit 12: Diseases and Infection

Level: **3**

Unit type: **Internal**

Guided learning hours: **60**

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## Unit in brief

Learners will gain understanding of five types of diseases, their causes and how humans try to prevent and treat them.

## Unit introduction

The prevention and treatment of disease and infection is a key part of the work health professionals around the world. It is important to understand what disease is and the causes of diseases and infections that affect humans. While non-infectious diseases caused by dietary, environmental, genetic and degenerative factors will be briefly studied in this unit, the main focus will be on causes of infectious diseases, and their transmission, prevention and treatment. There will be the opportunity to research the different types of pathogens and diseases they cause. Disease and infections can be caused by a wide range of pathogens and it is the knowledge of how these pathogens interact with the environment and the human body that forms the study of disease, which is also known as epidemiology.

You may know, or have had contact with, someone suffering from a genetic or degenerative disease. This unit will give you the opportunity to better understand the causes of these diseases and possible treatments.

You will gain an understanding of how the human body has natural defence mechanisms and can establish its own immunity to infectious disease. You will consider the periodic outbreak of infectious diseases and the problems associated with preventing their transmission and treating those affected. With global travel easily accessible to many people, pandemics are a real possibility, so you will investigate the role of organisations in preventing and treating infectious diseases.

The understanding and knowledge of factors that relate to disease, pathogens, their transmission and management is an essential requirement for those wishing to pursue a health science or bioscience related occupation. This could, for example, be in public health, microbiology, international health, the pharmaceutical industry or the food sector. This unit will help provide access to higher education to allow you to pursue these and related careers.

## Learning aims

In this unit you will:

- A** Investigate different types of diseases and infections that can affect humans
- B** Examine the transmission of infectious diseases and how this can be prevented
- C** Understand how infectious diseases can be treated and managed
- D** Understand how the human body responds to diseases and infections.

## Summary of unit

Learning aim	Key content areas	Recommended assessment approach
<b>A</b> Investigate different types of diseases and infections that can affect humans	<b>A1</b> Pathogens and infectious diseases <b>A2</b> Dietary and environmental diseases <b>A3</b> Genetic and degenerative diseases <b>A4</b> Progression of disease over time	Having researched a variety of infectious and non-infectious diseases, learners could produce case studies relating to their chosen diseases. The case studies would detail the cause and the effect the disease can have on body systems over time. The effect on the quality of life of the individual suffering from the disease must also be evaluated.
<b>B</b> Examine the transmission of infectious diseases and how this can be prevented	<b>B1</b> Methods by which infectious diseases can be spread <b>B2</b> Methods by which infectious diseases can be prevented from spreading <b>B3</b> Management of infectious diseases	In addition to research work, practical work and simulations should be used to ensure that learners are familiar with the methods by which infectious diseases can be transmitted. Prevention of transmission at a personal level and by organisations must be researched. A report or information leaflet can be produced as evidence.
<b>C</b> Understand how infectious diseases can be treated and managed	<b>C1</b> Methods of treatment <b>C2</b> Access to and acceptance of treatment	Research will need to be undertaken on the different methods of treating diseases. The mode of action of the treatments will need to be analysed. The accessibility or appropriateness of treatments for some people will be evaluated and reported.
<b>D</b> Understand how the human body responds to diseases and infections	<b>D1</b> Defence mechanisms <b>D2</b> Non-specific <b>D3</b> Specific	Information leaflets detailing and comparing the components of the two defence mechanisms and their mode of action could be produced.

## Content

### Learning aim A: Investigate different types of diseases and infections that can affect humans

#### A1 Pathogens and infectious diseases

- Pathogens – types and characteristics, life cycle and actions:
  - bacteria: prokaryotic, rapid production, damage to cells, toxins
  - parasites: require host, endoparasite, ectoparasite
  - viruses: akaryotic, takes over host cell metabolism
  - fungus; eukaryotic, ectoparasitic
  - protozoa: eukaryotic, toxin release damages cells.
- Infectious diseases:
  - pathogenic organisms invading the body: HIV, malaria, hepatitis, gonorrhoea, Ebola, tuberculosis
  - zoonotic (from animal to human): ringworm, tapeworm, rabies, avian flu H5N1, ticks, mites, fleas.

#### A2 Dietary and environmental diseases

- Dietary:
  - dietary deficiency or excess
  - diabetes
  - anaemia
  - cardiovascular disease
  - obesity
  - liver disease.
- Environmental:
  - pollutants, air (asbestos, smog), water (cholera)
  - radiation – UV (skin cancer).

#### A3 Genetic and degenerative disease

- Genetic – inherited through DNA or DNA mutation, e.g. cystic fibrosis, sickle cell anaemia, Huntington's disease:
  - patterns of inheritance
  - recessive alleles
  - Punnett square
  - mutation of DNA sequence.
- Degenerative – gradual decline in function, e.g. Alzheimer's, osteoporosis, osteoarthritis.

#### A4 Progression of disease over time

- Asymptomatic.
- Latency of disease.
- Effect on ability to lead a normal life/work.

## **Learning aim B: Examine the transmission of infectious diseases and how this can be prevented**

### **B1 Methods by which infectious diseases can be spread**

- Direct contact – transmission:
  - human to human, body fluids
  - animal to human, animal waste (droppings).
- Indirect contact:
  - vectors – fleas, lice, ticks, mosquitoes
  - transmission – surfaces, infected water droplets (sneezes, vapour from coughing)
  - contamination – food or water, e.g. salmonella, typhoid.

### **B2 Methods by which infectious diseases can be prevented from spreading**

- Prophylaxis:
  - antibiotics
  - antimalarial
  - antiviral.
- Personal protective equipment (PPE):
  - gloves
  - biohazard suits.
- Behaviours:
  - safe sex
  - mosquito nets
  - hand washing.
- Environmental:
  - no open water sources
  - use of chemical spray.
- Isolation/quarantine.
- Vaccination to prevent spread of disease:
  - vaccination programmes
  - types of vaccine (modified, attenuated, live antigens)
  - specificity to pathogen
  - stimulation of antibody production
  - herd immunity.

### **B3 Management of infectious diseases**

- Work of national and global organisations:
  - World Health Organization (WHO)
  - Médecins sans Frontières
  - Oxfam
  - NHS
  - WaterAid.

## **Learning aim C: Understand how infectious diseases can be treated and managed**

### **C1 Methods of treatment**

- Specific treatments for particular diseases.
- Antibiotics: disruption of reproductive process, disruption of energy process, cell wall/lysis, specificity, resistance.
- Antiviral, disruption of reproductive process.
- Antiretroviral, disruption of entry to cell.
- Antifungal, disruption of cell wall, disruption of reproductive process.
- Antiprotozoal, disruption to DNA replication.
- Antimalarial, disruption of lifecycle.
- Anthelmintic, disruption to nervous system, disruption of uptake of glucose.
- Rehydration therapy: use of salt, sugar, water to reverse effects of dehydration.
- Immunoglobulins, antibodies to fight infection.

### **C2 Access to and acceptance of treatment**

- Social barriers, stigma associated with the disease.
- Cultural beliefs, religious beliefs.
- Treatment regime, duration – one-off, long-term treatment.
- Accessibility of treatment, distance, cost.
- Adverse reaction, contraindications.

## **Learning aim D: Understand how the human body responds to diseases and infections**

### **D1 Defence mechanisms**

Categories:

- non-specific: immediate response; physical barrier, phagocytosis
- specific: slower response, specific to pathogen; cell mediated (T-lymphocytes), humoral response (B-lymphocytes).

### **D2 Non-specific**

- Physical barrier, e.g. skin, nasal hairs.
- Chemical barriers, e.g. mucus, stomach acid (HCl), tear duct secretions.
- Process of phagocytosis: phagocyte, role of histamine, lysosomes, lysozyme.

### **D3 Specific**

Differentiate between cell-mediated and humoral response (lymphocytes, location of lymphocyte development and maturation):

- cell-mediated response; response to invasion of non-self-material, T-lymphocytes action, role of antigens, viruses
- humoral response; B-lymphocytes action, role of antibodies, role of antigens, memory cells, secondary immune response, interaction with T-cells.

## Assessment criteria

Pass	Merit	Distinction
<b>Learning aim A: Investigate different types of diseases and infections that can affect humans</b>		<b>A.D1</b> Analyse how an infectious and a non-infectious disease will progress over time, and the effects this may have on affected individuals.
<b>A.P1</b> Explain the characteristics of the five main types of pathogens and a disease caused by each. <b>A.P2</b> Explain the causes of non-infectious diseases in humans.	<b>A.M1</b> Assess the effect of a named infectious and non-infectious disease on body systems.	
<b>Learning aim B: Examine the transmission of infectious diseases and how this can be prevented</b>		<b>B.D2</b> Evaluate the role of organisations in limiting the spread of infectious diseases.
<b>B.P3</b> Explain how infectious diseases can be transmitted.	<b>B.M2</b> Assess how infectious diseases can be prevented from spreading.	
<b>Learning aim C: Understand how infectious diseases can be treated and managed</b>		<b>C.D3</b> Evaluate why treatments may not always be accessible, or appropriate, for particular individuals.
<b>C.P4</b> Describe the method available to treat a type of infectious disease.	<b>C.M3</b> Analyse different treatment methods to combat disease process.	
<b>Learning aim D: Understand how the human body responds to diseases and infections</b>		<b>D.D4</b> Evaluate the roles of the cell-mediated and humoral responses to pathogens.
<b>D.P5</b> Explain the components of the specific and the non-specific defences, in protecting the body.	<b>D.M4</b> Compare the roles of the specific and non-specific defence mechanisms in the human body.	



## Essential information for assignments

The recommended structure of assessment is shown in the unit summary along with suitable forms of evidence. *Section 6* gives information on setting assignments and there is further information on our website.

There is a maximum number of four summative assignments for this unit. The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.P2, A.M1, A.D1)

Learning aim: B (B.P3, B.M2, B.D2)

Learning aim: C (C.P4, C.M3, C.D3)

Learning aim: D (D.P5, D.M4, D.D4)

## Further information for teachers and assessors

### Resource requirements

For this unit, learners must have access to:

- general biology reference material
- online media databases
- biology software packages or apps.

There are a number of different kits available from scientific supply companies that help learners to understand how diseases are transmitted among humans. Prepared slides and micrographs can be used to support understanding.

### Essential information for assessment decisions

#### Learning aim A

**For distinction standard,** learners will choose a named infectious disease and analyse how the pathogen, having entered the body, will cause infection, disruption and damage to the body systems. Learners must also choose a non-infectious disease and analyse the effects of this on the affected individual. Depending on the two diseases chosen, learners may need to include reference to the fact that individuals may experience asymptomatic periods. They must methodically examine the progress of the infection or diseases and relate this to the individual's ability to lead a normal life.

Learners could be encouraged to produce a case study for each of the diseases they have chosen. They could adopt a holistic approach to the learning aim and use diseases they have already studied. Alternatively for this criterion, different diseases could be selected and analysed.

**For merit standard,** learners will choose a named infectious disease, and the effects the pathogen has on the various body systems must be considered in detail. They will highlight the most important factors associated with damage caused to various body systems and draw conclusions as to their importance in relation to the impact they have on the overall function of the body.

Similarly, learners must choose a non-infectious disease and assess how it affects the various body systems and its overall impact on the body. For instance, learners may detail how the progressive nature of a disease such as multiple sclerosis will result in damage to the nervous pathways over time. The body systems affected will need to be identified and the impact of the effect to the systems assessed. In the case of multiple sclerosis, learners should also assess the impact of possible periods of remission. The diseases do not have to be chosen from the unit content.

**For pass standard,** learners will identify and explain the main features of the five main categories of pathogens in the unit content. Learners will need to research and identify a named disease caused by each pathogen. Learners will use their research material to explain the involvement of the pathogens in causing the infectious diseases that have been identified. The characteristics and life cycle of the pathogen for each of the five named diseases must be included in the evidence presented for assessment.

Learners are required to research the causes of non-infectious diseases and select one disease from each of the four categories in the unit content. Reasons as to how and why each named disease has arisen must be given. It is expected that Punnett squares/genetic diagrams will be used when learners are providing details for a genetic disease. However, these are unlikely to provide sufficient detail without a commentary explaining what they show. The examples of infectious and non-infectious diseases in the unit content do not have to be used. It is acceptable for learners to choose their own examples based on their own interests or experiences, but not for all of the learners to provide evidence for all the same diseases.

## Learning aim B

**For distinction standard,** learners will extend their knowledge, having explored how infectious diseases are caused and transmitted, to include an understanding of how organisations are working to limit the spread of infectious diseases. It is not expected that all methods listed in unit content B2 will be covered at this level, as they are not all used for every disease. Learners will need to evaluate the strengths and weaknesses, and advantages and disadvantages of the methods being used and their significance in limiting the spread of disease(s).

Learners can meet the criterion by choosing a named disease and providing a case study on organisations involved in preventing the spread of that disease. Alternatively, they can choose an organisation and evaluate the methods adopted to help prevent the spread of diseases the organisation is involved in. Examples of some suitable organisations are given in the unit content, but learners are free to choose their own.

**For merit standard,** learners will assess the methods that can be used to prevent the transmission and spread of infectious diseases. They should assess each method in relation to specific examples of diseases in order to reach a conclusion about the effectiveness/relevance of the method in preventing the disease. For example, with the use of prophylaxis for preventing malaria, learners should consider the effectiveness of the method in relation to people remembering to take it, cost and possible side effects. They must consider vaccination programmes and cite their importance in the evidence presented.

**For pass standard,** learners will need to become familiar with the methods by which infectious diseases can be transmitted. While much information will be acquired through research, it is expected that learners have the opportunity to investigate this practically (swabs of surfaces, and water samples cultivated on agar plates could be used, depending on availability of equipment and health and safety regulations in centres). Practical work will not be formally assessed. Alternatively, to engage learners and increase their understanding, simulation activities of 'swapping body fluids' and transmission by touching/shaking hands can be carried out. Assessment evidence requires learners to demonstrate knowledge and understanding of direct and indirect methods of transmission in the unit content.

## Learning aim C

**For distinction standard,** learners will extend their knowledge and understanding of methods of treating disease to consider the relevance and significance of the available treatments and why they may not be suitable for everyone. They will need to consider the method of delivery of the treatment. Is it easily available? Who administers it? How is it administered (tablet, injection)? Learners will need to explore and evaluate social, cultural and religious beliefs, as well as contraindications and consideration of potential side effects.

**For merit standard,** learners will examine and provide detail about how and why the different treatments work and why, in some instances, they might not work. Learners must refer to specific diseases and make comparisons. They should examine vaccination, detailing types of vaccine and giving the mode of action. This could be in relation to a specific vaccination programme.

**For pass standard,** learners will identify the pathogen and the method of treating a named disease. They should provide detail on the delivery of the treatment – oral, injection and so on. All the unit content should be covered.

## Learning aim D

**For distinction standard**, learners will consider the relevance, significance, advantages and disadvantages, and strengths and weaknesses of having a cell-mediated and a humoral response to infection caused by a pathogen. They could produce an illustrated report as evidence. They must detail the significance of the speed and specificity of the response in relation to the defence process and progression of the disease in the body. Learners are expected to use examples of specific diseases in their evidence.

**For merit standard**, learners will examine the key aspects and processes of the specific and non-specific defence mechanisms and their suitability for the purpose of defending the body. They must compare in detail similarities and differences, and reasons why it is beneficial to have both types available to help protect the body. Learners should include details on the speed and specificity of the response to the disease.

**For pass standard**, learners will explain the defence systems of the body. They could produce an information leaflet that explains how and why the non-specific defences of physical and chemical barriers and phagocytosis works. Another section of the leaflet could explain the components and function of the specific defence system.

## Links to other units

This unit links to:

- Unit 1: Principles and Applications of Science I
- Unit 11: Genetics and Genetic Engineering
- Unit 17: Microbiology and Microbiological Techniques
- Unit 20: Biomedical Science.

## Employer involvement

A visit from the local Environmental Health Department may afford learners an opportunity to understand the role of the department in identifying pathogens and sources of infection and in preventing transmission of pathogens. They may also be able to provide information in relation to environmental diseases and their prevention.

It may be possible to arrange a visit from a pharmacist/pharmacologist who will be able to discuss prophylaxis, vaccination and possible treatments for various types of pathogens.

Local representatives of local and national organisations and charities may be available to provide information about initiatives in which their organisations are involved to help prevent the spread of disease.

# Unit 13: Applications of Inorganic Chemistry

Level: **3**

Unit type: **Internal**

Guided learning hours: **60**

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## Unit in brief

The unit covers three important inorganic chemistry topics: acid-base equilibria, redox reactions and transition metal complexes.

## Unit introduction

Acid-base equilibria are important industrially and in biology. Analysts in many companies carry out acid-base titration – for example in the production of fatty acids from fats, finding the acid number in the oil industry, and determining the acidity of wine and vinegar. The phosphate and carbonic acid buffer systems help to maintain pH in cells. Compounds are often added to food products to ensure that the pH remains constant and the mixture stable. In this unit, you will learn how to calculate the pH of solutions and carry out acid-base titrations using pH meters, learning how to select suitable indicators for titrations and how autotitrators work. You will also explore buffer action.

Oxidation-reduction reactions, involving loss and gain of electrons, have applications in industry and in biology. You will learn how to write oxidation-reduction half-equations and balance overall redox equations in terms of the number of electrons involved. The concept of oxidation number will allow you to identify redox equations. There are several industrial analytical methods that involve redox reactions, and you will have the opportunity to use and research some of these.

Many compounds of biological importance are transition metal complexes. You will learn about complexes of the period 4 transition metals, exploring terms related to complexes and investigating substitution reactions and acid-base reactions of transition metal complexes. You will make and explain very detailed observations from the reactions and you will summarise the main reactions that transition metals undergo, devising a scheme for distinguishing between metal ions in solution.

Most of the chemistry in this unit is particularly applicable to the water testing and water treatment industries. For example, pH is routinely measured when testing the quality of effluent. Dichromate oxidation is used to determine chemical oxygen demand which gives an indication of the extent of contamination of water by organic substances. The corrosion of industrial water boilers must be carefully controlled and this work is often sub-contracted to specialists. The level of acidity and the concentration of transition metal ions is important when determining the nature and concentration of treatment chemicals. Aqueous effluent is often treated by neutralisation.

## Learning aims

In this unit you will:

- A** Investigate acid-base equilibria in order to understand buffer action and to optimise acid-base titration procedures
- B** Investigate oxidation-reduction reactions in order to understand their many applications in analysis
- C** Investigate practically a range of reactions involving solutions of transition metal ions in order to understand the basis for their qualitative analysis.

## Summary of unit

Learning aim	Key content areas	Recommended assessment approach
<b>A</b> Investigate acid-base equilibria in order to understand buffer action and to optimise acid-base titration procedures	<p><b>A1</b> Calculation of the pH of strong acids, strong alkalis, weak acids and buffer solutions</p> <p><b>A2</b> Behaviour of strong and weak acids and alkalis and buffer solutions</p>	<p>pH calculations. Results of finding <math>K_a</math>, descriptions and assessment of buffer action. Results and graphs from four pH titrations and a statement justifying choices of suitable indicators for titrations.</p> <p>A report evaluating titrations using indicators, pH meters and autotitrators.</p>
<b>B</b> Investigate oxidation-reduction reactions in order to understand their many applications in analysis	<p><b>B1</b> Displacement reactions and electrochemical cells</p> <p><b>B2</b> Use of oxidation number</p> <p><b>B3</b> Titrimetric methods involving oxidation-reduction reactions</p>	<p>Oxidation, reduction and redox equations and standard cell voltages for a range of electrochemical cells. Comparison of three measured cell voltages with the standard voltages. Identification of the redox reactions in a list of six given reactions justified on the basis of oxidation numbers. Results and calculations for a range of redox titrations plus discussion of the redox bases for these titrations. Observations from the oxidation of an alcohol with acidified dichromate. An evaluation of the use of iodine/thiosulfate titration and determination of chemical oxygen demand in industry.</p>
<b>C</b> Investigate practically a range of reactions involving solutions of transition metal ions in order to understand the basis for their qualitative analysis	<p><b>C1</b> The nature of transition metal complexes</p> <p><b>C2</b> Reactions of transition metal complexes</p>	<p>Results table for test tube reactions involving transition metals and explanations of the reactions including equations.</p> <p>A PowerPoint presentation analysing the types of reactions that transition metals undergo and providing a reaction scheme to identify five transition metal ions in solution.</p>

## Content

### Learning aim A: Investigate acid-base equilibria in order to understand buffer action and to optimise acid-base titration procedures

#### A1 Calculation of the pH of strong acids, strong alkalis, weak acids and buffer solutions

- Brønsted-Lowry acid is a proton donor.
- Brønsted-Lowry base is a proton acceptor.
- Conjugate acids and bases.
- $\text{HA} = \text{H}^+ + \text{A}^-$
- Definition of acid dissociation constant  $K_a$  in terms of the above equilibrium  $K_a = \frac{[\text{A}^-][\text{H}^+]}{[\text{HA}]}$
- Magnitude of  $K_a$  related to degree of dissociation.
- Strong acids and alkalis are fully dissociated.
- Weak acids and alkalis are partially dissociated.
- $K_a$  for a strong acid is large – virtually no whole acid molecules are present.
- $K_a$  for a weak acid is small – most of the acid is dissolved as whole molecules.
- $\text{pH} = -\log[\text{H}^+]$
- $[\text{H}^+] = 10^{-\text{pH}}$
- $\text{p}K_a = -\log K_a$
- $[\text{H}^+] =$  acid concentration for strong acids.
- pH of  $0.1 \text{ mol dm}^{-3}$  strong acid is  $\sim 1$ , of  $0.01 \text{ mol dm}^{-3}$  strong acid is  $\sim 2$  etc.
- Ionic product for water  $K_w = [\text{H}^+][\text{OH}^-] = 1 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$
- $\text{p}K_w = -\log K_w$
- $[\text{OH}^-] =$  alkali concentration for strong alkalis.
- For strong alkalis,  $[\text{H}^+] = \frac{K_w}{[\text{OH}^-]}$
- For weak acids,  $[\text{H}^+] = \sqrt{(K_a \times [\text{HA}])}$
- Acidic buffer – a solution of a weak acid and a salt of the weak acid.
- $\text{pH} = -\log K_a + \log \left( \frac{[\text{A}^-]}{[\text{HA}]} \right)$  for a buffer solution (Henderson-Hasselbalch equation).
- Calculation of pH for strong acids, weak acids, strong alkalis and buffer solutions.
- Industrial applications of pH measurement:
  - in wastewater treatment, pH should be in the range 6–10 for safety, to ensure that pipes and pumps are not damaged and to ensure that microbiological treatment processes are not compromised
  - in the wine industry, pH may have an effect on the rates of different fermentation processes, flavour, aroma, colour, tartrate content, ability to absorb carbon dioxide and the keeping quality of the wine
  - pH is measured by pharmaceutical companies as an indicator of what the water that is used in their processes may contain.

**A2 Behaviour of strong and weak acids and alkalis and buffer solutions**

- Determination of  $K_a$  from the pH of the solution where half the acid is neutralised.
- Investigate buffer action.
- Roles of carbonic acid molecules and hydrogen carbonate ions in controlling blood pH.
- pH titrations of strong acid/strong alkali, strong acid/weak alkali, weak acid/strong alkali, weak acid/weak alkali and descriptions of the shapes of the pH/volume titration curves.
- Excel differential plots ( $\Delta\text{pH}/\Delta\text{volume}$  versus volume added) and the use of these plots in determining end point of a titration.
- Selection of indicator for an acid-base titration on the basis of the rapid change of pH (or spike from a differential plot) being within the pH range of the indicator.
- Awareness of the use of autotitrators – programming the additions to make for a particular industrial analysis, appreciation of how the instrument determines end point.
- Industrial applications of acid-base titration:
  - wine industry
  - determination of the acid number of biodiesel
  - manufacture of soft drinks
  - manufacture of fatty acids from fats.
- Industrial applications of buffers and acidity regulators in the food industry.

**Learning aim B: Investigate oxidation-reduction reactions in order to understand their many applications in analysis****B1 Displacement reactions and electrochemical cells**

- Oxidation defined in terms of loss of electrons.
- Reduction defined in terms of gain of electrons.
- Displacement reactions for metals, to include zinc with lead nitrate solution and copper(II) sulphate solution, lead with copper(II) sulphate solution.
- Half-equations for oxidation and reduction and full redox equations for displacement reactions for metals.
- Metal/metal ion half cells.
- Standard conditions (1 bar pressure, temperature of 298 K and ionic concentration (more strictly, activity) of 1).
- Standard hydrogen electrode.
- Table of standard reduction potentials.
- Standard cell notation.
- Measurement of voltage of the following cells (using 0.1 mol dm<sup>-3</sup> solutions):
  - $\text{Zn}_{(s)}/\text{Zn}^{2+}_{(aq)} \parallel \text{Cu}^{2+}_{(aq)}/\text{Cu}_{(s)}$
  - $\text{Zn}_{(s)}/\text{Zn}^{2+}_{(aq)} \parallel \text{Pb}^{2+}_{(aq)}/\text{Pb}_{(s)}$
  - $\text{Pb}_{(s)}/\text{Pb}^{2+}_{(aq)} \parallel \text{Cu}^{2+}_{(aq)}/\text{Cu}_{(s)}$
- Calculation of voltage using table of standard reduction potential and comparison with theoretical voltages.
- Half cells involving platinum electrodes.
- Using table of standard reduction potential to calculate the voltages of a range of cells under standard conditions.
- Balancing redox equation in terms of the number of electrons involved in the oxidation-reduction process.
- Consideration of the extent to which standard reduction potentials are useful in predicting corrosion behaviour.
- Industrial applications of displacement reactions and electrochemical cells
  - making batteries
  - determination of corrosion behaviour.



**B2 Use of oxidation number**

- Working out oxidation number for elements in elements, compounds and ions, including compound ions from rules.
- Using oxidation number to identify oxidation-reduction equations.
- The oxidation number of the element that undergoes oxidation in an oxidation-reduction reaction becomes more positive (less negative).
- The oxidation number of the element that undergoes reduction in an oxidation-reduction reaction becomes more negative (less positive).
- Industrial applications – understanding oxidation/reduction reactions.

**B3 Titrimetric methods involving oxidation-reduction reactions**

- Balancing oxidation-reduction half equations.
- Determination of iron(II) concentration by titration with potassium manganate(VII):
  - self-indicating
  - $\text{Fe}^{2+} \rightarrow \text{Fe}^{3+} + \text{e}^-$
  - $\text{MnO}_4^- + 8\text{H}^+ + 5\text{e}^- \rightarrow \text{Mn}^{2+} + 4\text{H}_2\text{O}$
  - 5 : 1 ratio of  $\text{Fe}^{2+}$  to  $\text{MnO}_4^-$  in redox equation
  - $5\text{Fe}^{2+} + \text{MnO}_4^- + 8\text{H}^+ \rightarrow 5\text{Fe}^{3+} + \text{Mn}^{2+} + 4\text{H}_2\text{O}$
  - requirement for sulfuric acid to be added to supply the hydrogen ions on the left hand side of the equation in order for the titration to work
  - application to finding the amount of iron(II) in commercial iron tablets.
- Iodine/thiosulfate titration:
  - standardisation of thiosulfate with potassium iodate
  - use of thiosulfate to determine the concentration of iodine in a solution
  - quantitative conversion of added iodide from KI crystals or tablets to iodine by the presence of an oxidising agent
  - determination of hypochlorite ( $\text{ClO}^-$ ) in bleach by titration with standardised thiosulfate solution
  - determination of  $\text{Cu}^{2+}$  in a solution by titration with standardised thiosulfate solution
  - determination of peroxide in a rancid fat by titration with standardised thiosulfate solution
  - iodine number of an oil
  - awareness of the position of iodine in the periodic table facilitating the conversion of iodine to iodide and iodide to iodine
  - review industrial applications of the iodine/thiosulfate titration.
- Potential use of dichromate(VI) as a titrant:
  - half-equation  $\text{Cr}_2\text{O}_7^{2-} + 14\text{H}^+ + 6\text{e}^- \rightarrow 2\text{Cr}^{3+} + 7\text{H}_2\text{O}$
  - colour change of orange to blue-green
  - need for acid to supply the hydrogen ions to make the reaction work
  - test tube oxidation of suitable organic compounds with acidified potassium dichromate(VI) – colour change indicates oxidation of the organic compound has taken place.
- Potassium dichromate(VI) as a hazardous substance:
  - dichromate causes serious damage to eyes, skin, organs, respiratory system, fertility and causes cancer, genetic defects and may be a skin allergen
  - crystals of potassium dichromate are small enough to be inhaled accidentally by those preparing solutions
  - use of large volumes as in a titration increases risk of exposure
  - potential risk of fire if combustible material is used to clean spillages.

- Risks involved in the titration process outweigh the educational benefits.
- Use of dichromate(VI) in industry to determine chemical oxygen demand:
  - used extensively to test water in a range of organisations
  - digestion process is potentially dangerous so commercial kits are used
  - additives are included in the kits
  - amount of dichromate used is often determined using colorimetry (rather than titration) in commercial kits.
- Industrial applications of oxidation-reduction:
  - the wastewater treatment and water testing industries
  - iodometry and iodimetry
  - food industry uses the iodine/thiosulfate titration to determine peroxide value of fats and oils as an indicator of rancidity
  - food industry and other industries may determine iodine number as a measure of unsaturation
  - metal plating industry may use iodine/thiosulphate titration to determine the concentration of  $\text{Cu}^{2+}$
  - water treatment industry may use iodine/thiosulfate titration to measure  $\text{ClO}^-$ -concentration in bleach.

**Learning aim C: Investigate practically a range of reactions involving solutions of transition metal ions in order to understand the basis for their qualitative analysis**

**C1 The nature of transition metal complexes**

- Deduce electronic configurations of atoms and ions of the d-block elements of period 4 (Sc–Zn) given the atomic number and the charge.
- Ligands:  $\text{H}_2\text{O}$ ,  $\text{NH}_3$ ,  $\text{CN}^-$ ,  $\text{Cl}^-$ ,  $\text{OH}^-$ ,  $\text{SCN}^-$ ,  $\text{SO}_4^{2-}$ , EDTA, diaminoethane, ethanedioate, mandedate, multidentate.
- Complex ions containing a transition metal ion surrounded by ligands.
- Co-ordinate (dative) bonding in complex ions.
- Charge on complex ions, taking account of ligand charge.
- Formulae of complex ions using square bracket notation.
- Co-ordination number.
- Most common arrangements of ligands (octahedral, tetrahedral and square planar) and examples of each.
- Colour of transition metal complexes due to splitting of d-orbitals due to the presence of ligands:
  - simple crystal field theory.
- Colour affected by oxidation number, ligand and co-ordination number.
- Industrial applications of transition metal complexes:
  - pigments
  - catalysts
  - inkjet printing of circuits
  - pharmaceuticals.

**C2 Reactions of transition metal complexes**

- Practical investigation of ligand substitution in hexaaqua complexes:
  - $\text{Cl}^-$  from very concentrated hydrochloric acid to include:
    - $[\text{CuCl}_4]^{2-}$  from  $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$
    - $[\text{CoCl}_4]^{2-}$  from  $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$
    - $[\text{Cr}(\text{H}_2\text{O})_4\text{Cl}_2]^+$  from  $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}$
  - reversal of substitution by addition of water
  - ammonia to include formation of:
    - $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$  from  $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$  via  $\text{Cu}(\text{OH})_2(\text{H}_2\text{O})_4$
    - $[\text{Co}(\text{NH}_3)_6]^{2+}$  from  $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$  via cobalt (II) hydroxide
    - $[\text{Cr}(\text{NH}_3)_6]^{3+}$  from  $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}$  via chromium (III) hydroxide
  - $[\text{Cr}(\text{H}_2\text{O})_5\text{SO}_4]^+$  by warming chromium (III) sulphate solution containing  $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}$
  - $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$  reacting with the ligand  $\text{SCN}^-$  to give the deep red  $[\text{Fe}(\text{SCN})(\text{H}_2\text{O})_5]^{2+}$  – a test for  $\text{Fe}^{3+}$  in solution
  - colour changes accompanying substitution reactions and colours of precipitated hydroxides.
- Substitution of CO for oxygen in haemoglobin in carbon monoxide poisoning.
- Addition of sodium hydroxide to transition metal ions in solution:
  - low pH of hexaaqua  $3^+$  ions in solution – ions acting as proton donors (Lewis acids)
  - $2^+$  ions are less acidic because the lower charge has less pull on the electrons of the water molecule and the  $\text{H}^+$  is less easily lost
  - hydronium ions involved – can be simplified to  $\text{H}^+_{(\text{aq})}$
  - adding hydroxide uses the hydrogen ions and forces the series of equilibria below to the right, ending with a neutral complex (the metal hydroxide) which is insoluble – using iron as the example:
    - $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}_{(\text{aq})} \rightleftharpoons [\text{Fe}(\text{H}_2\text{O})_5(\text{OH})]^{2+}_{(\text{aq})} + \text{H}^+_{(\text{aq})}$
    - $[\text{Fe}(\text{H}_2\text{O})_5(\text{OH})]^{2+}_{(\text{aq})} \rightleftharpoons [\text{Fe}(\text{H}_2\text{O})_4(\text{OH})_2]^+_{(\text{aq})} + \text{H}^+_{(\text{aq})}$
    - $[\text{Fe}(\text{H}_2\text{O})_4(\text{OH})_2]^+_{(\text{aq})} \rightleftharpoons [\text{Fe}(\text{H}_2\text{O})_3(\text{OH})_3]_{(\text{s})} + \text{H}^+_{(\text{aq})}$
  - $2^+$  ions react in the same way with hydroxide to produce a precipitate of the hydroxide
  - $[\text{Zn}(\text{H}_2\text{O})_4(\text{OH})_2]$  may react further to produce  $[\text{Zn}(\text{OH})_4]^{2-}$
  - the reaction with  $3^+$  ions can go further in some cases to produce  $[\text{M}(\text{H}_2\text{O})_2(\text{OH})_4]^-$  and then  $[\text{M}(\text{H}_2\text{O})(\text{OH})_5]^{2-}$  and then  $[\text{M}(\text{OH})_6]^{3-}$
  - charged hydroxide complex ions redissolve.
- Addition of ammonia solution to transition metal ions in solution (apart from the effect of ligand substitution):
  - ammonia acts as a Lewis base and accepts  $\text{H}^+$  from complexes in the same way as water
  - $[\text{M}(\text{H}_2\text{O})_6]^{3+} + \text{NH}_3 \rightleftharpoons [\text{M}(\text{H}_2\text{O})_5(\text{OH})]^{2+} + \text{NH}_4^+$
- Addition of carbonate to transition metal ions in solution:
  - $3^+$  ions are strongly acidic and react to give a precipitate of the hydroxide and carbon dioxide
  - $2^+$  ions are less acidic and react to give the insoluble metal carbonate.
- Opportunity for carefully carrying out test tube reactions, noting colour changes and appearance of precipitates – reagents added dropwise and in excess.
- Use of descriptions and equations to explain observations.
- Use of matrices for determining unknown cations by test tube reactions.
- Industrial applications:
  - catalysts (making use of ligand substitution in catalysis)
  - understanding and preventing corrosion
  - removal of transition metal ions from wastewater by the addition of hydroxide ions.

## Assessment criteria

Pass	Merit	Distinction
<b>Learning aim A: Investigate acid-base equilibria in order to understand buffer action and to optimise acid-base titration procedures</b>		
<p><b>A.P1</b> Perform straightforward calculations to determine the pH of solutions.</p> <p><b>A.P2</b> Demonstrate accurately a reading of <math>K_a</math> in a weak acid and demonstrate buffer action.</p> <p><b>A.P3</b> Demonstrate accurate use of a pH meter in order to select suitable indicators.</p>	<p><b>A.M1</b> Perform complex calculations involving pH, including rearranging equations.</p> <p><b>A.M2</b> Assess the action of a buffer solution.</p> <p><b>A.M3</b> Justify the selection of indicators for the titrations.</p>	<p><b>A.D2</b> Evaluate the accuracy of acid-base titrations using an indicator, a pH meter and an autotitrator.</p>
<b>Learning aim B: Investigate oxidation-reduction reactions in order to understand their many applications in analysis</b>		
<p><b>B.P4</b> Compare measured cell voltages for electrochemical cells involving metal/metal ion half cells with voltages calculated by using oxidation, reduction and redox equations.</p> <p><b>B.P5</b> Demonstrate how to determine accurate oxidation numbers for species in equations to identify reactions involving oxidation and reduction.</p> <p><b>B.P6</b> Demonstrate how to determine the concentration of analytes using analytical procedures involving oxidation and reduction.</p>	<p><b>B.M4</b> Express oxidation, reduction and redox equations and calculate standard cell voltages for given pairs of half cells.</p> <p><b>B.M5</b> Explain the redox reactions involved in analytical procedures in terms of the oxidation numbers for the species involved.</p>	<p><b>B.D2</b> Evaluate the industrial use of analytical procedures using redox reactions.</p>
<b>Learning aim C: Investigate practically a range of reactions involving solutions of transition metal ions in order to understand the basis for their qualitative analysis</b>		
<p><b>C.P7</b> Describe features of transition metal complexes.</p> <p><b>C.P8</b> Make accurate observations from practical work involving reactions of transition metal complexes.</p>	<p><b>C.M6</b> Explain the results of practical work involving transition metal complexes.</p>	<p><b>C.D3</b> Analyse the reactions of transition metal complexes from practical work to show how metal ions may be identified from the reactions that they undergo.</p>

## Essential information for assignments

The recommended structure of assessment is shown in the unit summary along with suitable forms of evidence. *Section 6* gives information on setting assignments and there is further information on our website.

There is a maximum number of three summative assignments for this unit. The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.P2, A.P3, A.M1, A.M2, A.M3, A.D1)

Learning aim: B (B.P4, B.P5, B.P6, B.M4, B.M5, B.D2)

Learning aim: C (C.P7, C.P8, C.M6, C.D3)

## Further information for teachers and assessors

### Resource requirements

For this unit, learners must have access to a well-equipped laboratory with a fume cupboard.

### Essential information for assessment decisions

#### Learning aim A

**For distinction standard**, learners will evaluate the good and bad points of acid-base titrations using indicators, pH titrations and titrations using autotitrators in terms of producing accurate results. Learners will consider the effect of choosing the wrong indicator and any problems with using indicators, but they will be able to explain how indicator titrations may still provide highly accurate results. They will consider the cost of equipment and the need for calibration and maintenance of equipment. The amount of titrant added each time, for the three types of titration, could be considered. Learners must not assume that the more automated a process, the more accurate it will be.

**For merit standard**, learners will perform complex calculations involving pH and acid dissociation constant. Two questions will be set on each of strong acids, strong alkalis, weak acids and buffer solutions which involve rearrangement of the equations. For example, learners could be given the pH and the acid concentration of a solution and asked to calculate the acid dissociation constant. The answer to one of the two questions of each type must be completely correct in order to achieve the criterion. Learners will assess buffer action in terms of the Henderson-Hasselbalch equation and will explain the buffer action that occurs in the blood. Learners will justify their selection of indicator for the four titrations carried out using appropriate scientific language. This should involve considering the pH range of the indicator and the rapid change of pH in the pH versus volume curve for the titration.

**For pass standard**, learners will perform straightforward calculations to find the pH of strong acids, strong alkalis, weak acids and buffer solutions. Calculation of  $[H^+]$  from pH will also be included. Learners will be given extensive practice in preparation for a short test, with a formula sheet, where they perform two calculations of each type (ten questions). The answer to one of the two questions of each type must be completely correct in order to achieve the criterion.

Learners will make an acidic buffer solution, calculating its pH and comparing that pH with the measured pH using an accurately calibrated pH meter. They will add small amounts of strong alkali or strong acid (for example,  $1\text{ cm}^3$  of a  $0.1\text{ mol dm}^{-3}$  solution) to the buffer, measure the pH and describe what that tells them about the buffer solution in terms of the effects on pH of adding acid or alkali. Learners will be specific about the sizes of the pH changes observed and the quantities of acid and alkali added.

Learners will carry out pH titrations (strong acid/strong alkali, strong acid/weak alkali, weak acid/strong alkali, weak acid/weak alkali) adding  $0.5\text{ cm}^3$  of titrant at a time and noting pH. They will plot scatter graphs of pH against volume of acid added and  $\Delta\text{pH}/\Delta\text{volume}$  against volume of acid (in Excel®) and determine the end point of each of the four titrations. They will also note the extent of the rapid change in pH and use this to select a suitable indicator for each titration from research carried out on the pH ranges of indicators.

## Learning aim B

**For distinction standard,** learners will investigate a range of industrial analytical procedures involving redox reactions, to include the iodine/thiosulfate and the use of chemical oxygen demand kits. Learners will produce a report evaluating the industrial applications of redox titrations and use of chemical oxygen demand kits. They will evaluate how widespread these techniques are and the types of industry that use them. Learners will consider alternative analytical procedures that could be used if appropriate.

**For merit standard,** learners will be given four electrochemical cells for which they must write oxidation, reduction and redox equations and calculate the standard cell voltage. These will include the need to balance the redox equations in terms of the number of electrons involved and also half cells, involving platinum (of the type  $\text{Pt}_{(s)}/\text{Fe}^{3+}_{(aq)}, \text{Fe}^{2+}_{(aq)}$ ).

Learners will discuss the titrations carried out at pass standard, in terms of the oxidation, numbers of the species involved and the number of electrons involved, and how that allows the concentrations to be determined.

**For pass standard,** learners will write the oxidation and reduction half-cell and redox equations for all three of the electrochemical cells in the content and calculate their standard cell voltages using standard reduction potentials. They will measure the voltages of the three cells and compare their measurements to the standard voltages calculated.

Learners will be presented with a list of at least six equations, some of which are oxidation/reduction equations. Some should be equations of other types, for example acid/base and precipitation. They will correctly identify the oxidation and reduction equations and give limited explanation of how they have done this in terms of accurately calculating the oxidation numbers of the elements in the species (elements, compounds, ions) involved.

Learners will carry out the  $\text{Fe}^{2+}/\text{MnO}_4^-$  titration to standardise an  $\text{Fe}^{2+}$  solution with given standardised  $\text{MnO}_4^-$ , standardise sodium thiosulfate solution with potassium iodate,  $\text{KIO}_3$ , and use it to determine the concentration of at least two analytes in solution (iodine, hypochlorite,  $\text{Cu}^{2+}$ , peroxide). Observation reports and calculated results will provide evidence. Learners must also carry out a test tube reaction showing how an organic compound may be oxidised with acidified potassium dichromate solution and describe their observations.

## Learning aim C

**For distinction standard,** learners will analyse the reactions that transition metals undergo. Their presentations will have a clear structure, showing that they understand the concepts of ligand substitution and acidity. They will select five transition metal ions in solution and present a reaction scheme that allows these metal ions to be identified in terms of colours observed and the absence/presence of a precipitate when certain reagents are added. The underlying chemistry of the scheme will be explained.

**For merit standard,** learners will use equations to explain the results of the practical work carried out to achieve the pass criteria. They must explain at least one example of the ligand substitution reactions with ammonia and with chloride, and an example of the reactions with each of the reagents, hydroxide, ammonia, carbonate (dropwise and in excess). Learners will use accurate terminology in explanations and correct notation in equations.

**For pass standard,** learners will answer questions that allow them to describe what is meant by the terms 'transition metal', 'ligand', 'complex', 'octahedral', 'tetrahedral', 'square planar' and the square bracket notation in relation to specific transition metal complexes. They should be able to give a brief description of the bonding type in complexes. Learners will carry out ligand substitution reactions with ammonia and chloride and add sodium hydroxide, ammonium hydroxide and sodium carbonate (dropwise and in excess) to transition metal ions in solution. (Note that very concentrated hydrochloric acid must be used for chloride to substitute water molecules in complexes.) They will be required to design and use suitable tables for recording results and make accurate observations from practical work. Five of the Period 4 transition metals will be selected for an assessment.

## Links to other units

This unit links to:

- Unit 1: Principles and Applications of Science I
- Unit 2: Practical Scientific Procedures and Techniques
- Unit 3: Science Investigation Skills
- Unit 6: Investigative Project
- Unit 19: Practical Chemical Analysis.

## Employer involvement

Centres may involve employers in the delivery of this unit if there are local opportunities.

For example, it will be beneficial for learners to visit the testing laboratories of local companies that treat wastewater from industry. Speakers from the water treatment industry or specialist companies that treat boiler water to prevent corrosion will be able to explain the relevance of the chemistry in this unit.



# Unit 14: Applications of Organic Chemistry

Level: **3**

Unit type: **Internal**

Guided learning hours: **60**

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## Unit in brief

Learners will cover the skills required to prepare and test a range of organic compounds and develop an understanding of their properties and uses in everyday life.

## Unit introduction

In this unit, you will learn that the majority of the substances we use every day are, or contain, organic compounds. This is because carbon, the basis of organic compounds, can form molecules consisting of chains and rings of atoms that enable it to bond with itself and with other elements to form useful products. Pharmaceuticals such as aspirin and paracetamol, synthetic fibres for our clothes such as acrylics and polyesters, fuels for our transport vehicles, soaps and detergents, dyes, flavourings, perfumes and liquid crystal display materials are just a few of the many organic substances that are manufactured on an industrial scale for us all to use. The number of known organic compounds is enormous and growing.

You will study a number of key classes of organic compounds that are important industrially, and will collect information about them, including their naming, reactions and properties. This will include aromatic compounds and their industrially useful reactions and a range of functional group compounds. This study will include how they can be converted into one another, which allows the synthesis of organic compounds with particular structures, fitting them for specific commercial uses.

You will also learn about isomerism, the phenomenon whereby a number of organic compounds have the ability to form different arrangements of the same atoms. You will then gain practical technical skills by carrying out a number of reactions to prepare and test organic compounds.

This unit will support you in gaining access to higher education courses employment. It will open up an awareness of a wide range of exciting career paths such as research or analytical work, as a laboratory science technician or a science apprentice, in pharmaceuticals, chemistry, biochemistry or biotechnology. Being able to describe your understanding and practical experience in organic chemistry will help with interviews for advanced scientific apprenticeship roles, as well as degree courses in chemistry, biology or a biochemistry discipline.

## Learning aims

In this unit you will:

- A** Understand the structures, reactions and properties of functional group compounds
- B** Understand the reactions and properties of aromatic compounds
- C** Understand the types, structures, reactions, uses and properties of isomers
- D** Investigate organic chemistry reactions in order to gain skills in preparative organic chemistry.

## Summary of unit

Learning aim	Key content areas	Recommended assessment approach
<b>A</b> Understand the structures, reactions and properties of functional group compounds	<p><b>A1</b> Structures, reactions, uses and properties of non-carbonyl compounds: halogenalkanes, alcohols, amines</p> <p><b>A2</b> Structures, reactions, uses and properties of carbonyl compounds: aldehydes, ketones, carboxylic acids, esters, acyl chlorides, amides</p>	<p>A research report showing the different types of reactions for both carbonyl and non-carbonyl functional group compounds.</p> <p>Learners could produce visual presentations such as flow charts, mind maps, data charts, diagrams for the carbonyl and non-carbonyl compound properties, their reactions and their different types of mechanisms.</p>
<b>B</b> Understand the reactions and properties of aromatic compounds	<p><b>B1</b> Structures, reactions, uses and properties of benzene</p> <p><b>B2</b> Structures, reactions, uses and properties of monosubstituted benzene compounds</p>	<p>A research report showing the typical addition and substitution reactions undergone by benzene. Diagrams and explanations showing how the structure of benzene was established. Diagrams showing the different effects of monosubstituents on the benzene ring and their reactions.</p> <p>A summary of important industrial uses of benzene and example monosubstituent compounds.</p>
<b>C</b> Understand the types, structures, reactions, uses and properties of isomers	<b>C1</b> Types, structures, reactions, uses and properties of isomers	<p>A research report showing 2D and 3D structural diagrams of the different types of isomers. A summary of the different properties of cis and trans isomers. Simple models of optical isomers such as amino acids and sugars and their effects. Their industrial importance and therapeutic/chemical importance.</p>
<b>D</b> Investigate organic chemistry reactions in order to gain skills in preparative organic chemistry	<p><b>D1</b> Reactions of non-carbonyl compounds</p> <p><b>D2</b> Reactions of carbonyl compounds</p> <p><b>D3</b> Reactions of aromatic compounds using methylbenzene or methoxybenzene</p>	<p>A portfolio of reactions that learners have carried out in the course of this unit, including observations of safe working and risk assessment.</p>

## Content

### Learning aim A: Understand the structures, reactions and properties of functional group compounds

#### A1 Structures, reactions, uses and properties of non-carbonyl compounds: halogenoalkanes, alcohols, amines

- Halogenoalkanes – nomenclature.
- Nucleophilic substitution of halogenoalkanes ( $\text{OH}^-$ ,  $\text{NH}_3$ , primary amines),  $\text{SN1}$  and  $\text{SN2}$  mechanisms of nucleophilic substitution, elimination reactions.
- Primary, secondary and tertiary alcohols – nomenclature.
- Solubility of alcohols.
- Reactions of alcohols with sodium, oxidation with hot copper(II) oxide; oxidation of alcohols with acidified dichromate(VI); oxidation of primary, secondary and tertiary alcohols.
- Primary, secondary and tertiary amines.
- Amines as bases.
- Amines as nucleophiles.
- Reaction of amines with halogen alkanes.
- Synthesis of commercially important organic compounds – PVC, CFCs and HCFCs.

#### A2 Structures, reactions, uses and properties of carbonyl compounds: aldehydes, ketones, carboxylic acids, esters, acyl chlorides, amides

- Aldehydes and ketones – nomenclature.
- Oxidation of aldehydes with – Tollens' reagent, Benedict's or Fehling's reagents, acidified dichromate(VI).
- Reduction of aldehydes and ketones ( $\text{NaBH}_4$ ,  $\text{LiAlH}_4$ ).
- Nucleophilic addition of  $\text{HCN}$  to aldehydes and ketones.
- Addition-elimination reactions of aldehydes and ketones reaction with 2,4-dinitrophenylhydrazine, hydrazine, oxime.
- Carboxylic acids – nomenclature.
- Carboxylic acids – weak acidity of carboxylic acids.
- Reaction with alcohols to form esters – esters as solvents, flavours and fragrances, commercially important esters, e.g. polyester.
- Reaction of acyl chlorides with water, alcohols, phenol, ammonia and amines.
- Preparation of amides.
- From carboxylic acids.
- Acyl chlorides and acid anhydrides.
- Hydrolysis of amides.
- Synthesis of commercially important polyamides – nylon and Kevlar®.

**Learning aim B: Understand the reactions and properties of aromatic compounds****B1 Structures, reactions, uses and properties of benzene**

- Kekulé structure, hybridisation, delocalised pi bonding in benzene.
- Thermochemical, x-ray diffraction and infrared data evidence for the structure of benzene.
- Nomenclature of aromatic compounds.
- Combustion to form a smoky flame.
- Addition reactions with hydrogen, chlorine.
- Sulfonation reaction with concentrated sulfuric acid.
- Reaction of benzene sulfonic acid to form phenol.
- Friedel-Crafts reaction to form methylbenzene.
- Industrial importance of benzene in the manufacture of polymers, detergents and insecticides.

**B2 Structures, reactions, uses and properties of monosubstituted benzene compounds**

- Effect of substituents groups  $-OH$ ,  $-Cl$ ,  $-NO_2$ ,  $-CH_3$  on the benzene ring.
- Chlorination and nitration of methylbenzene.
- Chlorination and nitration of phenol.
- Methylation of chlorobenzene.
- Reduction of nitrobenzene.
- Commercial importance of phenol, methylbenzene.

**Learning aim C: Understand the types, structures, reactions, uses and properties of isomers****C1 Types, structures, reactions, uses and properties of isomers**

- Structural, chain, positional, functional group, stereoisomerism, geometric, optical.
- Three-dimensional structures, representations and recognition.
- Different properties of isomers – lower melting points of Z (cis) isomers, different boiling points of chain and positional isomers.
- Different reactions of functional group isomers.
- Cis and trans (E and Z) fats.
- Natural occurrence of particular optical isomers – optical isomers of sugars, optical isomers of amino acids.
- Different therapeutic effects of optical isomers of drugs.
- Difference between starch and cellulose.

**Learning aim D: Investigate organic chemistry reactions in order to gain skills in preparative organic chemistry****D1 Reactions of non-carbonyl compounds**

- Halogenoalkanes.
- Alcohols.
- Amines.

**D2 Reactions of carbonyl compounds**

- Aldehydes and ketones.
- Carboxylic acids.
- Esters.
- Amides.

**D3 Reactions of aromatic compounds using methylbenzene or methoxybenzene**

- Using methylbenzene or methoxybenzene.
- Phenol with bromine water and dilute nitric acid.

## Assessment criteria

Pass	Merit	Distinction
<b>Learning aim A: Understand the structures, reactions and properties of functional group compounds</b>		
<b>A.P1</b> Explain the reactions of a range of carbonyl and non-carbonyl functional group compounds.	<b>A.M1</b> Construct mechanisms for non-carbonyl and carbonyl compounds. <b>A.M2</b> Plan a multi-step synthesis of carbonyl and non-carbonyl organic molecules in order to produce many organic substances, taking more than one reaction step.	<b>A.D1</b> Analyse the types of reaction mechanisms undergone by non-carbonyl and carbonyl compounds.
<b>Learning aim B: Understand the reactions and properties of aromatic compounds</b>		
<b>B.P2</b> Explain the structure of benzene using sigma and pi bonding, providing evidence for the structure. <b>B.P3</b> Explain the chemical properties of industrially important benzene and monosubstituted benzene compounds.	<b>B.M3</b> Compare the mechanisms for addition and substitution reactions of benzene.	<b>B.D2</b> Analyse the effects of different monosubstituents on the benzene ring to predict further substitution position(s) of a reaction species on the benzene ring.
<b>Learning aim C: Understand the types, structures, reactions, uses and properties of isomers</b>		
<b>C.P4</b> Explain the different types of structural isomerism and stereoisomerism.	<b>C.M4</b> Compare the different types of isomers and their industrial importance.	<b>C.D3</b> Analyse the chemical/therapeutic importance of isomerism.
<b>Learning aim D: Investigate organic chemistry reactions in order to gain skills in preparative organic chemistry</b>		
<b>D.P5</b> Carry out practical examinations of organic chemical reactions safely and in order to produce the predicted products. <b>D.P6</b> Explain the chemical reactions carried out in terms of the functional groups and reaction conditions involved.	<b>D.M5</b> Assess the importance of the conditions chosen for the reactions carried out practically.	<b>D.D4</b> Evaluate the results obtained and the importance of the reaction conditions chosen for the reactions carried out practically.

## Essential information for assignments

The recommended structure of assessment is shown in the unit summary along with suitable forms of evidence. *Section 6* gives information on setting assignments and there is further information on our website.

There is a maximum number of four summative assignments for this unit. The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.M1, A.M2, A.D1)

Learning aim: B (B.P2, B.P3, B.M3, B.D2)

Learning aim: C (C.P4, C.M4, C.D3)

Learning aim: D (D.P5, D.P6, D.M5, D.D4)

## Further information for teachers and assessors

### Resource requirements

For this unit, learners must have access to a well-equipped laboratory with a fume cupboard.

### Essential information for assessment decisions

#### Learning aim A

**For distinction standard,** learners will analyse the typical reactions mechanisms undergone by carbonyl and non-carbonyl compounds and produce a relevant interpretation of the similarities and differences.

**For merit standard,** learners will construct at least one correct mechanism for an addition, substitution, elimination and addition-elimination reaction for an appropriate non-carbonyl or carbonyl reaction shown in the content. They will be given at least two starting materials and corresponding product materials to plan synthesis routes, involving at least two or more steps for each route. Alternatively, they could use a detailed synthesis map as evidence.

**For pass standard,** learners will present as evidence an explanation of typical non-carbonyl and carbonyl reactions shown in the content, to include the correct names and formulae of starting materials and products, balanced equations, reaction conditions and any commercially important products.

#### Learning aim B

**For distinction standard,** learners will analyse the effects of at least three monosubstituents on the benzene ring, using their effect on the benzene ring to predict the positions of further substitutions on the ring for both 2 and 4 positions and the 3 position.

**For merit standard,** learners will identify the main factors to explain the appropriate similarities and differences between the mechanisms for at least two addition and two substitution reactions.

**For pass standard,** learners will provide appropriate evidence, such as bond length, delocalisation of electrons, bond energies to give valid reasons or the structure of benzene. They will give relevant information and valid reasons why at least three examples of the suitability and purpose of why benzene and monosubstituted benzene compounds are of industrial importance.

#### Learning aim C

**For distinction standard,** learners will carry out a methodical examination of selected well-documented examples to provide appropriate evidence of optical isomers that have different chemical/therapeutic properties.

**For merit standard,** learners will examine the industrial importance of isomerism. This could be done conveniently by providing evidence of relevant differences in properties between them and the possible consequences of not being aware of isomerism.

**For pass standard,** learners will explain the different types of structural isomerism, giving at least two examples of chain, positional and functional group isomers. They will use diagrams, molecular models and properties of the isomers where appropriate. Learners will explain the different types of stereoisomerism, giving at least two examples of geometric and optical isomers. They will use diagrams, molecular models and properties of the isomers where appropriate.

### Learning aim D

**For distinction standard**, learners will draw valid conclusions from the results obtained to include strengths and weaknesses of the reaction conditions chosen for the reactions carried out practically.

**For merit standard**, learners will identify the reagents used and the temperature and time chosen in the given reaction methods, providing evidence and giving reasons why these have been chosen for at least three reactions.

**For pass standard**, learners will provide the results/notes from a portfolio of practical work, a witness testimony of working safely and a safety assessment of at least two of the practical exercises undertaken. They will provide relevant information at least three of the reactions carried out to include the reactants, products, balanced equations and the functional groups involved in the reactions and the appropriate reaction mechanisms.

### Links to other units

This unit links to:

- Unit 1: Principles and Applications in Science I
- Unit 5: Principles and Applications in Science II
- Unit 13: Applications of Inorganic Chemistry
- Unit 22: Materials Science.

### Employer involvement

Centres may involve employers in the delivery of this unit if there are local opportunities to do so. Visits from chemical, biochemical, biotechnology and pharmaceutical manufacturers would be advantageous.



# Unit 15: Electrical Circuits and their Applications

Level: **3**

Unit type: **Internal**

Guided learning hours: **60**

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## Unit in brief

This unit covers the principles of electricity, including measurements of electrical values and health and safety, the construction of circuits and their use in society today.

## Unit introduction

In this unit, you will explore what electricity is, how to use measuring devices and construct circuits, as well as gain an understanding of the many varied applications of electricity in our everyday lives. Since Thomas Edison's first demonstration of the electric lamp in 1879, it is difficult to imagine life without electricity and the immediate effects it provides.

Despite advances in modern electronic devices, fundamental electrical principles still form the basis of electrical and electronic development in all aspects of life. The unit will provide you with the knowledge and skills necessary to undertake essential tasks related to electrical circuits and their components.

You will perform practical investigations and report on aspects of electrical measurement, using mathematical relationships to explain readings while developing an understanding of the importance of correct calculations in order to determine how circuits behave. You will study health and safety in relation to alternating current (AC) and direct current (DC) circuits and develop an understanding of the principles used by electrical safety devices. The different types of measuring devices will also be covered in detail, providing you with information about the methods used by various types of electrical equipment and the part played by transducer devices.

This unit will help you progress to further education, to specialised electrical qualifications or help you to pursue a career as a science technician working in industry, education, health or modern research laboratories. The unit will give you knowledge and understanding of key electrical concepts. It can also help to develop your confidence in the use of instruments and measuring devices under safe working conditions.

## Learning aims

In this unit you will:

- A** Understand electrical symbols, units, definitions, relationships and properties of circuit components for use in the construction of circuits
- B** Construct series and parallel circuits for use in standard electrical applications and measure electrical values
- C** Examine AC and DC production and health and safety aspects in domestic and industrial applications
- D** Examine the uses of transducers, sensors and other measurement devices.

## Summary of unit

Learning aim	Key content areas	Recommended assessment approach
<b>A</b> Understand electrical symbols, units, definitions, relationships and properties of circuit components for use in the construction of circuits	<b>A1</b> Electrical symbols, units and definitions <b>A2</b> Electrical formulae and relationships <b>A3</b> Electrical properties and uses of materials	<p>A scientific report including use of terms, symbols, units and example calculations.</p> <p>Practical investigation of ohmic/non-ohmic conduction devices.</p>
<b>B</b> Construct series and parallel circuits for use in standard electrical applications and measure electrical values	<b>B1</b> Circuit characteristics <b>B2</b> Measurement devices	<p>Practical circuit assembly, combination circuits and recorded results.</p> <p>Records of measurement results of circuit values, resistance values, calculated and predicted comparison.</p> <p>Potential divider circuit work – diagrams and report.</p>
<b>C</b> Examine AC and DC production and health and safety aspects in domestic and industrial applications	<b>C1</b> DC production <b>C2</b> AC production and transmission <b>C3</b> Domestic applications and mains supply <b>C4</b> Industrial applications <b>C5</b> Safety, human physiology, and electricity and legislation	<p>A report using laboratory and research notes on domestic mains characteristics.</p> <p>A practical investigation into production of induced current/voltage.</p> <p>A general study of uses of AC and DC electricity in the home.</p> <p>A case study comparing industrial uses.</p> <p>A report on physiological study of electric shock effects (AC and DC).</p> <p>An industrial site visit to produce a site safety report and outline of safety devices.</p>
<b>D</b> Examine the uses of transducers, sensors and other measurement devices	<b>D1</b> Uses of passive transducers <b>D2</b> Uses of active transducers <b>D3</b> Uses of sensors and other measurement devices	<p>Circuit construction and a report on transducers, sensors and other measurement devices.</p> <p>A report on applications and operation of transducers, sensors and measurement devices.</p>

## Content

### Learning aim A: Understand electrical symbols, units, definitions, relationships and properties of circuit components for use in the construction of circuits

#### A1 Electrical symbols, units and definitions

- Symbols: cell, battery, switch, filament lamp, fixed resistor, thermistor, light-emitting diode (LED), light-dependent resistor (LDR), rheostat, capacitor, voltmeter, ammeter.
- Definitions: current (ampere), potential difference (volt), electrical charge (coulomb), resistance (ohm), conductance (siemen), electrical power (watt), capacitance (farad and sub-units).
- Definition of current in terms of rate of flow of mobile charge carriers.
- Definition of electromotive force (EMF) as measure of ratio of energy supplied per unit charge.
- Definition of conductance and resistance in relation to density of mobile charge carriers.

#### A2 Electrical formulae and relationships

- Energy supplied  $W = VIt$
- Use of Ohm's Law  $V = IR$
- Kirchoff's Laws.
- Power  $P = IV, P = I^2R$
- Charge  $Q = It$
- Conductance  $G = \frac{1}{R} = \frac{1}{V}$
- Resistivity  $R = \frac{\rho l}{A}$  ( $\Omega\text{m}$ )
- Capacitors:
  - charge stored by capacitors  $Q = CV$  in operation as a reservoir
  - charging and discharging graph representations
  - calculations of capacitances ( $C_T = C_1 + C_2$  for parallel capacitors,  $\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} \dots$  for series capacitors).

#### A3 Electrical properties and uses of materials

- Conductivity and resistivity.
- Insulators and conductors.
- Ohmic and non-ohmic conductors.
- Capacitors as a filter in AC circuits.
- Semiconductors.

### Learning aim B: Construct series and parallel circuits for use in standard electrical applications and measure electrical values

#### B1 Circuit characteristics

- Correct assembly of series and parallel resistive circuits using up to three resistors in series, parallel and series-parallel combination.
- Calculation of resistance and conductance ( $R_T = R_1 + R_2$  for series circuits  $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} \dots$  for parallel circuits and similarly for conductance).

**B2 Measurement devices**

- Use of ammeters and voltmeters (digital and analogue types for simple comparison).
- Nature of voltage drop across components as the energy dissipates per unit charge by a resistor (where the energy dissipated is transferred from electricity into heat).
- Potential divider circuits and potential divider calculation.
- Internal resistance and EMF with use of  $E = I(R + r)$

**Learning aim C: Examine AC and DC production and health and safety aspects in domestic and industrial applications****C1 DC production**

- Battery (dry cell) construction (zinc, zinc chloride/ammonium chloride and carbon/manganese dioxide).
- Passage of electrons as unidirectional.
- DC produced by thermocouples and solar cells.
- DC motor/generator (reverses polarity of AC motor).

**C2 AC production and transmission**

- Magnetic fields around permanent magnets and a wire carrying a current.
- Fleming's left hand rule.
- Fleming's right hand rule.
- Electromagnetic induction and Faraday's Law.
- Principles of Lenz's law.
- Transformer principles and equation (step-up and step-down).
- Transmission of power from 'supply' to 'load'.
- Power loss from cables ( $I^2R$ ).

**C3 Domestic applications and mains supply**

- Domestic ring main circuit.
- Nature of AC voltage as changing polarity with instantaneous values varying sinusoidally.
- Root mean square (RMS).
- Peak and peak-to-peak voltages.
- Domestic fuse ratings.
- Powering DC equipment from AC supply.
- Earthing systems.
- Fuses.
- Significance of double insulation.
- Residual current and earth leakage circuit breakers (RCCB and ELCB).

**C4 Industrial applications**

- DC, e.g. transport, lifting gear, electrolysis.
- AC, e.g. induction furnace, speedometer.
- Line isolation monitors.
- Variable socket design.
- Isolating transformers (for outside use).

**C5 Safety, human physiology and electricity and legislation**

- Typical resistance values for current pathways in the body.
- Skin resistance and changes of environment, e.g. moisture levels of the skin, contact with the ground.
- Heart responses to electric shock.
- Principles of the defibrillator.
- Effect of the length of current exposure time and amount of electrical current.
- Safe levels of DC voltage.
- The Electricity at Work Regulations 1989.

**Learning aim D: Examine the uses of transducers, sensors and other measurement devices****D1 Uses of passive transducers**

- As defined by: devices that change the electrical characteristics within a circuit by the influence of external physical factors (sensors). For example, light-dependent resistor (LDR) and their practical uses, thermistors, reed switch, strain gauge and Wheatstone bridge arrangement, and potential divider circuits.
- Uses of light meters, automatic cameras, alarm systems.

**D2 Uses of active transducers**

- Production of EMF by conversion of energy from external physical source, e.g. operation and structure of a thermocouple.
- Piezoelectric devices and fundamental principles.
- Understanding of the need for signal amplification for these devices.

**D3 Uses of sensors and other measurement devices**

- Oscilloscopes for voltage measurement and AC/DC display.
- Multi-meters and range of measurements.
- Data-logging devices, such as those that sense and store information from physical sources for use with visual/audio display and processing.
- pH meters, temperature sensors, moisture sensors, pressure sensors, light sensors.

## Assessment criteria

Pass	Merit	Distinction
<b>Learning aim A: Understand electrical symbols, units, definitions, relationships and properties of circuit components for use in the construction of circuits</b>		<b>AB.D1</b> Evaluate, by calculation and graphical representation, the operation of a range of circuit assemblies using measured values.
<b>A.P1</b> Explain principle electrical terms, quantities and relationships for given situations.	<b>A.M1</b> Demonstrate, by calculation, the use of principle electrical terms, quantities and relationships for given situations.	
<b>Learning aim B: Construct series and parallel circuits for use in standard electrical applications and measure electrical values</b>		
<b>B.P2</b> Accurately construct a range of circuits and record appropriate values accurately using suitable measurement devices.	<b>B.M2</b> Compare predicted and calculated fundamental electrical values for a range of circuit assemblies.	
<b>Learning aim C: Examine AC and DC production and health and safety aspects in domestic and industrial applications</b>		<b>C.D2</b> Evaluate the principles of AC production and transmission for safe use in suitable applications.
<b>C.P3</b> Explain the similarities and differences of AC and DC electrical circuits. <b>C.P4</b> Explain the dangers of working with electricity and its effects on human physiology.	<b>C.M3</b> Compare RMS and peak values of AC electricity. <b>C.M4</b> Discuss the procedures and practices used to minimise risk when working with electricity.	
<b>Learning aim D: Examine the uses of transducers, sensors and other measurement devices</b>		<b>D.D3</b> Evaluate the use of transducers, sensors and measurement devices in practical situations in terms of their fitness for purpose.
<b>D.P5</b> Describe the basic principles of operation of transducers, sensors and electrical measurement devices.	<b>D.M5</b> Demonstrate the correct basic principles and uses of transducers, sensors and electrical measurement devices in practical situations.	

## Essential information for assignments

The recommended structure of assessment is shown in the unit summary along with suitable forms of evidence. *Section 6* gives information on setting assignments and there is further information on our website.

There is a maximum number of three summative assignments for this unit. The relationship of the learning aims and criteria is:

Learning aims: A and B (A.P1, B.P2, A.M1, B.M2, AB.D1)

Learning aim: C (C.P3, C.P4, C.M3, C.M4, C.D2)

Learning aim: D (D.P5, D.M5, D.D3)

## Further information for teachers and assessors

### Resource requirements

For this unit, learners must have access to:

- DC electrical circuit boards and the components identified in unit content
- suitable range ammeters, voltmeters, multi-meters and high-impedance analogue or digital (DSO) oscilloscopes – single or dual trace
- a signal generator, microphone and speakers
- standard transformer packs
- 12 V DC power supplies and suitable single cells
- domestic wiring/fuse samples
- rheostats
- electrolysis apparatus
- RCCB and ELCB (for demonstration purposes)
- a variety of sensors for circuit use
- thermocouple components, piezoelectric example model
- data loggers and associated sensors (pH, moisture, light, temperature, pressure)
- a working model for AC transmission (demo) or National STEM Centre e-library video.



## Essential information for assessment decisions

### Learning aims A and B

**For distinction standard,** learners will perform fully independent calculations of essential electrical quantities using studied relationships. As many graphical representations for electrical relationships will be produced as are necessary (for example resistance, power, charge). Ohmic and non-ohmic examples will be used and evaluated. Learners will use data gathered from circuit construction and their calculations to compare measured and calculated values. They will provide a report with an evaluation of the operation of suitable circuits and the measured and calculated values obtained. This could also include a comparison of resistivity values obtained with the actual research values, for example. Any discrepancies between these values will be explained by example calculations and circuit and component understanding.

**For merit standard,** learners will demonstrate competence in using correct electrical relationships and calculating values of electrical quantities. Teachers can provide formulae sheets that incorporate many or all examples of standard suitable calculations that can be performed by learners and assessed. These calculations will be linked to a variety of circuit situations to provide suitable reference and context. Learners will use the values obtained in their circuit measurements to make accurate circuit calculations. Using calculations, learners will be able to predict values of current, voltage and resistance at various points in circuits. These predicted values can then be generally compared to measured values obtained from a variety of both series and parallel circuits. Practical determination and subsequent calculation of resistivity values could be incorporated into the work to enhance the electrical investigative work and understanding of electrical relationships.

**For pass standard,** learners will produce a comprehensive list all of the electrical terms and symbols given in the unit content, with a brief explanation of each. This may be carried out by producing a catalogue or poster. A list of the main electrical formulae used in this unit will also be provided by the teacher and accompanied by an explanation linking the formulae to their purpose in electrical circuit work.

Learners will be able to obtain measurements of voltage, current and resistance from the construction of series and parallel circuits and to record them in an appropriate tabular form for clarity. Circuit construction will incorporate a minimum of three resistors in a variety of configurations. There is no specific number of circuits to be completed, but teachers must ensure that they are varied and that learners are given guidance where necessary. In general, the expectation is that learners will construct functional series and parallel resistor circuits with resistors, filament lamps and capacitors.

### Learning aim C

**For distinction standard,** learners will provide a clear evaluation, with diagrams, to illustrate how AC electricity is produced, using the fundamental aspects of Fleming's left hand rule for electrical motors and right hand rule for electrical generators, and expanding this to include the generators in power stations. Learners will evaluate how electricity is transmitted to homes and industry and mathematically account for the need to use transformers and high voltages. The use of AC and DC in the home or industry will then be outlined in detail to identify the applications of AC and DC and the safety mechanisms in place. This will incorporate work covered at merit standard for safety devices and their operation, correct practices and procedures and the Electricity at Work Regulations 1989. It is expected that this work will be presented in a formal, well-written and well-organised report that attempts to combine all of the important aspects covered in the learning aim.

**For merit standard,** learners will provide a thorough review of AC production and the relationships that determine movement and current flow direction from Fleming's left and right hand rules. Detailed explanation of the sinusoidal waveform, with labelled diagrams, will be used to outline the key aspects of AC representation and allow for a comparison between RMS and peak values of AC electricity. In addition, learners will produce work that demonstrates how a generator operates and include the use and operation of step-up and step-down transformers

when transmitting AC on the national grid. Learners will give a valid discussion of how specific safety devices reduce risk from electricity, both AC and DC. Each device studied will be described with the aid of clearly labelled diagrams and explanatory notes on how the device is activated within its circuit. They will also include information on the ways in which organisations maintain health and safety in relation to hazards posed by the use of electrical equipment.

Learners will be able to discuss the operation of electrical safety devices and the safety practices and procedures used to help reduce or eliminate specific risks. They will include details of typical circuit breakers, line isolation monitoring, equipotential earthing systems and double insulation. Learners will then link their work to the Electricity at Work Regulations 1989.

**For pass standard,** learners will outline, by means of effective diagrams and clear descriptions, the essential similarities and differences between AC and DC when applied to simple electrical circuits. Learners' work will include AC changing in direction and DC one-directional current flow, loss of energy in DC circuits and power loss reduction of AC when transmitted, frequency of zero for DC and display as a horizontal line on an oscilloscope, no change in DC size with time, DC chemically produced in a cell or battery, AC from a generator, the use of a transformer to increase or decrease AC, and the fact that AC current cannot be stored in batteries.

Learners will illustrate the effects of both AC and DC on the human body with artistic work or a simple report that also reviews the work for covering differences between the two types of electricity. They will produce an explanation of the factors that contribute to the severity of the electric shock, such as the length of time involved and the amount of current.

### Learning aim D

**For distinction standard,** learners will produce an analytical account of the suitability of a chosen transducer/sensor/measurement device from those studied in the unit for a particular application. Evidence can focus on a working example of a device in industry and be presented as a case study, outlining its history, development and technological advancement to date. Alternatively, learners could present the work by developing an appraisal of each transducer/sensor/measuring device from initial practical study. This could then take the form of an evaluative report on the suitability of the equipment used for a given application, discussing its mode of operation, circuit suitability, accuracy and precision (i.e. fitness for purpose).

**For merit standard,** learners will demonstrate qualitative research capabilities and may use various order catalogues from equipment manufacturers to supplement their work. Learners will produce circuit diagrams of the transducers and sensors chosen and explain their operation and uses, referring to levels of potential difference, current and resistance. Practical investigation of the devices will provide operational evidence and correct values obtained can be verified by the teacher or research text. A suitable transducer for practical construction and calibration is the thermocouple. Learners will also produce a detailed comparison of an analogue and digital measurement device (data logger) for a given use.

**For pass standard,** learners will present a full list of various transducers and the uses of measurement devices commonly in operation from the unit content. The uses to which these devices are put will be clearly contextualised and evidence for this section will come from practical circuit work. Learners will demonstrate and describe the operational principles of at least one transducer and a range of sensors in simple circuits by carrying out suitable practical investigations, describing their findings using accepted reporting standards.

### Links to other units

This unit links to *Unit 3: Science Investigation Skills*.

### Employer involvement

It may be possible to arrange visits to regional electricity distributors, equipment and component manufacturers, large-scale industries and power stations. In addition, speakers from local electrical businesses, suppliers and manufacturers, or electricians will give learners an idea of how this unit links with everyday practice in industry.

# Unit 16: Astronomy and Space Science

Level: **3**

Unit type: **Internal**

Guided learning hours: **60**

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## Unit in brief

This unit covers the principles and present-day understanding of developments in astronomy.

## Unit introduction

In this unit, you will explore the main concepts that have formed the foundations of astronomy for hundreds of years. You will develop your knowledge and understanding of the key areas in astronomy and space flight, of the links between these exciting topics and related industries.

You will focus on the study of the Solar System and gain an appreciation of the advances made in space flight, their applications on Earth and the different scientific disciplines. Your skills in analysis, investigation and research will be enhanced as will your knowledge of key Solar System objects, leading to accurate night sky positioning and star mapping with ample opportunity for both short and long duration practical observation. You will be introduced to the many factors associated with space flight, gaining insight into the practicalities and problems associated with propelling an object beyond the Earth's atmosphere and sustaining an orbit.

With new and exciting planned missions for astronauts to Mars and the prospects of space tourism, the realities of interplanetary missions will be explored. In the light of renewed governmental and commercial plans for further development, you will gain an understanding of how physical laws are linked to complex deep-space exploration missions. You will discuss current theories in the formation and end of the Universe with an in-depth study of cosmological principles relating to the Big Bang theory, inflation and evolution as our current understanding allows.

The skills you learn in this unit can be applied to other areas of study and to workplace practices. You can progress to further education for science-related courses, and to the expanding space science industry, involving astronomical data analysis, research and development.

## Learning aims

In this unit you will:

- A** Understand the fundamental aspects of the Solar System
- B** Undertake measurement and observation of astronomical objects
- C** Investigate the essential factors involved in space flight
- D** Understand the fundamental concepts outlined in astrophysics and cosmology.

## Summary of unit

Learning aim	Key content areas	Recommended assessment approach
<b>A</b> Understand the fundamental aspects of the Solar System	<p><b>A1</b> Features and characteristics of the Sun</p> <p><b>A2</b> Features, characteristics and relationship factors of the Earth and Moon</p> <p><b>A3</b> Features and characteristics of the inner and outer planets</p> <p><b>A4</b> Features and characteristics of other Solar System objects</p>	<p>A scientific report and diagrams. Use of terms and numerical values.</p> <p>A presentation document. Outline of features/numerical values associated with Earth and Moon.</p> <p>Diagrams and text information for all planets.</p> <p>Descriptions of smaller components. Case studies of spacecraft encounters.</p>
<b>B</b> Undertake measurement and observation of astronomical objects	<p><b>B1</b> Earth-based telescope design and features</p> <p><b>B2</b> Space-based telescope design, features and observatories</p> <p><b>B3</b> Night-sky mapping and observations</p> <p><b>B4</b> Daytime observation</p>	<p>Descriptions of important telescopes, optical and radio. Geographical positions.</p> <p>A report on specific telescopes using range of wavelengths. Investigating focal points of concave mirror and convex lens.</p> <p>Practical observation logs. Map of night sky and terminology definitions.</p> <p>Practical observation by projection of sunspot activity.</p>
<b>C</b> Investigate the essential factors involved in space flight	<p><b>C1</b> Spacecraft design</p> <p><b>C2</b> Practicalities and physics of spaceflight</p> <p><b>C3</b> Future of space flight and exploration</p> <p><b>C4</b> Factors and benefits associated with Earth-based applications of space technology</p>	<p>A report on space craft materials using specified named vehicles. Conditions for space flight. Maths associated with speed, gravitational forces, re-entry conditions.</p> <p>Case study: PowerPoint presentation on spacecraft design, Moon missions, Mars probes space stations, international plans.</p>
<b>D</b> Understand the fundamental concepts outlined in astrophysics and cosmology	<p><b>D1</b> Principles of star creation</p> <p><b>D2</b> Principles of the 'death' of stars</p> <p><b>D3</b> Observable characteristics and properties of stars</p> <p><b>D4</b> Origin and theories of evolution of the Universe and astronomical dimensions</p>	<p>Space spin-offs: examples of research activities performed by astronauts.</p> <p>Information poster outlining the life cycle of stars.</p> <p>Report of star characteristics linked to star formation and death. Detailed Hertzsprung-Russell (H-R) diagram aspects.</p> <p>Trigonometric parallax principles outline.</p> <p>Presentation: origin and end of the Universe – current theories and evidence explained.</p>

## Content

### Learning aim A: Understand the fundamental aspects of the Solar System

#### A1 Features and characteristics of the Sun

- Structure – corona, chromosphere, photosphere, convective zone, radiative zone, core.
- Nuclear fusion, mass-energy conversion  $E = mc^2$  and proton-proton chain.
- Physical features: prominences, flares, solar winds, sunspots.
- The sunspot cycle.
- Physical parameters – diameter, average distance, rotation, mass, surface and core temperatures.
- The solar spectrum in visible and non-visible (UV, X-ray etc.) wavelengths.

#### A2 Features, characteristics and relationship factors of the Earth and Moon

- Internal structure of the Earth – crust, mantle, inner and outer cores, atmospheric composition.
- Rotations and orbital characteristics.
- Van-Allen radiation belts.
- Lunar features – surface detail, impact craters, phases, eclipses, composition, orbital characteristics, rotation, gravitational effects.

#### A3 Features and characteristics of the inner and outer planets

- Rocky and gaseous planets.
- Kepler's laws – inverse square relation of distance with gravitational attraction.
- Orbital plane and periods, distances, masses, diameters, ring systems, surface features.

#### A4 Features and characteristics of other Solar System objects

- Dwarf planets: locations and surface features.
- Numbers of moons orbiting the planets.
- Characteristic features of sample moons – surface, diameters, masses, asteroid belt position.
- Features of largest asteroids, e.g. NEAR Shoemaker to Eros, Rosetta/Philae to Comet 67P.
- Kuiper Belt and Oort Cloud.
- Short or period comets (generally less than 200 years orbit), e.g. Halley, Shoemaker-Levy 9.
- Long period comets and compositions (generally more than 200 years orbit), e.g. Hale-Bopp, Hyakutake, Kohoutek.
- Meteor showers, e.g. Perseids (August), Orionids (Oct.), Geminids (Dec.).
- Meteorite composition, to include stony (chondrites), stony-iron, iron (Widmanstätten lines from large crystal growth).
- Meteoroid origins, e.g. comet tails, asteroids and collisions with other objects, such as planets (Mars).

### Learning aim B: Undertake measurement and observation of astronomical objects

#### B1 Earth-based telescope design and features

- Reflector and refractor telescopes – ray diagrams, focal point of concave mirror:
  - reflector – principle of prime focus of concave mirror and measurement, positioning of small, flat mirror before prime focus to reflect out of the telescope
  - refractor – determination of focal length of principle converging lens and eye piece converging lens, ratio to determine magnification.
- Merits of reflector/refractor design.
- Aspects of image clarity – spherical and chromatic aberration, resolving power.
- Charge-coupled devices (CCDs).
- Radio telescope design.

- Telescopes giving a collective high resolution of brighter astronomical objects, e.g. Very Large Telescope (VLT) from the European Southern Observatory (ESO) project in the Andes (Chile).
- Gravity wave detection (LIGO).

### **B2 Space-based telescope design, features and observatories**

- Microwave – Wilkinson Microwave Anisotropy Probe (WMAP).
- Infrared – Spitzer, James Webb Space Telescope (JWST).
- Visible – Hubble Space Telescope (HST).
- Ultraviolet – HST.
- X-ray – Chandra X-ray Observatory, XMM-Newton.
- Gamma ray – INTEGRAL, Fermi Gamma-ray Space Telescope.
- Solar – Solar and Heliospheric Observatory (SOHO), Hinode.
- Gravity wave detection – Laser Interferometer Antenna (LISA).

### **B3 Night-sky mapping and observations**

- Naked-eye observations of stars and major constellations (including Orion, Ursa Major, Cassiopeia, Crux (for students in southern hemisphere), Cygnus, Andromeda)
- Identification of brightest stars in these constellations using published star charts using both equatorial co-ordinates (right ascension and declination) and horizontal co-ordinates (altitude and azimuth).
- Identification of Polaris, Milky Way, Celestial equator, Magellanic Clouds (for students closer to equator or in southern hemisphere).
- Naked-eye observations of the apparent motion of the Moon plotted onto a suitable star chart.
- Naked-eye observations of the direct and retrograde motion of planets, plotted onto a suitable star chart.
- Explanations of the apparent motion of the Moon and planets.
- Telescopic (or binocular) observations of Jupiter's Galilean moons, phases of Venus and Saturn's ring'.

### **B4 Daytime observation**

- Motion of the Sun and Moon.
- Principle of the sundial.
- Sunspot activity by projection.
- Eclipses and transits.

## **Learning aim C: Investigate the essential factors involved in space flight**

### **C1 Spacecraft design**

- Construction materials.
- Physical properties.
- Power supplies.
- Need for an oxidiser.
- Ceramic and carbon-carbon compound properties for protection.
- Fuel cells for electrical supply.
- Hazards – heat, cold, micro-meteorites, fuel components, radiation.

### **C2 Practicalities and physics of space flight**

- Lift-off principles.
- Mass, propulsion, gimbals, need for staging, spacesuit design features.
- Costs.
- Distance and time.
- Communications.
- Effects on humans – radiation exposure, micro-gravity environment, astronauts in constant free-fall, psychological and physical effects.
- Gravitation.

- Escape velocity using  $v = \sqrt{\frac{2GM}{r}}$
- Use of 'gravity assist', e.g. Voyager 1 and 2 case study.

### C3 Future of space flight and exploration

- International Space Station (ISS) and its future.
- Proposed inter-planetary manned missions, e.g. Inspiration Mars, Mars landing, Orion.
- Interplanetary unmanned missions, e.g. SOLO, Juno, Mars Exploration Rover mission.
- International missions, e.g. Russia, China, Japan, European Space Agency (ESA).
- Space tourism, e.g. Spaceship 1, Genesis 1 space hotel, water purification, food, near weightless conditions for long duration, astronaut relationships, time and psychological aspects
- Problems of space debris and grave yard orbits, e.g. NASA is currently tracking about half a million pieces, possible damage from very small particles to spacecraft, Inter-Agency Space Debris Committee (IADC), set up with 13 member countries to discuss the problem.

### C4 Factors and benefits associated with Earth-based applications of space technology

- Materials and manufacturing.
- Health and medicine, transport, public safety, industry, computer technology, consumers, environmental and agriculture.
- Orbital types:
  - High Earth Orbit (including geostationary for telecommunications, including satellite TV)
  - Medium Earth Orbit (for GPS and other positioning networks)
  - Low Earth Orbit (mainly polar) for satellites monitoring Earth's resources and physical systems (e.g. crop growth, sea-levels, volcanic and tsunami activity, etc.).
- Experiments carried out by astronauts in space.

## Learning aim D: Understand the fundamental concepts outlined in astrophysics and cosmology

### D1 Principles of star creation

- Giant molecular clouds (nebulae), gravitational collapse, fragmentation (Jeans mass).
- Internal temperature rise, initial nuclear reactions – lithium, deuterium.
- Equilibrium: outward radiation pressure balances inward gravitational force.
- Protostar.
- Slower evolution to main sequence.

### D2 Principles of the 'death' of stars

- Mass relation to life cycle – mass equal to the Sun, mass greater than the Sun.
- Core collapse.
- Red giants.
- White dwarfs.
- Electron-degenerate matter, Chandrasekhar limit.
- Supernovae.
- Neutron stars observed as pulsars.
- Black holes, accretion disc, event horizon, Schwarzschild radius, singularity.
- Stellar spectral energy distribution, temperature.

### D3 Observable characteristics and properties of stars

- Physical and chemical characteristics, mass, luminosity, apparent magnitude, absolute magnitude,  $M = m - 5 \log\left(\frac{d}{10}\right)$  (where d is the distance in parsec), black body radiation, stellar classification (O, B, A, F, G, K, M) based on spectral analysis of absorption lines
- Hertzsprung-Russell (H-R) diagram.

- Spectra:
  - colours indicate specific chemical elements and relate to star surface temperature, e.g. blue dominant (hot), red dominant (colder)
  - absorption lines represent ions of specific elements and relate to temperature by thickness of the line
  - comparison to the Sun, e.g. absorption lines may be shifted to either red end (moving away from us) or blue end (moving towards us)
  - wavelength increase or decrease – Doppler effect.

#### **D4 Origin and theories of evolution of the Universe and astronomical dimensions**

- Units: astronomical unit, light year, parsec.
- Methods of determining distance, parallax, Cepheid variables, brightness variation, eclipsing binaries.
- Redshift and absorption of wavelengths, cosmic microwave background (CMB), abundance of hydrogen and helium isotopes.
- Galaxies including their formation, classification (spiral, barred-spiral, elliptical and irregular).
- Quasars.
- The Big Bang.
- Hubble's law, the Universe and its composition: matter, dark matter, dark energy, projected time-line (Big Bang to photon age), critical density, the fate of the Universe.
- Olbers' paradox.
- Possibility of life elsewhere in the Universe: SETI and results; definition of life, i.e. carbon based-life cycle – not necessarily complex organisms; use of the Drake Equation to estimate the likelihood of intelligent life in our galaxy, discovery of more than 2000 exoplanets by light variation of stars, possible life-supporting chemistry.



## Assessment criteria

Pass	Merit	Distinction
<b>Learning aim A: Understand the fundamental aspects of the Solar System</b>		<b>A.D1</b> Analyse the importance of the Sun in its Solar System.
<b>A.P1</b> Describe the main features of the Solar System and the Sun's influence.	<b>A.M1</b> Explain the effects of the interaction between the Sun, Earth and Moon and other Solar System objects.	
<b>Learning aim B: Undertake measurement and observation of astronomical objects</b>		<b>B.D2</b> Evaluate the findings and validity of practical astronomical observations in understanding the Solar System.
<b>B.P2</b> Describe how different types of telescopes are used for astronomical observation.	<b>B.M2</b> Assess the findings of practical astronomical observations and their importance in astronomy.	
<b>B.P3</b> Explain the relative positions of night-time astronomical objects.		
<b>B.P4</b> Explain the relevant positions and features of daytime astronomical objects.		
<b>Learning aim C: Investigate the essential factors involved in space flight</b>		<b>CD.D3</b> Evaluate the future of space flight and space exploration and research.
<b>C.P5</b> Explain the main factors associated with achieving space flight for manned and unmanned exploration.	<b>C.M3</b> Assess the main factors and benefits associated with achieving space flight for manned and unmanned exploration.	
<b>Learning aim D: Understand the fundamental concepts outlined in astrophysics and cosmology</b>		
<b>D.P6</b> Explain current knowledge and theories of the life cycles of stars.	<b>D.M4</b> Assess the processes of star formation, their life cycles and evolution.	
<b>D.P7</b> Describe the evidence linked to theories of the evolution of the Universe.	<b>D.M5</b> Explain the evidence linked to theories of the evolution of the Universe related to observed phenomenon and its composition.	

## Essential information for assignments

The recommended structure of assessment is shown in the unit summary along with suitable forms of evidence. *Section 6* gives information on setting assignments and there is further information given on our website.

There is a maximum number of three summative assignments for this unit. The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.M1, A.D1)

Learning aim: B (B.P2, B.P3, B.P4, B.M2, B.D2)

Learning aims: C and D (C.P5, D.P6, D.P7, C.M3, D.M4, D.M5, CD.D3)

## Further information for teachers and assessors

### Resource requirements

For this unit, learners must have access to:

- scientific magazines and astronomical journals
- the internet, relevant DVDs, simulation models
- portable telescopes (min. 50 mm refr./100 mm refl.), binoculars (10 × 50 mm) and projection attachments
- optical physics equipment, lenses (converging and diverging), mirrors (concave spherical and parabolic, if possible), suitable light sources.

### Essential information for assessment decisions

**For distinction standard,** learners will explain in detail, the natural forces allowing the Sun to remain in equilibrium and the eventual outcome when these forces change in terms of their expected life cycle, with the ultimate effects on the Solar System. Learners will explain the process of nuclear fusion, detailing the magnetic forces and features on the surface of the Sun and their associated effects. Learners will explain the composition of the Sun, with suitable illustrations, identifying the gases involved and the layered structure.

**For merit standard,** learners will work with independence and produce descriptions of the main features in the Solar System. They will include such details as planetary axes of rotation, composition of planets, moons, asteroids, comets and meteors, planetary ring system labels, Van Allen radiation belts, surface features on chosen planets and moons etc.

**For pass standard,** learners will describe the main features of the Solar System. They will include a brief definition of structure, the forces involved, orbital characteristics, rotation, atmospheric compositions and physical data. They will briefly describe the relationship of the Earth with the Moon and the Sun by including diagrammatic representation of the particular aspects that occur as a result of interactions on a regular basis, such as day and night, phases of the Moon, eclipses of the Sun and the Moon, tidal effects on the Earth. In addition, learners will describe, by written or diagrammatic form, the other Solar System objects. This will include all the known planets, prominent moons, asteroids, comets and other associated features such as the Kuiper belt and Oort cloud.

### Learning aim B

**For distinction standard,** learners will evaluate their own practical observations and suggested improvements. Errors in observations will be identified and relevant comments made relating to visual aspects, inaccuracies of measurement and suitability of equipment for purpose. Learners will collect data that is represented in a suitable format with observations set against an accurately illustrated star map. The validity of learners' observations will be determined by comparison with known astronomical data, for example the size of sunspots, the position of the solar plane, a diagram of the surface of the moon and so on.

**For merit standard,** learners will work with independence and assess their results from observations, drawing suitable conclusions. Their observation of the night sky and solar activity will show accuracy and precision and correct positioning of night sky objects against background field stars identified by right ascension and declination. Learners will use suitable objects, requiring the use of a telescope or binoculars, and using projection methods for the Sun.

**For pass standard,** learners will present a list and associated diagrams or images identifying the types of telescopes used in modern astronomy. This activity could take the form of a poster or PowerPoint presentation, highlighting and naming the telescopes that use different parts of the electromagnetic spectrum. For light, learners will include both refractor and reflector telescopes. A detailed description of operation is not expected although the general mode of operation and principles will be outlined. This will include ray diagrams of both reflector and refractor telescope principles and some evidence of practical determination of focal lengths for converging lenses and prime focus for convex mirrors. They will keep logbooks and other suitable forms of presentation, detailing observational records to evidence practical observations taken over a length of time using suitable equipment. Learners will perform experiments to show that they have attempted to find the focal length of converging and diverging lenses, using a ray box and the focal length of a standard concave mirror using a twin-hole ray box. These pieces of equipment can then be used on objects to assess their effectiveness and the need for parabolic mirrors, for example. Learners will produce accurate ray diagrams and a log demonstrating observations of some aspects of the night sky and of the Sun. These activities will be carried out over a suitable time period and night sky observations will be set against their constellation position where appropriate. Their observations will be set onto a published map of a suitable portion of the night sky, with paths of objects shown against labelled constellations, and stars and distances accurately measured. Daytime observations will also be set against accurate sky-mapping. Sun-spot activity could be projected onto a circular template from which precise sunspot sketches can be made over a course of time. If this unit is delivered during times of solar or lunar eclipse, this will be a valuable opportunity for observation.

### Learning aims C and D

**For distinction standard,** learners will produce a comprehensive report demonstrating their knowledge and understanding of the history of space flight and the difficulties involved. They will include a discussion identifying a good selection of planned missions, manned and un-manned, proposed by various countries and organisations. Their work can be presented as a journalistic appraisal and will provide clear descriptions of the proposals and an evaluation of the developments of each space programme in terms of costs, difficulties that will be faced, benefits and other implications. Learners will also link this work to the improvement in our current understanding of the Universe – its origin, dynamic nature and theoretical future. This is a good opportunity for learners to present a discussion on the possibility of life on Earth being ‘unique’ and demonstrating clear thought on the probabilities of life elsewhere in the Universe and problems associated with space travel beyond the confines of the inner Solar System.

**For merit standard,** learners will produce a well-wordsed report depicting examples of the products used in everyday life that have been discovered or developed as a direct result of space flight. Their report will outline at least five products from materials and manufacturing and learners will provide general outlines of the work carried out by astronauts, which are research based and linked to particular areas of science and industry. This may be presented in the form of a list or table, including a description and an indication of its relevance to society in general. Learners’ work will be largely independent and will include research evidence, with correct referencing and bibliography. They will explain, in detail, the effects of space flight on the human body and provide some assessment of the implications of long-term space flight and what can be done to limit the problems, such as osteoporosis, change in blood flow, or drop in blood plasma levels. They will mention all effects on humans listed in the unit contents. Their evidence can take the form of a large poster or booklet, with clear labelling of the specific areas of the body that are affected. Learners’ work will also focus on the physical aspect of achieving and sustaining space flight for a vehicle. They will provide explanations that could be based on known launch and flight data and attempt to explain how an object achieves escape velocity and then maintains orbit. Calculations of escape velocity will be included and learners will provide some acknowledgement of the dangers involved, maybe provided by reference to well-known accidents such as Salyut 1, Apollo 1, Challenger and Columbia Space Shuttles.

Learners will also include a detailed explanation of the Hertzsprung-Russell diagram, including relevant stars by name at various points in the sequence. They will clearly present the current theoretical explanation of how stars form, using diagrams where necessary. This will include detail of pressure balance and imbalance, development of protostars to main sequence and eventual end. Clarity in explanation of the evidence for theories of the evolution of the Universe will be given by learners. This will involve information concerning galaxy movements, star formations and destructions, age of the Universe and further detail regarding the importance of redshift and the cosmic microwave background.

Learners will also provide detailed explanations of star evolution and will describe, in some detail, the variations of star types that occur, with reference to the H-R diagram. They will include spectral classes and the relationship with mass, as well as examples, by name, of the star types depicted. Learners will provide further expansion on the work to explain the variation in star evolution as a result of the mass of initial material, i.e. stars of mass equal to the Sun and those of mass greater than the Sun.

Learners will explain the methods used to measure astronomical distances and will show the limitations of trigonometric parallax to relatively short distances in addition to the principles behind Cepheid variables and eclipsing binaries. They will also appreciate the significance of the shift of wavelength from galaxies to indicate acceleration towards or away from our viewpoint.

Learners will also include sufficient explanation of Hubble's law, the reasons providing the current age of the Universe and the possible fate of the Universe based on density. They will give a clear explanation of Olbers' paradox.

**For pass standard,** learners will produce a comprehensive list of the various factors that need to be considered to achieve space flight. Their list will include, for example materials, fuels, escape velocity, hazards, costs, communication and effects on humans. They will provide a brief description of each, with the effects on humans completed by developing a case study identifying the issues that NASA faced in its preparations for astronaut training during the Apollo missions.

Learners will develop a clear document or sketch that illustrates the various stages of a star's life, and the different outcomes that can result from variations in the mass of the material that comprises the star. Brief notes will accompany each stage.

Learners will include a representation of the Hertzsprung-Russell diagram for stars. A further diagram will show how the stages in the life of stars depends on their mass in relation to the Sun. Notes to accompany labelled diagrams will be expected. A valid description of the principles of redshift and cosmic microwave background will be provided. These will be linked to the theory of the Big Bang. Additional descriptions of objects and measurements in the Universe, such as galaxies, nebulae, supernovae, distances and so on will enhance learners' work to outline the continued evolution of the Universe.

Learners will all present cosmological theories of the present day, attempting to describe, briefly, the general ideas of each by summarising relevant material and describing the evidence in support. They will include the essential physical laws that help to explain some key aspects.

## Links to other units

This unit links to:

- Unit 1: Principles and Applications of Science I
- Unit 2: Practical Scientific Procedures and Techniques
- Unit 4: Laboratory Techniques and their Application.

## Employer involvement

Visits can be arranged to regional universities' astronomy departments, materials technology departments, or computer applications/remote sensing departments, for learners to see, first hand, the types of applied research being carried out and the equipment being used.

Guest speakers from observatories, aerospace, satellite and space development companies will give learners an idea of the range of employment opportunities in this field.



# Unit 17: Microbiology and Microbiological Techniques

Level: **3**

Unit type: **Internal**

Guided learning hours: **60**

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## Unit in brief

Learners will explore the characteristics of microorganisms and develop practical skills relating to their study, including microscopy and the practice of aseptic technique.

## Unit introduction

In this unit, you will discover how essential microorganisms are. They have been exploited for beneficial use for a long time, but more recently biotechnology has given microorganisms an important role in agriculture, food production and medicine. This is not to forget that some microorganisms can be disease causing and result in impaired health or even death for millions of people every year. Biomedical scientists are involved in a constant search for new antibiotics, antiseptics and preventative measures against disease-causing organisms.

Microbiology is a branch of biology that deals with microorganisms usually too small to be seen with the naked eye, including bacteria, viruses, some fungi and a group of even smaller organisms called prions. The latter are of interest because of the devastating diseases they cause in humans. You will study microorganisms and the factors that affect their growth. You will also learn how to safely handle some types of microorganisms in a laboratory setting and develop the manipulative skills needed for good aseptic techniques, including risk analysis.

In the unit you will carry out practical work to prepare and use different types of growth media and different inoculation techniques safely. You will also experience the different methods used to measure microbial growth, as these techniques are very important in commercial laboratories. You will develop your skills using microscopes and their attachments to better be able to identify some microorganisms. Your research will ask you to look at other types of specialist microscopes, which are vital to understanding the structure of microbes.

The skills associated with microbiology are in great demand and microbiologists are at the centre of developments in areas such as biochemical and biomedical products, crop health and food production, livestock health, genetic engineering and forensic science. This unit will help you to progress to a wide range of microbiology-related courses in higher education, including medical microbiology and biomedical sciences

## Learning aims

In this unit you will:

- A** Understand the importance of microbial classification to medicine and industry
- B** Undertake microscopy for specimen examination in laboratories
- C** Undertake aseptic techniques to culture microorganisms
- D** Explore factors controlling microbial growth in industrial, medical and domestic applications.

## Summary of unit

Learning aim	Key content areas	Recommended assessment approach
<b>A</b> Understand the importance of microbial classification to medicine and industry	<b>A1</b> Microorganisms and infectious agents <b>A2</b> Classification <b>A3</b> Microorganisms in medicine and industry	<p>A research report using any appropriate format that covers four of the listed microorganisms.</p> <p>Practical work setting up and using light microscopes and oil immersion lenses to look at the structure of microorganisms. Scientific drawings of specimens, laboratory notebooks and practical write-ups supported by teacher observations.</p>
<b>B</b> Undertake microscopy for specimen examination in laboratories	<b>B1</b> Microscopes <b>B2</b> Specimen and slide preparation <b>B3</b> Setting up and using a compound light microscope	<p>Practical work setting up and using light microscopes and oil immersion lenses to look at the structure of microorganisms. Scientific drawings of specimens, laboratory notebooks and practical write-ups supported by teacher observations.</p> <p>A presentation of their work which also outlines the uses and limitations of the instruments used when compared with other types of microscopy, including specimen preparation and imaging.</p>
<b>C</b> Undertake aseptic techniques to culture microorganisms	<b>C1</b> Safety and prevention of contamination in microbial culturing <b>C2</b> Growth media <b>C3</b> Inoculation and incubation	<p>Laboratory notebooks recording the practical work done plus observations of practical work by suitably qualified staff. Any parts not covered in practical work can be addressed by research reports.</p>
<b>D</b> Explore factors controlling microbial growth in industrial, medical and domestic applications	<b>D1</b> Growth requirements <b>D2</b> Growth inhibitors <b>D3</b> Measuring microbial growth	<p>Laboratory notebooks recording the practical work done plus observations of practical work by suitably qualified staff. Any parts not covered in practical work can be addressed by research reports.</p>



## Content

### Learning aim A: Understand the importance of microbial classification to medicine and industry

#### A1 Microorganisms and infectious agents

Similarities and differences in relative sizes, structural features and means of reproduction/replication in the following (both non-pathogenic and pathogenic examples should be examined):

- bacteria (prokaryotes)
- fungi, including yeasts (eukaryotes)
- protozoa
- viruses
- viroids
- prions.

#### A2 Classification

- Characteristics used to classify microorganisms, limited to bacteria, fungi and viruses.
- Bacteria, to include reference to *Bergey's Manual of Systematic Biology*:
  - Gram staining
  - phenotypic classification, e.g. cocci, bacilli, spirilla
  - oxygen requirements (obligate and facultative aerobes/anaerobes).
- Fungi – Chytridiomycota, Zygomycota, Ascomycota and Basidiomycota.
- Viruses, e.g. size, nucleic acid, capsid structure, host and disease.

#### A3 Microorganisms in medicine and industry

Basic stages involved in classifying and using microorganisms:

- identification of causes of disease
- biowaste processing
- food and beverage production
- nitrogen fixation
- antibiotic and hormone production
- flora and fauna in the human digestive tract.

### Learning aim B: Undertake microscopy for specimen examination in laboratories

#### B1 Microscopes

Basic principles behind different types of microscopes and attachments, including the suitability and preparation of samples for use in each case.

- definitions of resolution, magnification, focus, image
- stereomicroscopes (dissection microscopes)
- compound light microscope, to include the use of oil immersion lenses
- phase contrast, to include uses of special lenses to convert the differences between transmitted and refracted light into variations in intensity
- electron microscope, including transmission and scanning.

**B2 Specimen and slide preparation**

Methods and equipment involved in preparing specimens, including relevant theoretical background, for viewing microorganisms under a compound light microscope. This should include practical application of techniques as appropriate:

- use of flat and concave slides
- cover slips
- wet and dry mounts
- air drying and heat fixing
- smear slides
- staining, e.g. methylene blue, Indian ink, Gram staining.

**B3 Setting up and using a compound light microscope**

- Component parts of the light microscope and their functions:
  - eyepiece and eyepiece graticules
  - coarse and fine adjustment knobs
  - stage
  - mirror and/or light source
  - condenser and adjustment knob
  - iris diaphragm.
- Using the microscope and correct procedures to follow:
  - preparation of microscope to use with a slide
  - adjustment of condenser
  - use of lowest power lens
  - use of other lens magnifications
  - calculation of actual size from scientific drawing of specimens.

**Learning aim C: Undertake aseptic techniques to culture microorganisms****C1 Safety and prevention of contamination in microbial culturing**

- Reasons for and practices in sector-specific safety equipment and procedures in laboratories where microbial investigation takes place.
- Awareness of the meaning of classifications of biosafety in levels 1-4.
- Personal protective equipment (PPE), e.g. nitrile gloves, eye protection, lab coat.
- Safety procedures to follow in a biosafety Level 1 microbiology practical:
  - attention to personal hygiene, hand washing
  - equipment sterilisation
  - mechanical pipetting
  - inoculation of plates
  - culture and examination of plates
  - safe disposal of materials, e.g. autoclaving.
- Biosafety cabinets:
  - negative/positive pressure
  - stainless steel construction
  - class I, II and III.

**C2 Growth media**

- Aseptic techniques and equipment required for preparation of growth media. Learners should prepare growth media where possible.
- Nutrient broths.
- Nutrient agar plates.
- Selective media:
  - MacConkey agar
  - mannitol salt agar
  - blood agar
  - potato dextrose agar.

**C3 Inoculation and incubation**

Role of inoculation and incubation; aseptic techniques and equipment required (the practical application of these techniques by learners is expected):

- inoculation of liquid and solid media, to include streaking and lawn spreads
- importance of incubation temperature, e.g. why incubation at 37 °C is not recommended in school/college laboratories
- use of tape strips to anchor but not seal petri dishes, inversion of dishes during incubation
- length of incubation.

**Learning aim D: Explore factors controlling microbial growth in industrial, medical and domestic applications****D1 Growth requirements**

Factors affecting growth of bacteria and fungi, including relevance to industrial, medical and domestic settings:

- nutrients
- light and temperature preferences.
- oxygen requirements
- pH levels
- growth surfaces.

**D2 Growth inhibitors**

Methods of inhibiting microbial growth in industrial, medical and domestic settings. (Where appropriate, these should be practically investigated by learners.)

- Irradiation.
- Antimicrobials – antibiotics, antivirals.
- Antifungals.
- Disinfectants, e.g. household and industrial cleaning products, hand sanitisers.
- Sterilisation procedures.
- Osmotic potentials in strong salt/sugar solutions as preservatives.
- Controlled atmospheres for food preparation.

**D3 Measuring microbial growth**

Theoretical background and practical application of growth monitoring techniques, to include the interpretation of resulting data:

- colorimetry for fungal, bacterial and viral growth showing turbidity
- haemocytometer, such as in yeast cell counts
- mycelial discs measured as increase in diameter or dry mass
- counting bacterial colonies and use of serial dilution.

## Assessment criteria

Pass	Merit	Distinction
<b>Learning aim A: Understand the importance of microbial classification to medicine and industry</b>		
<b>A.P1</b> Explain how the structures and characteristics of microorganisms are used to classify them.	<b>A.M1</b> Compare the characteristics of microorganisms used for classification.	
<b>Learning aim B: Undertake microscopy for specimen examination in laboratories</b>		<b>AB.D1</b> Evaluate the use of microscopy techniques to observe structures and classify microorganisms.
<b>B.P2</b> Correctly set up and use a light microscope and oil immersion lens to observe structures of microorganisms under magnification. <b>B.P3</b> Illustrate, with accuracy, the structures of microorganisms observed using a light microscope and an oil immersion lens.	<b>B.M2</b> Compare the use of different microscopy techniques to observe the structures of microorganisms.	
<b>Learning aim C: Undertake aseptic techniques to culture microorganisms</b>		<b>CD.D2</b> Evaluate own aseptic techniques used to culture microorganisms with specific reference to the type of media, methods of inoculation chosen and the biocontainment procedures carried out.
<b>C.P4</b> Correctly prepare and inoculate growth media and measure microbial growth using aseptic techniques. <b>C.P5</b> Explain biocontainment procedures in your centre laboratory and within industrial laboratories.	<b>C.M3</b> Demonstrate skilful application of aseptic techniques in inoculation and preparation of growth media and in measuring microbial growth. <b>C.M4</b> Compare biocontainment procedures in your centre laboratory to those used in industrial laboratories.	
<b>Learning aim D: Explore factors controlling microbial growth in industrial, medical and domestic applications</b>		
<b>D.P6</b> Carry out investigations into the effect of growth requirements on microorganisms. <b>D.P7</b> Explain how growth inhibitors affect microorganisms.	<b>D.M5</b> Analyse how growth of microorganisms is affected by changing environmental factors.	

## Essential information for assignments

The recommended structure of assessment is shown in the unit summary along with suitable forms of evidence. *Section 6* gives information on setting assignments and there is further information given on our website.

There is a maximum number of two summative assignments for this unit. The relationship of the learning aims and criteria is:

Learning aims: A and B (A.P1, B.P2, B.P3, A.M1, B.M2, AB.D1)

Learning aims: C and D (C.P4, C.P5, D.P6, D.P7, C.M3, C.M4, D.M5, CD.D2)

## Further information for teachers and assessors

### Resource requirements

For this unit, learners must have access to:

- a well-equipped laboratory
- materials/apparatus/equipment and/or laboratory instruments/sensors
- computers, DVDs and suitable texts, appropriate science and maths software packages (especially when working with the results of growth data, which may involve the use of graphs).

### Essential information for assessment decisions

#### Learning aims A and B

**For distinction standard,** learners will look at the structures that can be seen under different microscopes and evaluate the advantages and limitations in their use for medicine and industry. They will use their observations and knowledge of the characteristics of microorganisms to argue/reason for their placement in different groups and then evaluate the reasons for such a division. Their work will be detailed and comprehensive, using named examples of at least four of the microorganisms and infectious agents as part of the evaluation process.

**For merit standard,** learners will show they understand the reasons for the classification of microorganisms, comparing the similarities and differences in size, structure, reproduction and their importance in medicine and industry. They will refer to how the structure of microorganisms is viewed using two types of microscope, including their own drawings of specimens viewed under a compound light microscope. They will compare photomicrographs of microorganisms taken using two types of microscopes, showing they understand the differences and similarities between them in terms of their characteristics and how these factors are used to put them into groups before commenting on their importance.

**For pass standard,** learners will use the microscope and an oil immersion lens to look at microorganisms, following instructions to set up and use a light microscope correctly. Learners will produce accurately drawn and labelled diagrams of specimens they have viewed themselves, which will include the magnification used and a calculation of the actual size of objects they have drawn. Learners will use photomicrographs and annotated diagrams to describe the structures observed. They will use named examples where appropriate, and they can include other features providing they state under what circumstances they can be seen, i.e. oil immersion or electron microscope. Learners must use their own drawings in addition to published photomicrographs and other sources of information to explain how microorganisms are classified, making reference to four microorganisms from the unit content.

#### Learning aims C and D

**For distinction standard,** learners will evaluate the impact of the use of the correct media and inoculation techniques on the successful growth of microbes, using their evaluation of practical work plus any research. They will also evaluate their own techniques in comparison with other learners and suggest areas for improvement. They will explain the biocontainment measures taken in the classroom that contributed to the successful growth of the microbes, as well as the importance of biocontainment procedures used in industry and the impact of this when not followed. Learners will list the factors that affect growth in microorganisms, evaluating how effective their methods were in being able to analyse the effects on growth of changing environmental factors and suggesting suitable alternatives or extensions to the methods or equipment that would enhance their results.

**For merit standard,** learners will work in an efficient way with minimal guidance, demonstrating good aseptic technique that leads to little or no contamination of results. They will measure the resultant microbial growth with precision, leading to a coherent analysis of the results from which sensible conclusions can be drawn. Learners will refer to secondary data to support their analyses.

Learners will discuss their experience of the biocontainment measures used in their laboratory in relation to the systems used in industry. They will compare the two settings and explain the reasons for the differences.

**For pass standard,** learners will demonstrate adherence to safety procedures, including the production of suitable risk assessments making it clear that they understand the reasons behind the precautions that must be taken when working with microorganisms. They will follow instructions to obtain results investigating the effect on microbial growth of changing at least one environmental factor. This will include learners preparing and inoculating both liquid and solid media. Learners' measurements will be accurate in terms of taking more than one measurement and averaging the result. They will describe what their results show in terms of microbial growth requirements and growth inhibitors. They will then give an explanation of the biocontainment measures they used for their work, and how these relate to biocontainment procedures in industrial laboratories. Learners may demonstrate isolated elements of knowledge and understanding, with basic but correct use of relevant terminology.

### Links to other units

This unit links to:

- Unit 1: Principles and Applications of Science I
- Unit 2: Practical Scientific Procedures and Techniques
- Unit 5: Principles and Applications of Science II
- Unit 8: Physiology of Human Body Systems
- Unit 11: Genetics and Genetic Engineering
- Unit 12: Diseases and Infections
- Unit 20: Biomedical Science.

### Employer involvement

It may be possible to arrange a visit to a local facility, hospital or university that has an electron microscope. The local Environmental Health Department may be able to support the centre by providing a visiting Environmental Officer to discuss their role in dealing with the effects of pathogens.

A visit to a microbiology laboratory would be very useful, and a local food-processing factory may be able to offer opportunities for a visit or provide a speaker and additional information.





# Unit 18: Industrial Chemical Reactions

Level: **3**

Unit type: **Internal**

Guided learning hours: **60**

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## Unit in brief

This unit covers aspects of chemical thermodynamics, kinetics, chemical equilibrium and how these physical chemical topics are used in industrial processes.

## Unit introduction

In this unit, you will carry out practical work, perform calculations and investigate industrial processes. You will build on your knowledge of exothermic and endothermic reactions by measuring enthalpy changes in chemical reactions and exploring the accuracy of your measurements. You will use data to calculate the enthalpy changes expected in reactions as well as the other two functions of state, entropy and Gibbs energy. Entropy is a measure of the degree of disorder in a system. Spontaneous chemical reactions are often exothermic, but an increase in entropy is another driver of chemical change. You will be able to predict whether reactions are feasible under standard conditions by calculating changes in Gibbs energy.

The thermodynamic factors mentioned above will allow you to identify whether reactions may occur spontaneously, but do not give an indication of the rate of the reactions. You will learn how to calculate the rates of chemical reactions from given data and to work out the relationship between the rate and the concentrations of the reactants. You will carry out practical investigations of factors affecting the rate of reaction and explain these factors in terms of collision theory. You will also learn how to describe the characteristic features of equilibrium reactions and to calculate the equilibrium constant, exploring the effects on equilibrium of changes in concentration, pressure, temperature and catalysts.

Finally, you will investigate how industrial chemical reactions may be controlled by using physical chemistry concepts. The fundamental concepts of thermodynamics, rate and equilibrium introduced in this unit are extended in higher education courses involving chemistry and biology. A range of industries that employ scientists make use of these topics. For example, process operators and the technicians in the bulk chemical, polymer, agrochemical and pharmaceutical industries use the concepts learned in this unit to optimise production.

## Learning aims

In this unit you will:

- A** Investigate chemical thermodynamics in order to understand spontaneous reactions
- B** Investigate factors affecting rate of reaction in order to understand collision theory
- C** Investigate chemical equilibrium in order to understand the extent to which reactions go to completion
- D** Understand physical chemistry concepts and how industry controls chemical reactions.

## Summary of unit

Learning aim	Key content areas	Recommended assessment approach
<b>A</b> Investigate chemical thermodynamics in order to understand spontaneous reactions	<b>A1</b> Enthalpy changes <b>A2</b> Entropy and Gibbs energy	Observation reports of measurement of enthalpies of reactions plus completed worksheets from the practical activities, discussion of the assumptions made, evaluation of the sources of error and calculations of expected values.  Worksheets containing calculations, involving enthalpy changes, entropy changes, Gibbs energy and equilibrium constant.
<b>B</b> Investigate factors affecting rate of reaction in order to understand collision theory	<b>B1</b> Rate of reaction	A workbook containing calculations of rates of reaction, the results and conclusions of experimental investigations into the factors affecting rate of reaction and explanations of the results of these experiments.  Worksheets showing the analysis of the results of initial rate experiments and calculations of activation energy from data on rate constants at different temperatures.
<b>C</b> Investigate chemical equilibrium in order to understand the extent to which reactions go to completion	<b>C1</b> Chemical equilibrium	Worksheets describing the features of equilibrium reaction, showing calculations of $K_c$ and describing/explaining the effects of changes in concentration, pressure, temperature and the presence of a catalyst on equilibrium, and analysis of the effects of temperature on equilibrium constant.
<b>D</b> Understand physical chemistry concepts and how industry controls chemical reactions	<b>D1</b> Industrial application of physical chemistry concepts	An explanation of the reason for three specified features of the operation of an industrial process. An explanation of three further factors that may be altered on the basis of physical chemistry concepts. Analysis of other industrial processes in terms of the physical chemistry concepts involved.

## Content

### Learning aim A: Investigate chemical thermodynamics in order to understand spontaneous reactions

#### A1 Enthalpy changes

- Definitions of a range of standard enthalpy changes: combustion, formation, solution, hydration, neutralisation, dissociation, ionisation, electron affinity, lattice, sublimation, fusion, vaporisation, interpretation of the size and sign of values, literature values.
- Principle of conservation of energy.
- Measurement of enthalpy changes – solution of anhydrous sodium carbonate, solution of ammonium chloride, neutralisation of hydrochloric acid with sodium hydroxide, combustion of alcohols using spirit burners.
  - comparison of measured values with literature values
  - sources of error
  - calculation of enthalpy changes from supplied experimental data.
- Hess's Law.
- Straightforward calculation of enthalpy changes from supplied data:
  - standard enthalpy of reaction from standard enthalpies of formation  $\Delta H_f^\ominus$
  - $\Delta H_{\text{reaction}}^\ominus = \Sigma \Delta H_{\text{f products}}^\ominus - \Sigma \Delta H_{\text{f reactants}}^\ominus$
  - calculation of enthalpy of formation from bond enthalpies
  - complex calculations involving rearrangement of equations:
  - calculation of  $\Delta H_f^\ominus$  of a reactant or product, given a standard reaction enthalpy and  $\Delta H_f^\ominus$  for the other reactants and products
  - calculation of bond enthalpy for a particular bond, given the enthalpy of formation and the other values of bond enthalpy.

#### A2 Entropy and Gibbs energy

- Entropy as a measure of the degree of disorder.
- Symbol  $S$  and units  $\text{J K}^{-1} \text{mol}^{-1}$ .
- Standard entropy  $S^\ominus$ .
- $\Delta S_{\text{total}} = \Delta S_{\text{system}} + \Delta S_{\text{surroundings}}$
- $\Delta S_{\text{reaction}}^\ominus = \Sigma S_{\text{products}}^\ominus - \Sigma S_{\text{reactants}}^\ominus$
- Comparison and rationalisation of  $\Delta S^\ominus$  values for different reactions.
- Gibbs energy ( $G$ ).
- $\Delta G$  and  $\Delta G^\ominus$ .
- Units of  $\Delta G$   $\text{kJ mol}^{-1}$ .
- $\Delta G = \Delta H - T\Delta S_{\text{system}}$
- Condition for a feasible (products predominating) reaction  $\Delta G$  negative.
- Calculations using  $\Delta G^\ominus = \Delta H^\ominus - T\Delta S^\ominus$ .
- Calculation of feasibility under standard conditions.
- Estimation of temperature at which reaction becomes feasible.
- Reactions that are thermodynamically feasible may be inhibited by kinetic factors.

## Learning aim B: Investigate factors affecting rate of reaction in order to understand collision theory

### B1 Rate of reaction

- Definition of reaction rate.
- Units of rate of reaction  $\text{mol dm}^{-3} \text{s}^{-1}$ .
- Rate as – slope of the tangent to a concentration/time graph.
- Calculation of rate from drawing tangents to concentration/time graphs and calculating gradient.
- Possible ways of collecting concentration/time data.
- Order of reaction with respect to reactants – first order, second order, zero order, possibility of other orders.
- Initial rate of reaction as rate (slope of tangent) when time = 0 s when the reaction has just begun.
- Method of initial rates for working out order of reaction.
- Overall order of reaction.
- Rate equations and rate constants.
- Units of rate constant.
- Experimental investigations:
  - effect of concentration – hydrochloric acid and calcium carbonate or sodium thiosulfate and hydrochloric acid or crystal violet with sodium hydroxide
  - effect of particle size – hydrochloric acid and calcium carbonate or hydrochloric acid and magnesium ribbon
  - effect of temperature – sodium thiosulfate and hydrochloric acid or persulphate with iodide
  - effect of a catalyst:
    - heterogeneous – effect of different potential catalysts on the decomposition of hydrogen peroxide
    - homogeneous – traffic light reaction: effect of cobalt (II) chloride, on the rate of the reaction between potassium sodium 2,3-dihydroxybutanedioate and hydrogen peroxide.
- Explanation of factors affecting rate of reaction:
  - collision theory
  - for the effect of concentration, concentration affects the number of collisions per second
  - for the effect of particle size, surface area affects the number of collisions per second
  - for the effect of temperature and presence of a catalyst, include reaction profile showing activation energy,  $E_a$ , and the Maxwell-Boltzmann distribution of energies
  - Arrhenius equation – the relationship between rate constant and activation energy

$$k = Ae^{-\frac{E_a}{RT}}$$

- plot of  $\ln(k)$  versus  $\frac{1}{T}$  gives a graph of slope  $-\frac{E_a}{RT}$

- straightforward application of the equation:

$$\ln\left(\frac{k_2}{k_1}\right) = -E_a\left(\frac{1}{T_2} - \frac{1}{T_1}\right) \text{ or } \ln(k_2) - \ln(k_1) = -E_a\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

## Learning aim C: Investigate chemical equilibrium in order to understand the extent to which reactions go to completion

### C1 Chemical equilibrium

- Features of an equilibrium reaction:
  - once equilibrium is established, the forward and backward reactions continue to happen
  - once equilibrium is established, rate of forward and backward reactions are equal
  - shapes of graphs of concentration versus time for an equilibrium reaction
  - may be described using an equilibrium constant.
- Writing of the equilibrium constant in terms of concentration,  $K_c$ , for given equilibrium reactions.
- Units of  $K_c$ .
- Awareness of  $K_p$ , the equilibrium constant in terms of pressure.
- Calculation of  $K_c$ , given values of concentration.
- Calculation of concentration, given  $K_c$  and required values of concentration.
- Re-establishment of equilibrium following an imposed change in concentration, pressure and temperature.
- Le Châtelier's principle.
- Explanation of the effect of changes in concentration on the position of equilibrium at constant temperature ( $K_c$  unaffected).
- Explanation of the effect of changes in pressure on the position of equilibrium at constant temperature ( $K_c$  (and  $K_p$ ) unaffected).
- Explanation of the effect of changing temperature on the equilibrium constant:
  - in terms of whether the forward and backward reaction is favoured by an increase/decrease in temperature
  - $K_c$  increases as temperature increases when the forward reaction is endothermic (backward reaction exothermic)
  - $K_c$  decreases as temperature increases when the forward reaction is exothermic (backward reaction is endothermic)
  - $K_c$  decreases as temperature decreases when the forward reaction is endothermic (backward reaction is exothermic)
  - $K_c$  increases as temperature decreases when the forward reaction is exothermic (backward reaction is endothermic).
- Explanation of the effect of a catalyst on the position of the equilibrium.
- Use of the equation  $\Delta G^0 = -RT \ln(K)$  to show that reactions that are feasible in terms of  $\Delta G$  have large values for the equilibrium constant and vice versa.
- Awareness that reactions are often not run under equilibrium conditions in order to keep the reaction happening. (One of the products may be constantly removed.)

**Learning aim D: Understand physical chemistry concepts and how industry controls chemical reactions****D1 Industrial application of physical chemistry concepts**

- Physical chemistry concepts:
  - exothermic and endothermic reactions: use of heat exchangers, hot spots, design of reaction vessels, mixing to dissipate heat, controlled addition of reagents
  - altering conditions for reactions that are not feasible under standard conditions:
    - Solvay process:  $\text{CaCO}_3 + 2\text{NaCl} \rightarrow \text{CaCl}_2 + \text{Na}_2\text{CO}_3$
  - effect of particle size, concentration, temperature and presence of a catalyst on rate
    - the need to control (increasing or decreasing) rate by varying conditions, use of powdered reagents, use of mixing to enable more effective contact between reagents, variation of the temperature, preheating reactants, use of catalysts
  - running reactions under non-equilibrium conditions
  - optimising the operating temperature and pressure
  - taking account of the physical state and solubility of reactants and products to facilitate their separation
  - distillation and filtration
  - choice of materials for chemical plant based on chemical properties of reactants and products.
- Explaining features of industrial case studies.

## Assessment criteria

Pass	Merit	Distinction
<b>Learning aim A: Investigate chemical thermodynamics in order to understand spontaneous reactions</b>		
<p><b>A.P1</b> Demonstrate accurate measurement of enthalpy changes and assess the quality of the results</p> <p><b>A.P2</b> Perform straightforward calculations involving enthalpy changes.</p> <p><b>A.P3</b> Interpret values from calculations involving thermodynamic data.</p>	<p><b>A.M1</b> Discuss the sources of error and assumptions in enthalpy change measurements.</p> <p><b>A.M2</b> Perform complex calculations involving enthalpy changes, which require rearrangement.</p> <p><b>A.M3</b> Interpret values from calculations, estimating the temperatures at which reactions may become feasible.</p>	<p><b>A.D1</b> Demonstrate accurate determination of experimental details for enthalpy change by carrying out straightforward and complex calculations.</p>
<b>Learning aim B: Investigate factors affecting rate of reaction in order to understand collision theory</b>		
<p><b>B.P4</b> Carry out calculations to determine the correct rate of reaction from the concentration/time plots.</p> <p><b>B.P5</b> Explain the factors affecting rate of reaction.</p>	<p><b>B.M4</b> Demonstrate accurate determination of reaction order, overall rate equation, rate constant and its units for straightforward data.</p> <p><b>B.M5</b> Carry out calculations to accurately determine the activation energy of a reaction from data on the rate constant at different temperatures.</p>	<p><b>B.D2</b> Demonstrate accurate determination of reaction order, overall rate equation and rate constant and units for complex data.</p>
<b>Learning aim C: Investigate chemical equilibrium in order to understand the extent to which reactions go to completion</b>		
<p><b>C.P6</b> Describe the features of an equilibrium reaction.</p> <p><b>C.P7</b> Carry out calculations involving <math>K_c</math>.</p> <p><b>C.P8</b> Describe the effects of increases in concentration of a reactant, pressure, temperature and the presence of a catalyst on an equilibrium reaction.</p>	<p><b>C.M6</b> Discuss the effects of changes in concentration, pressure and temperature on equilibrium and interpret the value of the standard change in Gibbs energy.</p>	<p><b>C.D3</b> Analyse the relationship between equilibrium constant and temperature.</p>
<b>Learning aim D: Understand physical chemistry concepts and how industry controls chemical reactions</b>		
<p><b>D.P9</b> Explain identified aspects of the operation of an industrial process in terms of physical chemistry concepts.</p>	<p><b>D.M7</b> Discuss actions that may be taken to control a chemical process.</p>	<p><b>D.D4</b> Analyse the operation of a chemical process in terms of the physical chemistry concepts involved.</p>

## Essential information for assignments

The recommended structure of assessment is shown in the unit summary along with suitable forms of evidence. *Section 6* gives information on setting assignments and there is further information on our website.

There is a maximum number of four summative assignments for this unit. The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.P2, A.P3, A.M1, A.M2, A.M3, A.D1)

Learning aim: B (B.P4, B.P5, B.M4, B.M5, B.D2)

Learning aim: C (C.P6, C.P7, C.P8, C.M6, C.D3)

Learning aim: D (D.P9, D.M7, D.D4)



## Further information for teachers and assessors

### Resource requirements

For this unit, learners must have access to a well-equipped laboratory.

### Essential information for assessment decisions

#### Learning aim A

**For distinction standard,** learners will use literature values for enthalpy change and work back to calculate experimental details for two different planned experiments. For example, learners could be given the enthalpy of solution for a substance and then work out the mass of the substance needed to produce a given temperature change for a given amount of water. For validity and authenticity teachers would have to ensure that all learners are not given the same substance to test. Learners could work out the temperature change they may expect by burning a different amount of alcohol, making appropriate assumptions about the lack of efficiency of the process. Learners will clearly explain the logic used.

**For merit standard,** learners will provide detailed commentary on the differences between literature values and class results for values of measured changes. Learners will suggest realistic and specific sources of error for the discrepancies and discuss how those suggested errors would account for the observed results. They would be expected to identify the difference in the nature between experiments, such as enthalpy of solution or neutralisation where the reaction was taking place in direct contact with the water whose heat change was measured, and enthalpy of combustion. Learners will discuss the assumptions made in each of the four enthalpy change experiments. Learners will also perform calculations of a similar type to those at pass standard, but where a different outcome is required, for example calculating the enthalpy of formation of a substance, given other enthalpies of formation and the enthalpy of a reaction.

Using data for the standard enthalpy and entropy changes in at least three given reactions, learners will estimate the temperature at which a reaction is likely to become feasible, stating any assumptions made about the variation with temperature of values used in the calculation.

**For pass standard,** learners will individually accurately measure the enthalpy of solution for anhydrous sodium carbonate and ammonium chloride, the enthalpy of neutralisation of hydrochloric acid with sodium hydroxide and the enthalpy of combustion of an alcohol. The assessor should provide observation reports to supplement the learners' evidence. Learners will assess the quality of the data obtained. They will compare the values obtained with literature values and with those of their classmates and comment on whether their result is higher or lower than the literature value and the extent of the difference. They will comment on whether class results are broadly in agreement with each other and with the literature value or not.

Learners will calculate the standard enthalpy of a reaction – for example, combustion – given the standard enthalpies of formation of reactants and products and estimate the enthalpy of formation for a gaseous compound from average bond enthalpies. They may perform this calculation procedure mechanistically.

Learners will calculate the standard entropy change for three given reactions and comment on the size and sign of the values. One reaction should involve more gaseous products than gaseous reactants. One reaction should involve fewer gaseous products than gaseous reactants. The third should involve a reaction where the entropy change is small. Learners will interpret the size and sign of the change in terms of the degree of disorder in the reactants and products. They will also calculate standard entropy changes, standard enthalpy changes and standard changes in Gibbs energy at 298 K for three given different reactions and comment on the feasibility of the reaction under standard conditions.

### Learning aim B

**For distinction standard**, learners will work out, from data on initial rates and concentration, the order of reaction with respect to each reactant and hence determine the overall rate equation. More deduction will be required than at merit standard, for example ratios may not involve simply doubling a concentration. Another example would be for it to be straightforward to work out the order with respect to one reactant but there may be data from an experiment where the concentration of that reactant and another have changed, making deduction more complex.

**For merit standard**, learners will be given very straightforward data on an initial rate of reaction for two reactions involving three reactants. Learners will inspect the data and will easily see that, for example, doubling the concentration of one of the reactants, while holding the concentrations of the other two reactants constant, quadruples the rate (meaning that the reaction is second order with respect to that reactant). The orders involved should be first, second or zero order. Learners will write the overall rate equation for the reaction and use the data to determine the rate constant.

Learners will also be given the rate constant and temperature data and accurately determine activation energy graphically, working out activation energy, given two values of the rate constant for two different temperatures. (Rearrangement of the Arrhenius equation to determine a temperature or a rate constant may be too complex mathematically at this level.)

**For pass standard**, learners will calculate the slopes of tangents to a concentration time graph for a range of concentrations and hence correctly determine the rate of reaction at each concentration. This should include the initial concentration at zero time.

Learners will carry out experiments to determine the effects on the rate of changing concentration, particle size, temperature and homogeneous and heterogeneous catalysts on the rate of reaction. Appropriate, correctly labelled graphs will be produced for the effects of concentration, particle size and temperature. Learners will state conclusion(s) for each practical and will provide an appropriate explanation of the effect in terms of collision theory, reaction profiles, activation energy and the Maxwell-Boltzmann distribution. Their investigations will be presented in the form of a workbook and the assessor will confirm that learners have undertaken each aspect of the practical work.

### Learning aim C

**For distinction standard**, learners will analyse the effect of temperature on a given equilibrium reaction in terms of the sign of the enthalpy change and the slope of a plot of  $\ln(K)$  versus  $\frac{1}{T}$ .

**For merit standard**, learners will discuss the effects of increases and decreases in concentration, pressure and temperature on equilibrium, three examples for each and containing more detail than the descriptions given at pass standard. They will work out an equilibrium constant constant

(based on  $\Delta G^0 = -RT\ln(K)$  and hence  $K = e^{\frac{\Delta G^0}{RT}}$  for the reaction, and conclude whether there are significant amounts of both reactants and products in the equilibrium mixture or whether the reaction has effectively gone to completion or not taken place.

**For pass standard**, learners will describe equilibrium reactions and show that they understand that concentrations of reactants and products remain constant once equilibrium has been reached, the reactions continue to happen and the rates of forward and backward reactions are equal. Learners will sketch concentration/time diagrams for the reactants and products. Learners must also be able to write an expression for  $K_c$  for three reactions and calculate the value of  $K_c$  with its units from given concentrations of reactants and products at equilibrium.

Learners will demonstrate understanding that an increase in the concentration of a reactant will mean that the reaction is no longer at equilibrium. Initially it will speed up the forward reaction and then the backward reaction until equilibrium is re-established, maintaining the same value of  $K_c$ .

Learners will describe how increasing pressure will favour the reaction (forward or backward), producing fewer molecules of gas and the equilibrium will move accordingly to ensure  $K_c$  remains the same. One given example should have the same number of gas molecules either side of the reaction. Learners will describe how increasing temperature favours the endothermic reaction (forward or backward) and explain whether  $K_c$  increases or decreases as a result. Learners will describe how the presence of a catalyst reduces the activation energy of both forward and backward reactions and hence has no effect on equilibrium.

### Learning aim D

**For distinction standard**, learners will review ways in which physical chemistry concepts are used in analysis of a process that they have investigated. This process should be different from the one used at merit and pass standard.

**For merit standard**, learners will be presented with a chemical process. From this, they will identify and discuss three potential measures, other than those identified at pass standard, which may be used to control or affect the operation of the industrial process.

**For pass standard**, learners will explain three specified features of the operation of the chemical process, as described at merit standard, for example why the reaction vessel was in contact with a heat exchanger, why a powdered catalyst was used, why one of the products was continuously removed etc.

### Links to other units

This unit links to:

- Unit 2: Practical Scientific Procedures and Techniques
- Unit 4: Laboratory Techniques and their Application
- Unit 5: Principles and Applications of Science II.

### Employer involvement

A visit to or a visiting speaker from a chemical plant, for example bulk chemicals, agrochemicals, pharmaceuticals, polymers, will enhance the delivery of this unit. Industry representatives will be able to explain the importance of thermodynamics, kinetics and equilibrium concepts to their processes, for example how heat from exothermic reactions is used, how the particle size of solid surface particles is optimised and how the yield of products may be maximised by removing one or more products to stop the reaction from reaching equilibrium.



# Unit 19: Practical Chemical Analysis

Level: **3**

Unit type: **Internal**

Guided learning hours: **60**

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## Unit in brief

This unit covers quantitative analysis, spectroscopy, chromatography and industrial quality-assurance procedures.

## Unit introduction

Chemical analysis has many applications in manufacturing, particularly in product quality control, the monitoring of production processes and drug development processes in the pharmaceutical industry. In addition, chemical analysis of body fluids is critical to the diagnosis of disease and to policing the use of banned substances in sport. For all major sporting events a team of analytical chemists is active behind the scenes, analysing a variety of body fluids for microscopic traces of illegal and banned substances. Chemical analysis is also used to monitor air and effluent for pollutants and when testing building land for toxic contaminants.

In this unit, you will apply your knowledge of extraction and quantitative techniques to the analysis of the components of natural or commercial products. In addition to the component being analysed, there are usually other substances present that complicate the analysis and require the use of specially adapted procedures.

You will learn how to interpret the information from a range of spectroscopic and instrumental chromatographic methods, which have become the techniques of choice for many industries. For example, a pharmaceutical laboratory technician will be trained to routinely use instrumental techniques, including infrared and ultraviolet-visible spectroscopy, gas chromatography and high-performance liquid chromatography techniques, with which you will become familiar.

The experience gained from this unit will be a useful introduction to many analysis techniques used in laboratories and, should you progress to higher education, you will use them on courses in chemistry, biochemistry, sports science, biomedical science, public health and environmental science.

## Learning aims

In this unit you will:

- A** Investigate quantitative analysis on the components of matrices to determine their composition
- B** Investigate spectroscopic techniques to identify compounds and determine concentrations
- C** Investigate chromatographic techniques to identify components and determine the amounts present in samples.

## Summary of unit

Learning aim	Key content areas	Recommended assessment approach
<b>A</b> Investigate quantitative analysis on the components of matrices to determine their composition	<b>A1</b> Quantitative analysis of products	<p>A portfolio of method sheets and calculated results for the three analyses.</p> <p>A report comparing 'primary and secondary titrimetric standards', analysis of specific errors and how accuracy may be affected by analytes being part of a matrix.</p>
<b>B</b> Investigate spectroscopic techniques to identify compounds and determine concentrations	<b>B1</b> Beer-Lambert applications <b>B2</b> Organic structure elucidation	<p>A portfolio of method sheets, calibration graphs and calculated results.</p> <p>Completed exercises on use of percentage composition and mass spectrometry to determine molecular formula, evidence of identification of the class of compound, giving rise to particular infrared spectra, matching <math>^1\text{H}</math> and <math>^{13}\text{C}</math> NMR spectra to structural formulae of simple organic molecules.</p> <p>An account of how two unknown organic compounds have been identified from their percentage composition, mass spectra, infrared spectra and <math>^1\text{H}</math> and <math>^{13}\text{C}</math> NMR spectra.</p>
<b>C</b> Investigate chromatographic techniques to identify components and determine the amounts present in samples	<b>C1</b> Gas chromatography (GC) <b>C2</b> High-performance liquid chromatography (HPLC)	<p>Description of how the techniques GC and HPLC work.</p> <p>A portfolio of qualitative and quantitative interpretation of chromatograms and peak area results for HPLC and GC.</p> <p>A report describing how an HPLC method would be developed and how either an HPLC or GC procedure would be modified to give optimum separation of peaks.</p>

## Content

### Learning aim A: Investigate quantitative analysis on the components of matrices to determine their composition

#### A1 Quantitative analysis of products

- Determination of the copper content of brass:
  - digestion of brass in acid and making it up to a known volume
  - colorimetric determination of copper content, to include matched standards.
- Bicarbonate content of bottled water:
  - standardisation of 0.1 mol dm<sup>-3</sup> hydrochloric acid by titration with sodium carbonate (bromophenol blue indicator)
  - quantitative dilution of 0.1 mol dm<sup>-3</sup> hydrochloric acid to make 0.01 mol dm<sup>-3</sup> hydrochloric acid
  - pH titration of bottled water with standardised 0.01 mol dm<sup>-3</sup> hydrochloric acid.
- Iron(II) content of iron tablets:
  - extraction of Fe<sup>2+</sup> by grinding tablets and heating with water
  - standardisation of potassium manganate(VII) with sodium ethane dioate
  - titration of Fe<sup>2+</sup> by titration with potassium manganate(VII).

### Learning aim B: Investigate spectroscopic techniques to identify compounds and determine concentrations

#### B1 Beer-Lambert applications

- Colorimetry or spectrometry in the visible region by adding a colour reagent.
- Colorimetry or spectrometry by intensification of Cu<sup>2+</sup> colour by adding ammonia and use of matched standards.
- Interpretation of data from quantitative infrared spectroscopy.
- Interpretation of data from quantitative ultraviolet spectroscopy.

#### B2 Organic structure elucidation

- Determination of empirical formula from % elemental composition.
- Mass spectroscopy:
  - block diagram of instrumentation
  - use of mass to charge ratio  $\frac{m}{z}$
  - determination of the molecular ion peak
  - determination of molecular formula from molecular ion peak and empirical formula
  - simple fragmentation to include presence of peak at 15 for methyl.
- Drawing all possible isomeric structures for molecules of general formula:
  - C<sub>n</sub>H<sub>2n+2</sub> – alkane/branched alkane
  - C<sub>n</sub>H<sub>2n</sub> – alkene or cycloalkane
  - C<sub>n</sub>H<sub>2n+2</sub>O – alcohol or ether
  - C<sub>n</sub>H<sub>2n</sub>O – aldehyde, ketone or alkenol
  - C<sub>n</sub>H<sub>2n</sub>O<sub>2</sub> – carboxylic acid or ester
  - aromatic compound – low number of hydrogens.

- Infrared spectroscopy:
  - spectra in terms of wavenumber ( $\text{cm}^{-1}$ ) and transmission
  - energy used to make bonds bend and stretch
  - Fourier transform infrared spectroscopy (FTIR)
  - principles of operation
  - sample preparation, to include:
    - an awareness of use of agate mortar and pestles in preparation of solid samples
    - transparency of halide salts
    - common use of NaCl plates exclusion of moisture
    - liquid films
    - solid mulls
    - KBr discs
    - diamond ATR
    - solution cell for quantitative work
    - gas cell
  - correlation chart relating wavenumbers to functional groups, to include:
    - C-H – alkanes, alkenes and aromatics
    - C=C – alkenes
    - O-H – alcohols and carboxylic acids, including peak shape
    - C=O – for aldehydes, ketones, esters, carboxylic acids
  - identification of unknown matrices by matching positions and relative transmission values of the peaks.
- Proton ( $^1\text{H}$ ) and ( $^{13}\text{C}$ ) NMR spectroscopy:
  - radio waves of appropriate frequency in the presence of large magnetic field of correctly tuned magnitude cause nucleus to spin-flip
  - presence of electron density in covalent shields  $^1\text{H}$  or  $^{13}\text{C}$  from magnetic field – greater field needed to bring nucleus into resonance
  - number of chemically equivalent protons or carbon atoms in a molecule
  - relation of the number of low-resolution peaks to the number of chemically distinct protons ( $^1\text{H}$  NMR) or carbon atoms ( $^{13}\text{C}$  NMR)
  - relation of the number of low-resolution peaks to the number of chemically distinct protons ( $^1\text{H}$  NMR) or carbon atoms ( $^{13}\text{C}$  NMR)
  - relation of degree shielding to chemical shift,  $\delta$ , [0 for tetramethylsilane (TMS) and around 10 for an aldehyde proton]
  - correlation charts
  - relation of area under peak (integration) to the number of atoms in the molecule giving rise to the peak
  - simple splitting patterns and use of the  $n + 1$  rule
  - distinguishing between isomeric structures on the basis of NMR.

### **Learning aim C: Investigate chromatographic techniques to identify components and determine the amounts present in samples**

#### **C1 Gas chromatography (GC)**

- Difference between gas-solid chromatography (GSC) and gas-liquid chromatography (GLC).
- Block diagram of GC and function of components.
- Mobile phase – carrier gases.
- Packed columns (becoming less common) and capillary columns.
- Stationary phase – solid ceramic material in GSC, viscous liquid coating solid support material in GLC with packed columns, viscous liquid coating the inside of capillary tubing in capillary GC, oven surrounding the column.
- Injection – higher temperature than oven temperature, septum, method of filling a microsyringe, known sample size, headspace, autosampler.



- Detector – flame ionisation detector (FID) (most common), additional gas cylinders needed for FID, awareness that there are other types of detector.
- Display/output:
  - old instruments may have a monitor and chart paper
  - modern instruments are PC driven and chromatograms may be printed from a computer printer.
- Data obtained:
  - optimum resolution of the peaks
  - retention time as a measure of a component's identity (qualitative)
  - use of spiking to confirm the identity of a component
  - area under the peak as a quantitative measure
  - use of an internal standard in quantitative work
  - calibration graph based on ratio area due to known concentrations/area due to internal standard
  - type of samples/analytes for which this technique is appropriate
  - industries/organisations using GC
  - awareness of the possibility of coupling with mass spectroscopy.
- Parameters that may be altered:
  - different columns chosen to match the analytes
  - use of internet methods and column manufacturers' data in method development
  - oven temperature:
    - the higher the temperature, the faster the molecules move – lowers retention time and separation
    - fixed temperature setting
    - programmed to increase in the course of a run (where one or more component may have a much longer retention time)
  - different detectors for certain components.

## **C2 High-performance liquid chromatography (HPLC)**

- Block diagram of HPLC and function of components – system under pressure to make the separation of components faster.
- Normal phase (polar column and non-polar solvent) and reverse phase (non-polar column and polar solvent).
- Mobile phase – degassed solvent chosen to optimise separation, methods of degassing, problems if solvent is not degassed, design of solvent bottles, isocratic elution, gradient elution.
- Stationary phase – column selected to match analyte.
- Injection – the need to degas samples, use of the rheodyne valve, injection loop
  - method of filling a microsyringe
  - autosampler.
- Detector:
  - ultraviolet – most common for organic molecules
  - awareness that there are other types of detector.
- Display/output:
  - old instruments may have an integrator connected to a chart recorder
  - modern instruments are PC driven and chromatograms may be printed from a computer printer.

- Data obtained:
  - retention time as a measure of a component's identity (qualitative)
  - optimum resolution of the peaks
  - use of spiking to confirm the identity of a component
  - area under the peak as a quantitative measure
  - construction of a calibration curve from peak areas of solutions of known concentration
  - determination of the concentration of an analyte from its peak area and a suitable calibration curve
  - type of samples/analytes for which this technique is appropriate
  - industries/organisations using HPLC
  - awareness of the possibility of coupling with mass spectroscopy.
- Parameters that may be altered:
  - different columns chosen to match the analytes
  - use of internet methods and column manufacturers' data in method development
  - different solvents
  - virtually limitless possible combinations of columns/solvents, allowing almost any mixture to be separated
  - gradient elution – where one or more components may have a much longer retention time than the other components of the mixture
  - wavelength of the UV detector
  - use of a different detector if UV is not suitable.

## Assessment criteria

Pass	Merit	Distinction
<b>Learning aim A: Investigate quantitative analysis on the components of matrices to determine their composition</b>		
<p><b>A.P1</b> Demonstrate accurately the amount of analyte in matrices.</p> <p><b>A.P2</b> Describe the composition of the matrices analysed.</p>	<p><b>A.M1</b> Discuss the measures taken to ensure accuracy in determining the amount of analyte in the matrices.</p> <p><b>A.M2</b> Compare the use of primary and secondary titrimetric standards.</p>	<p><b>A.D1</b> Analyse errors specific to each method and how the inclusion of analyses in matrices may affect the accuracy of the results.</p>
<b>Learning aim B: Investigate spectroscopic techniques to identify compounds and determine concentrations</b>		
<p><b>B.P3</b> Demonstrate accurately the concentrations of solutions using the Beer-Lambert law.</p> <p><b>B.P4</b> Describe the key features of a range of spectra of unknown compounds to determine the identity these compounds.</p>	<p><b>B.M3</b> Explain correctly the structures of simple organic compounds from their percentage composition, infrared spectra, mass spectra, <math>^1\text{H}</math> NMR and <math>^{13}\text{C}</math> NMR spectra.</p>	<p><b>B.D2</b> Analyse the process of determining the structures of simple organic compounds from their percentage composition, infrared spectra, mass spectra, <math>^1\text{H}</math> NMR and <math>^{13}\text{C}</math> NMR spectra.</p>
<b>Learning aim C: Investigate chromatographic techniques to identify components and determine the amounts present in samples</b>		
<p><b>C.P5</b> Explain the operation and applications of capillary GC and HPLC instrumentation and measurements.</p> <p><b>C.P6</b> Demonstrate accurately the identity and amount of analytes using qualitative and quantitative GC and HPLC data.</p>	<p><b>C.M4</b> Discuss how a method for finding the amount of a given organic compound in a given sample by HPLC could be developed.</p>	<p><b>C.D3</b> Analyse how the separation from an instrumental chromatographic technique may be optimised.</p>

## Essential information for assignments

The recommended structure of assessment is shown in the unit summary along with suitable forms of evidence. *Section 6* gives information on setting assignments and there is further information on our website.

There is a maximum number of three summative assignments for this unit. The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.P2, A.M1, A.M2, A.D1)

Learning aim: B (B.P3, B.P4, B.M3, B.D2)

Learning aim: C (C.P5, C.P6, C.M4, C.D3)

## Further information for teachers and assessors

### Resource requirements

For this unit, learners must have access to:

- a well-equipped laboratory with a fume cupboard
- colorimeters for practical spectroscopy work
- infrared spectrometers (likely to be FTIR) and ultraviolet/visible spectrometers in operation
- qualitative and quantitative data from gas chromatography (GC) and high-performance liquid chromatography (HPLC) (essential)
- GC or HPLC chromatograms relating to optimisation of a separation (or case-study material from another organisation).

### Essential information for assessment decisions

#### Learning aim A

**For distinction standard**, learners will analyse specific features of the three methods that may affect the results. Learners will consider why the results from these experiments may be different from those where a technician may have made solutions of pure compounds for analysis.

**For merit standard**, learners will discuss the aspects of good volumetric practice in their practical work that enabled them to accurately determine the composition of the matrices. Learners will provide a recorded (written or a sound recording) explanation of why they have repeated a flawed piece of work and their reason will be specific to the technique being carried out. Because secondary titrimetric standards are being used to determine hydrogen carbonate concentration and manganate concentration, learners will also compare the use of primary and secondary standards in context, using examples specific to the analyses. They will explain why secondary standards are being used in preference to primary standards and why the secondary standards must be standardised using primary standards.

**For pass standard**, learners will accurately measure the percentage of copper in a sample of brass by acid digestion and colorimetry, the concentration of hydrogen carbonate ( $\text{mg dm}^{-3}$ ) in a water sample by pH titration with standardised hydrochloric acid and the percentage of iron(II) in a commercial iron tablet by titration with standardised potassium manganate(VII) solution. Learners will carry out practical work independently, following standard methods provided by tutors, and they will demonstrate competence by practising good skills in weighing and in making volumetric measurements. This will be evidenced by use of an observation report or video recording. Results will be reasonably accurate. This may be evidenced by comparing learners' results with those of their classmates. Learners will research and describe the typical components of the three matrices, and provide an approximate percentage or concentration of each component. They will provide sources of reference for the information.

#### Learning aim B

**For distinction standard**, learners will present a full written analysis of the logic used to elucidate the structural formulae of the two compounds from their infrared spectra, mass spectra,  $^1\text{H}$  NMR and  $^{13}\text{C}$  NMR spectra. They will justify whether the conclusions they have reached are likely to be completely correct or whether there are justifiable options for the compounds that they have identified.

**For merit standard**, learners will correctly elucidate the structure of the compounds in a logical way, having been presented with the percentage elemental composition, infrared spectra, mass spectra,  $^1\text{H}$  NMR and  $^{13}\text{C}$  NMR spectra for two different compounds. Learners will demonstrate in writing or verbally that they have used appropriate logic to arrive at appropriate conclusions, but it may be necessary for the tutor to provide an observation report if this is not evident from their written work.

**For pass standard,** learners will carry out experiments that extend their knowledge of the applications of the Beer-Lambert law and will interpret infrared, mass,  $^1\text{H}$  NMR and  $^{13}\text{C}$  NMR spectra.

Learners will carry out two experiments from the following list, based on the Beer-Lambert law:

- use of either a colorimeter or visible spectrometer where a colour reagent is added to the standards and to the sample. Learners could determine nitrite concentration or phosphate concentration, which are both colourless before the addition of a reagent
- use of either a colorimeter or a visible spectrometer where ammonia is used to intensify the colour of  $\text{Cu}^{2+}$  standards and sample
- use of an infrared spectrometer with a solution cell
- use of an ultraviolet spectrometer to determine the concentration of a solution containing a substance (such as the nitrate ion or an organic molecule) that absorbs in the ultraviolet region of the spectrum.

Learners will follow given experimental methods and process results (plotting a calibration graph by hand or using Excel), using the graph to find the sample concentration.

Learners are likely to find the combined use of spectra to identify a compound too demanding. Learners will demonstrate the relevant skills separately for each different type of spectrum. They will calculate empirical formula from percentage elemental composition and determine molecular formulae from the compound's mass spectrum for at least two compounds. Additionally learners will use the key feature of infrared spectra, namely the absence or presence of peaks for O-H, C-H, C=O, C=C and C-O, in order to determine which spectrum corresponds to an alkane, alkene, alcohol, ester, carboxylic acid, aldehyde and ketone. Learners will also be given the displayed structural formulae of four simple compounds to work out the number of chemically equivalent hydrogens and carbons and proximity to an electronegative atom in order to match  $^1\text{H}$  and  $^{13}\text{C}$  NMR spectra to the appropriate structural formulae.

### Learning aim C

**For distinction standard,** learners will analyse either how the separation in a GC or an HPLC method would be optimised, including how increasing/decreasing temperature would affect separation in GC, or how polarity of solvent would affect separation in HPLC. For GC, learners will analyse column selection, oven temperature and temperature programming in relation to the separation of given compounds. For HPLC, learners will analyse the effects of changing the solvent composition (isocratic elution) and the benefits of gradient elution compared with isocratic elution. They will analyse how the UV detector wavelength would be set for HPLC. Learners will be aware that the baseline noise would need to be smoothed. The analysis could be based on experiments (where the centre has a functioning GC or HPLC) or on case study data (such as chromatograms run under different conditions) relating to optimising a specific separation. Learners could extend the discussion on HPLC method development, used at merit standard, analysing variables in more depth.

**For merit standard,** learners will discuss how an HPLC method for a specific, given analysis may be written and developed, in order to demonstrate the depth of their understanding of instrumental chromatography. This is likely to include a discussion of their initial research on possible HPLC methods that could be adapted and how they would determine whether the methods identified would work for the given analyte. They will discuss the most appropriate solvents and columns to use, the initial experiments that they would carry out and the further refinements that may be needed. Learners may carry out the practical work related to method development if the centre has a functioning HPLC instrument, but this is not essential as it is an understanding of how a method could be developed that is required. In all merit-level work, learners will acknowledge the sources of information.

**For pass standard,** learners will draw, on paper or computer, a block diagram of a capillary GC and an HPLC instrument and explain the function of the components. A photocopy from a book or a downloaded diagram is not acceptable. Learners will research at least two specific examples of how HPLC is used and two specific examples of how GC is used. Learners will explain how the techniques are used in the four applications.

Learners will accurately identify the components of a mixture from retention times and/or spiking results for a GC chromatogram/chromatograms and the components of a mixture from retention times and/or spiking results for an HPLC chromatogram/chromatograms. They will accurately use chromatograms or peak area data from either a GC or an HPLC chromatogram in order to determine the amount of an analyte present. This could involve the production of a calibration graph for the analyte. Learners may interpret their own data from GC and HPLC experiments or interpret given data.

### Links to other units

This unit links to:

- Unit 2: Practical Scientific Procedures and Techniques
- Unit 3: Science Investigation Skills
- Unit 4: Laboratory Techniques and their Application
- Unit 13: Applications of Inorganic Chemistry.

### Employer involvement

Centres may involve employers in the delivery of this unit if there are local opportunities to do so. A visit to, or a speaker from, any commercial laboratory, no matter how small, will add value to this unit. Suitable laboratories include those analysing raw materials or products in the following manufacturing industries: food and drink, dairy, pharmaceuticals, polymers, dye, paints, coatings, road surfacing, ceramics, refractories, bulk chemicals, fuels and lubricants, cement kiln fuel, animal feed, transformer oils, cleaning products, fertilisers, wastewater treatment. In addition, there are laboratories that undertake sub-contracted and accredited analysis, for example of water, soil, foodstuffs and petroleum products that offer wide-ranging expertise of benefit to learners.





# Unit 20: Biomedical Science

Level: **3**

Unit type: **Internal**

Guided learning hours: **60**

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## Unit in brief

This unit will help learners understand the role biomedical scientists play in identifying the causes of disease and in helping medical personnel to offer suitable treatments.

## Unit introduction

This unit will help you understand three key areas of biomedical science: haematology, histology/cytology and biochemical balance. The analytical and diagnostic testing carried out in these three areas supports other health professionals in screening, diagnosing, monitoring disease progression and treatment.

In this unit you will concentrate on biomedical science in relation to the human body, but many of the same techniques are used in veterinary science. Similar techniques are also valuable in the pharmaceutical industry, the blood and tissue transfusion and transplant service, forensic science and food technology.

You will have opportunities to investigate and understand blood and its importance, and how it can be used to diagnose and treat disease. Analysis of blood biochemistry provides important information to medical practitioners about the functions of the human body. You will consider the importance of maintaining 'norms' within the body and how deviations from these levels provide clues as to what is happening in the body to enable conditions to be diagnosed and treated.

Having completed this unit, you will be in a position to know which branch of biomedical science interests you and what further courses you can pursue to enter the profession. This may be entering as a trainee technician or after completing a biomedical science-related degree course.

## Learning aims

In this unit you will:

- A** Understand the principles of haematology and its use in medical diagnosis
- B** Examine the use of histology and cytology in medicine
- C** Examine the use of urinalysis as an analytical and diagnostic tool.

## Summary of unit

Learning aim	Key content areas	Recommended assessment approach
<p><b>A</b> Understand the principles of haematology and its use in medical diagnosis</p>	<p><b>A1</b> The components of blood  <b>A2</b> Changes to blood components and composition  <b>A3</b> Diagnostic techniques used in haematology</p>	<p>Practical work to investigate microscopically the components of blood and use of diagnostic techniques to identify disease. Observation records will be required.</p> <p>A report explaining blood component structure and function along with causes and consequences of dysfunction.</p> <p>Analysis of the use of diagnostic blood tests for different diseases.</p>
<p><b>B</b> Examine the use of histology and cytology in medicine</p>	<p><b>B1</b> Tissue investigation and consequences of diagnosis  <b>B2</b> Role of informatics and record keeping</p>	<p>A report/presentation on the implications for society, the health service and individual patients of using histology and cytology in detecting and diagnosing disease occurrence, including how information is used and communicated to key stakeholders.</p>
<p><b>C</b> Examine the use of urinalysis as an analytical and diagnostic tool</p>	<p><b>C1</b> Urine composition  <b>C2</b> Urinalysis</p>	<p>Practical work and a report on the use of urinalysis in diagnosing changes to health status.</p>

## Content

### Learning aim A: Understand the principles of haematology and its use in medical diagnosis

#### A1 The components of blood

Structure and function of the following blood components:

- erythrocytes
- leucocytes
- thrombocytes (platelets)
- plasma and serum.

#### A2 Changes to blood components and composition

The effects of diseases and disorders on the overall composition of blood, including the effects on the structure and function of key blood components:

- erythrocytic diseases associated with types of anaemia, thalassaemia, vitamin B12 and foliate deficiency, sickle cell anaemia
- leucocytes (white blood cell) diseases associated with lymphocytosis, AIDS, infectious mononucleosis
- bone marrow failure
- leukaemia
- lymphomas such as Hodgkin's, non-Hodgkin's diseases
- haemostasis and thrombosis, and their significance to the body
- hepatitis B and C
- syphilis
- HIV.

#### A3 Diagnostic techniques used in haematology

The principles behind haematological diagnostic techniques, including the practical application of these techniques as appropriate:

- counts of red blood cells and platelets
- mean corpuscular and blood volumes
- analysis for iron deficiency
- coagulation/clotting
- haemoglobin tests
- blood grouping (typing).

### Learning aim B: Examine the use of histology and cytology in medicine

#### B1 Tissue investigation and consequences of diagnosis

- Types and methods of sample removal, preservation and examination, including consideration of appearance of normal and abnormal results, methods of recording these and the implications of the results on patients, their families, the health service and society in general.
- Cell and tissue specimen analysis:
  - screening (bowel cancer)
  - aspirates (cerebrospinal fluid, amniocentesis)
  - surgical removal of tissues for disease identification (cervical, breast, prostate tissue)
  - allergic reactions tested by skin tests
  - tissue typing for bone marrow transplantation
  - purposes of specimens taken in autopsies to establish causes of death.

- Implications of disease diagnosis to individuals, the health service and society:
  - importance of correct and timely diagnosis and treatment
  - prognosis and quality of life for individuals and their families
  - financial implications of screening costs for early diagnosis as opposed to cost of treatment when disease is diagnosed later
  - confirmation of diseases likely to cause epidemics and resulting plans for prevention.

## **B2 Role of informatics and record keeping**

Consideration of how information regarding diagnostic tests is recorded, stored and disseminated:

- right information to right person at right time
- processing and reporting, correct results matched with correct sample
- medical records – accurate and complete
- confidentiality.

## **Learning aim C: Examine the use of urinalysis as an analytical and diagnostic tool**

### **C1 Urine composition**

Main constituents of urine, including their biochemical sources in the body and how these vary in relation to healthy renal function:

- water
- organic solutes, e.g. urea, hormones, carbohydrates
- inorganic ions, e.g. sodium, chloride and potassium.

### **C2 Urinalysis**

- Urine sampling to prevent misleading results in urinalysis:
  - why cleanliness of genitalia and sterility of collection vessels before sample collection is important
  - the purpose of mid-stream sample collection
  - why specific times of day for sample collection are sometimes recommended
  - length of time between sample collection and testing, and preservation methods of samples that will not be tested immediately.
- For each of the key indicators present in urine, the following must be considered:
  - normal ranges (as appropriate)
  - when each kind of test (visual, chemical or microscope) is considered appropriate
  - problems presented in result interpretation and steps to counter this, e.g. use of optical readers in digital pregnancy tests and automation of result reading
  - the mechanisms each analysis uses
  - health implications of changes in these levels, to include how and why the changes are brought about.
- Key indicators used in urinalysis:
  - visual – colour and clarity
  - chemical tests using test strips: specific gravity for determining concentration, pH, blood, protein, glucose, bilirubin, urobilinogen, ketones, nitrite, human chorionic gonadotropin (HCG)
  - under the microscope: crystalline structures, trichomonads, blood cells, micro-organisms, epithelial cells, casts.

## Assessment criteria

Pass	Merit	Distinction
<b>Learning aim A: Understand the principles of haematology and its use in medical diagnosis</b>		<b>A.D1</b> Evaluate the use of diagnostic testing of blood in relation to the detection of diseases.
<b>A.P1</b> Explain the structure and function of the main components of blood. <b>A.P2</b> Explain how diseases affect the composition of blood. <b>A.P3</b> Correctly carry out diagnostic testing of blood.	<b>A.M1</b> Discuss the basis of diagnostic tests for different diseases.	
<b>Learning aim B: Examine the use of histology and cytology in medicine</b>		<b>B.D2</b> Evaluate the implications of screening and early disease diagnosis for the individual and for the health service and society.
<b>B.P4</b> Explain the use of analytical investigation in disease screening. <b>B.P5</b> Explain the use of analytical investigations of tissue samples. <b>B.P6</b> Explain the use of informatics and data handling in biomedical science.	<b>B.M2</b> Analyse how the interpretation and informatics of diagnostic test results are used as a tool for planning appropriate treatment.	
<b>Learning aim C: Examine the use of urinalysis as an analytical and diagnostic tool</b>		<b>C.D3</b> Evaluate the use of urinalysis in domestic and clinical settings.
<b>C.P7</b> Explain how urine composition may vary in relation to health. <b>C.P8</b> Correctly carry out simple urinalysis.	<b>C.M3</b> Analyse how the results of urinalysis are used in diagnoses of health status changes.	

## Essential information for assignments

The recommended structure of assessment is shown in the unit summary along with suitable forms of evidence. *Section 6* gives information on setting assignments and there is further information on our website.

There is a maximum number of three summative assignments for this unit. The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.P2, A.P3, A.M1, A.D1)

Learning aim: B (B.P4, B.P5, B.P6, B.M2, B.D2)

Learning aim: C (C.P7, C.P8, C.M3, C.D3)

## Further information for teachers and assessors

### Resource requirements

For this unit, learners must have access to:

- a well-equipped laboratory
- research facilities.

### Essential information for assessment decisions

#### Learning aim A

**For distinction standard,** learners must clearly link the disease and blood composition, and make judgements about the appropriate selection, implementation and interpretation of diagnostic tests by medical workers. They will give a detailed consideration of the implications of misdiagnosis of disease, with the accurate use of appropriate scientific terminology throughout.

**For merit standard,** learners must consider how diagnostic testing of blood relates to accurate identification of two diseases. They must discuss changes to the composition of blood with reference to normal ranges in humans. Learners will make reference to required equipment and techniques used in each diagnostic test. They must give sustained lines of reasoning, free of fundamental errors.

**For pass standard,** learners must link the structure and function of each of the main components of blood. They must select two diseases associated with dysfunction or abnormality of blood components, and clearly state the cause of each disease and its effect on blood composition with reference to key indicators in blood composition. Observation records will be required to validate learners' practical work. At this level, learners must be able to follow instructions, work methodically and demonstrate awareness of good health and safety practice. Evidence of this should be identified in the write-up and records of the practical work produced by the learners should have a good level of accuracy in results/observations obtained.

#### Learning aim B

**For distinction standard,** learners must demonstrate an understanding of the value of screening for disease and how the early detection of disease can impact on prognosis and quality of life. They must evaluate the importance of early diagnosis leading to treatment and the implications of this, including a consideration of the associated emotional, economic and financial costs to the individual, the health service and society. Learners must demonstrate an understanding of the importance of accurately sampling and reporting diagnostic results, along with accurate medical records being available to the right people at the right time. It is expected that learners will access secondary data to support their conclusions about prevention and early treatment.

**For merit standard,** learners must provide a methodical and detailed examination of how the accuracy of testing and reporting of results to other health professionals is important in the treatment of the patient. They must consider how informatics are managed to ensure the prompt and accurate recording and dissemination of diagnostic test results. This will include an awareness of monitoring methods in automated sample analysis.

**For pass standard,** learners should consider the dual role of screening for disease and for detecting early signs of disease. They will describe different screening techniques and explain their role in early detection of disease. Learners should discuss the analysis of tissue samples removed surgically for examination in relation to how this can relate to the type of treatment that may be required. Learners must explain the use of informatics in biomedical science, including the management of data to maintain confidentiality while ensuring key personnel involved with the treatment of a patient have essential information in a timely and accessible format.

## Learning aim C

**For distinction standard,** learners must demonstrate their understanding and knowledge of the normal biochemical functioning of body systems. They will need to be able to access and quote data identifying normal ranges of values for substances present in urine samples. Learners must evaluate the role of the biomedical scientist in providing the data requested by other health professionals to ensure effective monitoring of the progression and treatment of a patient in at least three cases. Learners will need to explain the issues related to sample collection, preservation and analysis in domestic and clinical settings, including a consideration of the implications of inaccurate interpretation of results and how errors can be reduced.

**For merit standard,** learners must identify and discuss how screening compares test results indicating abnormal values with normal values when attempting a diagnosis for particular diseases. They will make reference to how changes in health status along with contamination when collecting or preserving urine samples can cause abnormal levels of substances in three or more cases.

**For pass standard,** learners will provide clear details about how normal biochemical values are maintained in the body in relation to urine production, and why these are among the first tests ordered when diagnosing and treating patients.

Learners will carry out simple urinalysis tests, accurately identifying the changes in three or more substances in samples of urine and suggesting what these changes indicate in relation to health. They must specify how the samples of urine should be obtained in order to prevent misleading results.

## Links to other units

This unit links to:

- Unit 1: Principles and Applications of Science I
- Unit 2: Practical Scientific Procedures and Techniques
- Unit 4: Laboratory Techniques and their Applications
- Unit 5: Principles and Applications of Science II
- Unit 8: Physiology of Human Body Systems
- Unit 10: Biological Molecules and Metabolic Pathways
- Unit 17: Microbiology and Microbiological Techniques.

## Employer involvement

Centres may involve employers in the delivery of this unit if there are local opportunities. Visiting speakers from health centres, the blood transfusion service, doctors' surgeries and pathology laboratories can give a valuable insight into their work.

All large hospitals have laboratories where blood products, cells and so on are dealt with. Since health and safety regulations may make it difficult to gain access, it is possibly best to approach the head of the medical services at a local hospital or the blood transfusion service to find out what access, speakers or other facilities are available to a centre teaching this unit.



# Unit 21: Medical Physics Applications

Level: **3**

Unit type: **Internal**

Guided learning hours: **60**

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## Unit in brief

This unit gives learners an understanding of the principles and production of ionising and non-ionising radiation, applications of medical physics, and their uses in the diagnosis and treatment of the human body.

## Unit introduction

In this unit, you will gain an understanding of the physics that underpins the production of ionising and non-ionising radiation. This understanding will enable you to focus on a number of medical applications of physics and its importance in the diagnosis and treatment of patients.

Surgery today is faster, less invasive and more effective than ever, thanks in part to improvements in medical imaging technology as a result of developments in medical physics. Imaging gives the doctor a clearer understanding of the patient's condition so treatment can be planned more effectively and therapy delivered more precisely.

You will investigate and gain an understanding of a number of technological advances that have resulted in the use of faster, less-invasive and more effective medical physics ionising and non-ionising radiation diagnosis and treatment technologies. You will also learn about health and safety, risks and the side effects of using ionising and non-ionising radiation.

The knowledge and understanding you will gain in this unit will support you as you consider applying for a role as a science technician or apprentice, particularly in physics or medical laboratory sciences. It can also support you in your progression to higher education in areas such as medical laboratory sciences, biomedical sciences or applied biology.

## Learning aims

In this unit you will:

- A** Explore the principles, production, uses and benefits of non-ionising instrumentation techniques in medical applications
- B** Explore the principles, production, uses and benefits of ionising instrumentation techniques in medical applications
- C** Understand health and safety, associated risks, side effects and limitations of ionising and non-ionising instrumentation techniques in medical applications.

## Summary of unit

Learning aim	Key content areas	Recommended assessment approach
<b>A</b> Explore the principles, production, uses and benefits of non-ionising instrumentation techniques in medical applications	<b>A1</b> Magnetic resonance imaging (MRI) <b>A2</b> Lasers <b>A3</b> Infrared thermography (IRT) <b>A4</b> Ultrasound	<p>A research report showing the different types of non-ionising and ionising radiation techniques.</p> <p>Learners could produce visual presentations for the underlying principles and production. They could produce tables and use case studies for comparisons in justifying techniques used for diagnosis and treatment.</p>
<b>B</b> Explore the principles, production, uses and benefits of ionising instrumentation techniques in medical applications	<b>B1</b> X-rays <b>B2</b> Computerised tomography (CT) or computerised axial tomography (CAT) <b>B3</b> Gamma ray imaging <b>B4</b> Radiotherapy, Gamma Knife surgery and proton beam therapy	<p>A report showing the health and safety and risk implications for operators and patients with the use of case studies, and reference to legislative requirements and associated articles.</p> <p>Information from visits or visiting speakers.</p>
<b>C</b> Understand health and safety, associated risks, side effects and limitations of ionising and non-ionising instrumentation techniques in medical applications	<b>C1</b> Safety precautions, side effects and risks for operators and patients of ionising radiation <b>C2</b> Safety precautions, side effects and risks for operators and patients of non-ionising radiation	<p>A report showing the health and safety and risk implications for operators and patients with the use of case studies, and reference to legislative requirements and associated articles.</p> <p>Information from visits or visiting speakers.</p>

## Content

### Learning aim A: Explore the principles, production, uses and benefits of non-ionising instrumentation techniques in medical applications

#### A1 Magnetic resonance imaging (MRI)

- Uses radiofrequency waves and strong magnets to produce detailed images of soft tissues in the body.
- Instrumentation/production: main, circular, strong, permanent, superconducting magnet cooled by liquid helium; MRI scanner coils; sliding platform; radio frequency waves input; output signal receiver linked to a powerful computer.
- Magnetic resonance imaging principles from radio frequency input to output of high-resolution images (from protons in different environments), analysed by a radiologist.
- Diagnostic uses: brain and spine, joints, blood vessels, heart conditions, abnormal body water conditions.
- Benefits: non-contact, non-invasive, painless.

#### A2 Lasers

- Light of specific wavelength passes through a gain medium, which amplifies light with higher energy by stimulated emission.
- Reflectors send the light backwards and forwards in the gain medium until it has gained enough energy.
- High-energy amplified light emitted as a narrow beam or is spread out, depending on application, through a laser oscillator.
- Main types of medical lasers used for different procedures – carbon dioxide, argon, yttrium aluminium garnet (YAG), pulsed dye.
- Treatment, diagnosis and therapy uses, e.g. eye surgery, removal of kidney stones, removal of tumours.
- Benefits: can focus on a small area and damage less tissue surrounding the area to be treated; less pain, swelling and scarring than using traditional surgery.

#### A3 Infrared thermography (IRT)

- An infrared thermographic camera produces thermal images (thermograms) that show areas of abnormal body temperature, 'hot spots' on the skin that result from higher blood flow due to tumours.
- Uses, e.g. in screening programmes, cardiovascular/circulatory disorders, respiratory problems, dentistry.
- Benefits: fast, passive, non-contact and non-invasive, maps body surface temperature remotely.

#### A4 Ultrasound

- Used by radiologists and sonographers.
- Instrumentation – earthed case, coaxial cable, absorber, crystal and plastic cover, monitor screen.
- Pulses of ultrasound transmitted from the probe in the transducer into the body and reflected back.
- The density characteristics of the different structures inside the body are displayed as an image.
- Medical ultrasound usually 2 megahertz (MHz) and higher-frequency ultrasound.
- Types:
  - external ultrasound scan, e.g. screening of fetus
  - internal ultrasound scan – produces images of organs in more detail
  - endoscopic ultrasound – long, thin flexible tube (endoscope) inserted into the body through mouth to examine stomach, gullet or lymph nodes in chest.
- Treatment uses – kidney stones, benign and malignant tumours.
- Diagnosis uses – narrowing of blood vessels, strokes and heart attacks; echocardiogram to measure blood flow rates.

## **Learning aim B: Explore the principles, production, uses and benefits of ionising instrumentation techniques in medical applications**

### **B1 X-rays**

- High-frequency rays, ionising radiation waves pass through soft body tissue, absorbed by dense bones.
- Produces image on a photographic plate placed behind the required part of the body, image is processed by a computer.
- Image analysed by radiologist.
- Where x-rays are absorbed, e.g. by bones, they appear white; other areas are dark on the photographic film.
- X-ray imaging principles and production:
  - heated cathode filament produces negatively charged electrons
  - electrons accelerate to a positively charged tungsten anode, where some of their kinetic energy is transformed into x-rays.
- Treatment and diagnosis uses – cancers and breaks in bones, pneumonia, tuberculosis, screening for breast cancer, mammograms.

### **B2 Computerised tomography (CT) or computerised axial tomography (CAT)**

- A series of x-rays create detailed images, called tomograms, of the inside of the body, layer by layer.
- Image examined by radiologist.
- CT scan is created by an x-ray tube that rotates around the body: the body is inside a tunnel and is moved continuously through a rotating beam of x-rays, a detector is on the opposite side of the body.
- Diagnosis and monitoring uses – brain tumours, certain bone conditions, injuries to internal organs such as the kidneys, liver and spleen, and the heart.

### **B3 Gamma ray imaging**

- Principles include:
  - a short-lived, positron-emitting (positive electron  $e^+$ ) radioactive tracer (radionuclide) with a short half-life, e.g. iodine-123 ( $^{123}\text{I}$ ), technetium-99 ( $^{99}\text{Tc}$ ), is injected into the body
  - emitted positrons combine with nearby electrons ( $e^-$ ) to produce gamma rays
  - gamma ray emissions from the cancerous area produce an image for diagnosis
  - the body is inside a ring of detectors to give a signal, which is used by the computer to produce a three-dimensional functional image of inside the body given off by a radiotracer.
- Uses of positron emission tomography (PET) – imaging scans for diagnosis of cancer, detection of recurrent tumours.
- Benefits – high-energy, penetrating power.

### **B4 Radiotherapy, Gamma Knife surgery and proton beam therapy**

- Radiotherapy – gamma rays externally or internally inside the body:
  - external beam radiotherapy uses linear accelerator, focuses high-energy gamma ray beams onto the area requiring treatment
  - a series of daily treatments over a number of days or weeks
  - uses – to treat cancerous tumours.
- Gamma Knife surgery:
  - a highly accurate therapeutic dose of gamma radiation for brain tumours
  - dose volume controlled for treatment required.

- Proton beam therapy:
  - an accelerator (synchrotron) accelerates charged protons accurately in a 3D pattern, giving greater control and precision and causing less damage to healthy cells
  - Bragg peak internal radiotherapy
  - cancerous cells lose ability to repair, divide and proliferate causing cellular death
  - uses – to treat cancerous and benign (non-cancerous) tumours, thyroid disease and some blood disorders
  - benefits – non-invasive and painless, less damage to healthy tissues.

### **Learning aim C: Understand health and safety, associated risks, side effects and limitations of ionising and non-ionising instrumentation techniques in medical applications**

#### **C1 Safety precautions, side effects and risks for operators and patients of non-ionising radiation**

- Safe operating procedures for possible effects on patients and staff operators.
- Health and Safety Executive (HSE) – legislative requirements.
- Ultrasound:
  - internal ultrasound scanner, placed into the vagina or rectum, can cause discomfort
  - endoscopic ultrasound: long, thin flexible tube (endoscope) inserted into the body through the mouth can cause discomfort – patients are usually given painkillers and a sedative
  - for some scans, patients need to drink and retain lots of water to fill their bladder, or avoid eating for several hours.
- Lasers – treatment may not be permanent, use of protective clothing laser safety goggles is necessary, exposure limits necessary, use of film badges required.
- MRI – quite noisy, can be claustrophobic in tunnel, safety related to use of powerful magnets, e.g. removal of all ferromagnetic materials, implants and foreign bodies.

#### **C2 Safety precautions, side effects and risks for operators and patients of ionising radiation**

- Safe operating procedures for possible effects on patients and staff operators.
- HSE – legislative requirements associated with using radiation in diagnosis, treatment and therapy.
- X-rays, CT, radiotherapy, proton beam therapy and gamma rays have high-energy penetrating power of ionising radiation, Ionising Radiation (Medical Exposure) Regulations 2000:
  - safe operating procedures for ionising radiation applications and possible effects on patients and staff operators
  - occupational risk and exposure to high levels of radiation (100 mSv or more)
  - patient dose limits required
  - typical levels of exposure during medical tests in milliseverts (mSv), such as single chest x-ray (0.014 mSv); mammogram (0.4 mSv); CT scan to whole spine (10 mSv)
  - use of protective clothing and film badges required.
- Ionising radiation can damage healthy cells and cause cancer.
- CT scanning can be claustrophobic in the tunnel.
- Possible radiotherapy side effects – tiredness, hair loss, loss of appetite, diarrhoea, sore skin.
- Gamma Knife surgery – can cause discomfort in head control device, has fewer side effects than radiotherapy.
- Proton beam therapy has fewer harmful side effects.

## Assessment criteria

Pass	Merit	Distinction
<b>Learning aim A: Explore the principles, production, uses and benefits of non-ionising instrumentation techniques in medical applications</b>		
<b>A.P1</b> Explain how the principles and production of non-ionising radiation technologies are used in medical applications.  <b>A.P2</b> Explain why non-ionising radiation technologies are used for diagnosis and treatment of the human body.	<b>A.M1</b> Compare the principles, production and uses of different non-ionising radiation techniques in medical applications.	
<b>Learning aim B: Explore the principles, production, uses and benefits of ionising instrumentation techniques in medical applications</b>		
<b>B.P3</b> Explain how the principles and production of ionising radiation technologies are used in medical applications.  <b>B.P4</b> Explain why ionising radiation technologies are used for diagnosis and treatment of the human body.	<b>B.M2</b> Compare the principles, production and uses of different ionising radiation techniques in medical applications.	
<b>Learning aim C: Understand health and safety, associated risks, side effects and limitations of ionising and non-ionising instrumentation techniques in medical applications</b>		<b>C.D2</b> Discuss the consequences of poor health and safety when using non-ionising and ionising radiation technologies and the prevention and safety measures employed.
<b>C.P5</b> Explain the health and safety risks, side effects and limitations of non-ionising and ionising radiation technologies.  <b>C.P6</b> Explain how hospitals can employ health and safety measures, when using instrumentation, for the protection of operators and patients.	<b>C.M3</b> Compare the health and safety risks, side effects and limitations of non-ionising and ionising radiation technologies in medical applications to maximise the protection of operators and patients.	

## Essential information for assignments

The recommended structure of assessment is shown in the unit summary along with suitable forms of evidence. *Section 6* gives information on setting assignments and there is further information on our website.

There is a maximum number of two summative assignments for this unit. The relationship of the learning aims and criteria is:

Learning aims: A and B (A.P1, A.P2, B.P3, B.P4, A.M1, B.M2, AB.D1)

Learning aim: C (C.P5, C.P6, C.M3, C.D2)

## Further information for teachers and assessors

### Resource requirements

For this unit, learners must have access to appropriate library/learning resource centre physics/medical science books and access to the internet.

### Essential information for assessment decisions

#### Learning aims A and B

**For distinction standard,** learners will give valid reasons for the justification of non-ionising and ionising radiation techniques for diagnosis and treatment purposes. They will do this using a number of scenarios of different medical cases that require diagnosis, treatment or screening, and they will rationalise their selection of the combination of non-ionising and ionising radiation techniques. Learners will consider patient choice and consent when considering the use of radiation therapy/techniques.

**For merit standard,** learners will effectively apply their understanding of the principles and production of at least two non-ionising (i.e. MRI, lasers, IRT or ultrasound) and at least two ionising (i.e. x-rays, CT/CAT, gamma ray imaging, radiotherapy, Gamma Knife surgery and proton beam therapy) radiation technologies. They will succinctly compare the benefits and limitations of using these in the treatment and diagnosis of patients in a medical setting.

**For pass standard,** learners will produce valid labelled diagrams/flow charts showing the principles and production of at least two non-ionising (i.e. MRI, lasers, IRT or ultrasound) and at least two ionising (i.e. x-rays, CT/CAT, gamma ray imaging, radiotherapy, Gamma Knife surgery and proton beam therapy) radiation technologies. They will use their understanding of the production and principles of non-ionising and ionising technologies to give reasons why these techniques are used for diagnosis and treatment.

#### Learning aim C

**For distinction standard,** learners will put forward valid and effective reasons why precautions and measures are taken to protect patients and operators, and any consequences of not safeguarding patients and operators. They will coherently substantiate implications and health and safety measures, with underpinning scientific knowledge and an understanding of the relevant legislation and the role of the HSE.

**For merit standard,** learners will effectively apply their knowledge of health and safety risks, side effects and limitations in order to make a valid comparison of the different technologies for both patients and operators in a medical setting. Learners will differentiate and order the level of health and safety risks according to the types of radiation technologies used, and compare the impact this could have on patients and operators.

**For pass standard,** learners will use their understanding of health and safety risks, side effects and limitations across a range of ionising and non-ionising radiation technologies, in order to give a thorough explanation in a medical setting. Learners will refer to appropriate health and safety measures in place to help protect both patients and operators in a medical setting by referring to the relevant legislation and the HSE.

### Links to other units

This unit links to *Unit 1: Principles and Applications of Science I*.

### Employer involvement

Centres may involve employers in the delivery of this unit if there are local opportunities, such as radiologists, oncologists and radiography technicians.



# Unit 22: Materials Science

Level: **3**

Unit type: **Internal**

Guided learning hours: **60**

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## Unit in brief

Learners cover the understanding required to classify a range of different materials, as well as their applications, benefits and limitations.

## Unit introduction

Materials scientists are constantly researching new materials to replace traditional ones to bring advances in new technologies, such as graphene and new composites used in display screens, electric circuits and solar cells. Scientists are constantly searching for new materials to replace traditional materials that are no longer sustainable in terms of their availability and cost, and for new materials that bring advances in new technologies. In this unit, you will gain an understanding of different types of new and traditional materials and their applications.

You will investigate how materials can be grouped into a number of main classifications and their different microscopic and macroscopic properties. A number of new, exciting developments are being made, such as in nanotechnology, where the properties of the materials at the microscopic level are not always the same as at the macroscopic level. You will also investigate polymers, and their properties, benefits, disadvantages and risks to the environment, and you will examine materials that are being used in everyday applications to reduce global warming and carbon dioxide emissions for a sustainable future.

This unit will support you in gaining access to higher education to study the biological, chemical or physical sciences, or gain employment as a science technician or apprentice.

## Learning aims

In this unit you will:

- A** Understand the classification and properties of different materials
- B** Examine the uses, benefits and limitations of developing nanotechnology materials
- C** Investigate the benefits and limitations of polymer technology
- D** Examine materials used in applications in order to reduce carbon emissions for a sustainable future.

## Summary of unit

Learning aim	Key content areas	Recommended assessment approach
<b>A</b> Understand the classification and properties of different materials	<b>A1</b> Classification of materials <b>A2</b> Macroscopic properties <b>A3</b> Microscopic structure	<p>An investigative report showing the different types of materials.</p> <p>Learners could then produce a classification visual presentation using microscopic and macroscopic pictures, diagrams and data for the different materials and their properties.</p>
<b>B</b> Examine the uses, benefits and limitations of developing nanotechnology materials	<b>B1</b> Defining nanotechnology <b>B2</b> Uses of nanotechnology <b>B3</b> Benefits of nanotechnology <b>B4</b> Environmental impact and health and safety risks of nanotechnology materials	<p>Learners could produce a report based on case studies, internet searches and class discussions about the benefits and risks of nanotechnology materials.</p>
<b>C</b> Investigate the benefits and limitations of polymer technology	<b>C1</b> Polymers and their sources <b>C2</b> Benefits of polymers <b>C3</b> Limitations and environmental risks of polymers	<p>A research report showing the different types of polymers, benefits and risks to the environment.</p>
<b>D</b> Examine materials used in applications in order to reduce carbon emissions for a sustainable future	<b>D1</b> Wind turbine blades <b>D2</b> Solar photovoltaic cells <b>D3</b> Light-emitting diodes (LEDs) <b>D4</b> Fuel cells	<p>Learners could research sources of information and compose a portfolio of case studies with reference to examples of everyday uses.</p>

## Content

### Learning aim A: Understand the classification and properties of different materials

#### A1 Classification of materials

- Metals and alloys – ferrous and non-ferrous metals and alloys; iron and steels; noble metals (copper, silver and gold and their alloys); aluminium; rare earth metals.
- Glass – soda-lime-silica glass, sodium borosilicate glass, aluminosilicate glass, oxide glass, toughened glass; glass can be coloured by adding metallic salts.
- Polymers (plastics) – thermosetting plastics (urea formaldehyde, Bakelite, polyurethane), thermoplastics (polythene, nylon, polyvinyl chloride, polystyrene, Teflon, thermoplastic resins).
- Ceramics – structural, refractories, white wares, special, fine ceramics.
- Carbon – diamond, graphite, graphene, carbon fibres.
- Composites – reinforced plastics, carbon and glass fibre composites, carbon fibre-reinforced composites, metal composites, ceramic composites, sandwich structures, concrete composites.

#### A2 Macroscopic properties

- Melting point, boiling point.
- Strength, toughness, malleability.
- Electrical conductivity, thermal conductivity.
- Density.
- Biodegradability.

#### A3 Microscopic structure

- Atomic structure, bonding.
- Additives such as cross-linking agents, plasticisers.
- Reinforcing fibres/particles.

### Learning aim B: Examine the uses, benefits and limitations of developing nanotechnology materials

#### B1 Defining nanotechnology

- Nanoscale – 1 to 100 nanometers, 1 nanometer is  $1 \times 10^{-9}$  of a meter.
- Use of scanning tunnelling microscope (STM) and atomic force microscope (AFM).
- Manipulation and control of matter on a near-atomic size (including atoms and molecules).
- Movement of individual atoms.
- Nanotechnology materials at this size can have unique different chemical, biological and physical properties compared with their larger counterparts at the macroscopic level.
- Researching, developing and utilising these properties is at the heart of nanotechnology.
- Types of nanoparticles defined by shape, to include nanotubes, nanowires, nanofilms, nanotunnels, nanoplates.

#### B2 Uses of nanotechnology

- Computing and instrumentation – nanoscale transistors, nanosensors, nanoelectronics.
- Energy – nano-solar panel films.
- Nanosolar cells nanomedicine – drug delivery, biomedical instrumentation.
- Chemotherapy nanoengineering – nanorobotics, nanoelectronics.
- Nanomachines and nanochemistry – nanosunscreens, nanocatalysts, nanocarbon tubes, graphene, nanospheres.

**B3 Benefits of nanotechnology**

Improved biological, chemical and physical properties of materials, to include:

- higher strength
- lighter weight
- greater chemical reactivity
- scratch resistance
- improved catalysis
- improved electrical conductivity
- antibacterial coatings.

**B4 Environmental impact and health and safety risks of nanotechnology materials**

- Environmental impact – nanoparticles from transport exhaust fumes and respiratory system, effects on marine life.
- Health and safety risks – safe handling risks to employees, exposure levels, high toxicity.

**Learning aim C: Investigate the benefits and limitations of polymer technology****C1 Polymers and their sources**

- Terminology – natural and synthetic, thermosetting and thermoplastics, polymerisation, monomer, polymer and co-polymer, polymer composites, elasticity and plasticity.
- Sources of starting materials – petroleum oil, sugars, corn starch, cellulose, hydroxycarboxylic acids.
- Additives to improve properties – fillers, plasticisers, cross-linking agents, impact modifiers, antioxidants, stabilisers and decolourants.

**C2 Benefits of polymers**

- Improved properties compared with some conventional materials – low thermal and electrical conductivity, lightweight and easy to handle, durable and resistant to corrosion, easy to shape during manufacture, good electrical and thermal insulating properties, strong and flexible, new biodegradable plastics.
- Uses of polymers – construction, transport, electronics and computing, sport and leisure, packaging, domestic household uses.

**C3 Limitations and environmental risks of polymers**

- Limitations – some have low strength, can be toxic and flammable, UV light sensitive, fatigue sensitivity, most are not biodegradable.
- Environmental impact – most are not biodegradable in the short term, risks to marine welfare, some plastics cannot be recycled, high toxicity.

**Learning aim D: Examine materials used in applications in order to reduce carbon emissions for a sustainable future****D1 Wind turbine blades**

- Materials used – glass fibre composites, aluminium.
- Key useful properties of materials used – high strength and stiffness, low density, durable corrosion resistant.
- Limitations of materials used – low fatigue resistance.
- Benefits of use of wind turbines.

**D2 Solar photovoltaic cells**

- Materials, e.g. silicon wafer, cadmium telluride (CdTe).
- Key useful properties of materials used – CdTe responds well to light in the solar spectrum.
- Benefits and limitations of materials used – CdTe is environmentally unfriendly, silicon is readily available, tellurium is a very rare element and therefore costly.
- Benefits of solar photovoltaic cells.

**D3 Light-emitting diodes (LEDs)**

- Materials, e.g. gallium arsenide (GaAs), gallium nitride.
- Useful microscopic and macroscopic properties of materials used, e.g. electrons can travel very quickly, good conductor of thermal energy.
- Benefits and limitations of materials used – GaAs may be carcinogenic, gallium is expensive to extract.
- Applications – lighting, infrared beams.

**D4 Fuel cells**

- Materials – polymers for electrolyte membranes and ceramic-based electrolytes.
- Useful properties of materials used – decomposes water into hydrogen and oxygen more readily than many other materials.
- Benefits and limitations of materials used – easily obtained, are not environmentally friendly (disposal issues).

## Assessment criteria

Pass	Merit	Distinction
<b>Learning aim A: Understand the classification and properties of different materials</b>		<b>A.D1</b> Analyse the microscopic and macroscopic structure of different given materials and classify them into groups according to their properties.
<b>A.P1</b> Determine the classification of given materials by considering their properties.	<b>A.M1</b> Compare the microscopic structures and classifications of different given materials to determine their macroscopic properties.	
<b>Learning aim B: Examine the uses, benefits and limitations of developing nanotechnology materials</b>		<b>B.D2</b> Evaluate the uses, benefits, environmental impact and health and safety risks of using nanotechnology materials for given applications.
<b>B.P2</b> Explain what is meant by a nanotechnology material.	<b>B.M2</b> Discuss the uses, benefits and health and safety risks of nanotechnology materials.	
<b>B.P3</b> Explain the uses and benefits of nanotechnology materials.		
<b>Learning aim C: Investigate the benefits and limitations of polymer technology</b>		<b>C.D3</b> Evaluate the methods of testing, the uses, benefits, limitations and environmental risks of different types of polymers for given applications.
<b>C.P4</b> Explain the uses, benefits and limitations of polymers.	<b>C.M3</b> Justify the use of additives and the methods used for testing the suitability of different types of polymers for given applications.	
<b>C.P5</b> Explain the benefits of using additives to modify the properties of plastics.		
<b>Learning aim D: Examine materials used in applications in order to reduce carbon emissions for a sustainable future</b>		<b>D.D4</b> Evaluate the benefits and limitations of using the materials in order to reduce carbon emissions.
<b>D.P6</b> Explain how materials can be used to reduce global emissions.	<b>D.M4</b> Compare methods used to reduce carbon emissions for materials used in given applications.	

## Essential information for assignments

The recommended structure of assessment is shown in the unit summary along with suitable forms of evidence. *Section 6* gives information on setting assignments and there is further information on our website.

There is a maximum number of four summative assignments for this unit. The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.M1, A.D1)

Learning aim: B (B.P2, B.P3, B.M2, B.D2)

Learning aim: C (C.P4, C.P5, C.M3, C.D3)

Learning aim: D (D.P6, D.M4, D.D4)

## Further information for teachers and assessors

### Resource requirements

For this unit, learners should have access to books, magazines, journals and the internet.

### Essential information for assessment decisions

#### Learning aim A

**For distinction standard,** learners will examine and interpret the atomic structure and bonding of two different unknown materials that they have been given to determine their behaviour and properties at the macroscopic level, and classify them into their different classification groups.

**For merit standard,** learners will explain how the microscopic structure of two different known materials determine their properties at the macroscopic level, which allows them to be classified into their different groups. Learners could be given a metal, a polymer or a form of carbon metals and polymers as examples and how their microscopic properties determine how good they are at conducting electricity.

**For pass standard,** learners will be provided with at least three materials and will examine their macroscopic physical properties to draw conclusions and classify them into an appropriate group.

#### Learning aim B

**For distinction standard,** learners will draw valid conclusions from the evidence of the health and safety risks, environmental impact and benefits of using nanotechnology materials and draw conclusions.

**For merit standard,** learners will provide relevant aspects of the uses, benefits and risks of using nanotechnology materials to employees, the public and the environment.

**For pass standard,** learners must define what is meant by a nanotechnology material by its size and type and that its properties may be different at the microscopic and macroscopic levels. They will explain the uses and benefits of at least two different nanotechnology materials.

#### Learning aim C

**For distinction standard,** learners will draw valid conclusions from the evidence of environmental risks, limitations and benefits of using different types of polymers.

**For merit standard,** learners will need to provide evidence and give valid reasons to justify the benefits of using polymers in at least three different applications, relating their molecular structure and any additives used to improve their properties.

**For pass standard,** learners will investigate at least three types of polymers and their properties using the correct terminology to provide appropriate evidence and reasons for their suitability and limitations. Learners must explain the benefits of using at least three different types of additive and how they modify the properties of the polymers, such as the use of cross-linking agents to increase strength.

#### Learning aim D

**For distinction standard,** learners will need to provide appropriate evidence and review the benefits and limitations to draw conclusions of using at least three different materials used in given applications to reduce carbon emissions.

**For merit standard,** learners will need to identify the main factors and explain why the different methods are used to reduce carbon emissions for at least three different materials used in given applications.

**For pass standard,** learners will investigate and provide appropriate information about the functions and suitability of at least three different materials used in given applications to reduce carbon emissions.



**Links to other units**

This unit links to *Unit 5: Principles and Applications of Science II*.

**Employer involvement**

Centres may involve employers in the delivery of this unit if there are local opportunities to do so. Visits from rubber/composite manufacturers or sports equipment/clothing manufacturers, for example would be advantageous.



# Unit 23: Forensic Evidence, Collection and Analysis

Level: **3**

Unit type: **Internal**

Guided learning hours: **60**

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## Unit in brief

This unit covers techniques used in the collection, analysis and reporting of biological, chemical and physical evidence during forensic investigations.

## Unit introduction

Forensic science is any science used for the purposes of the law. Gathering information from the past and examining it to construct a sequence of events that may be presented in a court of law. In this unit, you will develop an understanding of the importance of health and safety, and the need for objectivity and justification in your approach to the identification, collection and analysis of forensic evidence. You will take part in a simulated crime scene investigation and be expected to demonstrate appropriate forensic techniques to process the scene, collecting biological, chemical and physical evidence. You will be required to document and package all evidence to provide a chain of continuity.

A forensic scientist is not routinely present at a crime scene; they generally receive evidence in a laboratory for analysis. Evidence will be sent to specialist laboratories depending on the area of analysis needed. Forensic scientists use biological analysis such as blood grouping of blood swabs, microscopy of hairs and fibres, and DNA testing of bodily fluids. The use of chemical analysis may involve documents to enhance latent fingerprints or presumptive tests to test for firearms residue, for example. Finally, physical analysis may comprise of analysing documents to determine handwriting patterns or comparing footwear impressions. In this unit, you will develop scientific, analytical thinking through the use of biological, chemical and physical concepts and evidence in order to prove or disprove theories, develop a chronology and provide scientific justification for analysis and conclusions drawn from investigations. This requires you to practically explore the principles of science that form the basis of some of the analytical techniques commonly used, as well as to carry out analysis using specialised equipment.

This unit outlines the practical approach to forensic investigation, allowing you to develop appropriate knowledge and skills. You will explore a variety of evidentiary principles, from collecting the evidence, through the analysis and, finally, to the presentation of your results in a variety of formats for use in the criminal justice system (CJS). A forensic scientist must also be able to present the results of their examination of evidence using a variety of methods – written, verbal and visual – and you will be given the opportunity to make your own presentations in an appropriate manner. This unit also provides an opportunity to learn more about some topical issues, such as advancement in forensic technology and professional certification following training. The range of procedures and concepts introduced in this unit will equip you to progress onto Bachelor of Science (BSc) courses in a variety of universities within the United Kingdom.

## Learning aims

In this unit you will:

- A** Understand how to gather forensic evidence, the integrity to forensic investigation and the importance of health and safety
- B** Investigate a simulated crime scene using forensic procedures
- C** Conduct scientific analysis of physical, biological and chemical evidence
- D** Be able to justify methods, interpret findings and report on conclusions of forensic techniques and analysis.

## Summary of unit

Learning aim	Key content areas	Recommended assessment approach
<b>A</b> Understand how to gather forensic evidence, the integrity to forensic investigation and the importance of health and safety	<b>A1</b> At the crime scene <b>A2</b> Preservation and recovery of evidence <b>A3</b> Search patterns <b>A4</b> Health and safety	A written report that demonstrates understanding of how to gather forensic evidence. The report should display a high level of presentation.
<b>B</b> Investigate a simulated crime scene using forensic procedures	<b>B1</b> Collection of biological evidence <b>B2</b> Collection of chemical evidence <b>B3</b> Collection of physical evidence <b>B4</b> Other important investigative considerations	Process a simulated crime scene. Learners should be given a simulated crime scene with a forensic scenario. They should preserve the scene and process the scene, documenting their practical work. They should include photographs of their evidence. Supported with an observation document, completed by the assessor.
<b>C</b> Conduct scientific analysis of physical, biological and chemical evidence	<b>C1</b> Biological evidence techniques <b>C2</b> Chemical evidence techniques <b>C3</b> Physical evidence techniques <b>C4</b> Other areas of forensic science	A portfolio of laboratory examination forms that includes drawings and photographs where appropriate, method sheets and results of analysis carried out. Supported with an observation document, completed by the assessor. A report explaining the scientific techniques and the conclusions drawn from analysis.
<b>D</b> Be able to justify methods, interpret findings and report on conclusions of forensic techniques and analysis	<b>D1</b> Interpretation of evidence <b>D2</b> Presentation of evidence <b>D3</b> Provision of forensic science service in England and Wales	An appropriately structured expert witness statement that includes conclusions, explanations and aspects of probability.

## Content

### Learning aim A: Understand how to gather forensic evidence, the integrity to forensic investigation and the importance of health and safety

#### A1 At the crime scene

- Scientific support at the crime scene – role of scenes of crime officers (SOCOs)/crime scene investigators (CSI).
- Structure of Scientific Support Units (SSU).
- Authorised personnel at the scene: first attending officer (FAO), (SOCO)/(CSI), crime scene manager, police officers, paramedics, fire and rescue service officers, forensic scientists.
- Who: victim, perpetrator, witnesses.
- When: timeline.
- Where.
- What: motive, modus operandi.

#### A2 Preservation and recovery of evidence

- Restriction of the scene and restriction of access.
- Observation and recording of the scene, identifying and targeting evidence.
- Documenting and recovering trace materials:
  - scene of crime documentation, e.g. crime scene notes, sketches and photographs, evidence labels, cordon log
  - case file
  - laboratory examination forms.
- Characterisation and comparison.
- Marks and impressions.
- Prevention of contamination.
- Methods of collection, e.g. casting, swabbing, hand picking, taping, shaking, brushing and vacuuming.
- Packaging and labelling, to include paper bag versus plastic bag, and knife tubes.
- Storage and transport of a variety of materials while preserving the integrity of the evidence.
- Continuity of evidence.
- Route of evidence: SOCO, SSU, forensic laboratory, court.

#### A3 Search patterns

- Quadrant.
- Lane.
- Grid.
- Spiral.
- Wheel.

#### A4 Health and safety

- Current regulations relating to:
  - Health and safety at work (COSHH).
  - Control of substances hazardous to health.
  - Management of health and safety at work.
- Use of disposable personal protective equipment (PPE).

**Learning aim B: Investigate a simulated crime scene using forensic procedures****B1 Collection of biological evidence**

- Blood, hair and fibres (human and animal), saliva, semen, bones, fingerprints.
- Types of evidence that will allow a perpetrator to be individualised.

**B2 Collection of chemical evidence**

- Drugs: Class A, B and C.
- Poisons: anions, corrosive poisons, gaseous and volatile poisons, metal and metalloid poisons, pesticides and toxins, accelerants.
- Firearm discharge residue (FDR).

**B3 Collection of physical evidence**

- Footprints: two dimensional and three dimensional.
- Tool marks: three dimensional.
- Firearms: handguns, rifles, shotguns.
- Bullets and cartridges.
- Documents: handwritten documents and printed documents.
- IT: mobile phones, computers, tablets and CCTV.

**B4 Other important investigative considerations**

- Prevention of contamination.
- Security.
- Records.
- Full documentation of procedures and methods.

**Learning aim C: Conduct scientific analysis of physical, biological and chemical evidence****C1 Biological evidence techniques**

- Blood group analysis.
- Genetics (DNA sequencing, genetic fingerprints).
- Fingerprints (four basic patterns, minutiae and ridge counting).
- Hair and fibre identification and analysis – microscopy.
- Bone and skeletal physiology.

**C2 Chemical evidence techniques**

- Instrumental analysis – visual examination, presumptive tests TLC, immunoassay GC-MS, UV and IR spectroscopy.
- Chromatography – separation of mixtures, e.g. paper, column, thin-layer chromatography (TLC), gas chromatography (GC), high-performance liquid chromatography (HPLC).
- Spectrometry– instrumental techniques, mass spectrometry, infrared, ultraviolet, colorimetry.
- Chemical presumptive tests – bodily fluids (blood, semen, saliva), poisons, modified Griess test, dermal nitrate test, sodium rhodizonate test.
- Chemical enhancement – fingerprints (ninhydrin, silver nitrate, iodine, amido black, and cyanoacrylate fuming).
- Toxicology – science of poisons (anions, corrosive poisons, gaseous and volatile poisons, metal and metalloid poisons, pesticides, toxins and drugs of abuse).
- Specimen collection (ante- and post-mortem).

### **C3 Physical evidence techniques**

- Ballistics – rifling, ballistic fingerprinting, propellants, microstamping, calibre wound patterns; trajectory.
- Footwear – oblique lighting, casting, electrostatic lifting, gel lifting, visual analysis and comparison.
- Tool marks – casting, comparison microscopy.
- Documents – handwriting (cursive, printing and signatures); printed documents (typewriters, photocopiers, laser printers, ink jet printers); paper; ink.
- IT, to include mobile phones, computers, tablets and CCTV.

### **C4 Other areas of forensic science**

- Entomologist.
- Forensic anthropologist.
- Forensic profiler.
- Palynologist.

## **Learning aim D: Be able to justify methods, interpret findings and report on conclusions of forensic techniques and analysis**

### **D1 Interpretation of evidence**

- Draw rational and balanced conclusions from observations of circumstances of the crime scene.
- Test results and measurements, including appropriate units.
- Probability of validity.
- Reconstruction of events.

### **D2 Presentation of evidence**

- Court case preparation and verbal presentation of evidence.
- Expert witness statement (written).
- Expert opinion (verbal).

### **D3 Provision of forensic science service in England and Wales**

- Forensic Science Society (FSS) archives.
- Forensic science accreditation: United Kingdom Accreditation Service (UKAS), Council for the Registration of Forensic Practitioners (CRFP).



## Assessment criteria

Pass	Merit	Distinction
<b>Learning aim A: Understand how to gather forensic evidence, the integrity to forensic investigation and the importance of health and safety</b>		<b>A.D1</b> Discuss the importance of documentation methods to forensic investigation and analyse each personnel used to gather evidence in relation to health and safety and to preserve the integrity of evidence.
<b>A.P1</b> Describe the procedures used to gather evidence for forensic investigation. <b>A.P2</b> Outline the roles of crime scene and authorised personnel who attend crime scenes.	<b>A.M1</b> Justify the importance of the procedures used to gather evidence for forensic investigations. <b>A.M2</b> Explain the structure and importance of Scientific Support Units and authorised personnel to forensic investigations.	
<b>Learning aim B: Investigate a simulated crime scene using forensic procedures</b>		<b>B.D2</b> Evaluate procedures used to process a simulated crime scene.
<b>B.P3</b> Carry out a forensic examination of a simulated crime scene, using appropriate forensic procedures to gather biological, physical and chemical evidence. <b>B.P4</b> Describe the forensic methods used to process a simulated crime scene.	<b>B.M3</b> Justify the forensic procedures used to process a simulated crime scene.	
<b>Learning aim C: Conduct scientific analysis of physical, biological and chemical evidence</b>		<b>CD.D3</b> Evaluate the techniques used in forensic science to analyse the physical, chemical and biological evidence gathered and evaluate the findings, including aspects of probability.
<b>C.P5</b> Explain the techniques used in forensic science to analyse physical, chemical and biological evidence. <b>C.P6</b> Demonstrate analysis of physical, biological and chemical evidence gathered from a simulated crime scene to draw conclusions.	<b>C.M4</b> Draw valid conclusions from the analysis of physical, chemical and biological evidence.	
<b>Learning aim D: Be able to justify methods, interpret findings and report on conclusions of forensic techniques and analysis</b>		
<b>D.P7</b> Draw conclusions from the analysis of physical, chemical and biological evidence.	<b>D.M5</b> Explain how physical, chemical and biological forensic analysis justifies the conclusions.	

## Essential information for assignments

The recommended structure of assessment is shown in the unit summary along with suitable forms of evidence. *Section 6* gives information on setting assignments and there is further information on our website.

There is a maximum number of three summative assignments for this unit. The relationship of the learning aims and criteria is:

Learning aim: A (A.P1, A.P2, A.M1, A.M2, A.D1)

Learning aim: B (B.P3, B.P4, B.M3, B.D2)

Learning aims: C and D (C.P5, C.P6, D.P7, C.M4, D.M5, CD.D3)

## Further information for teachers and assessors

### Resource requirements

For this unit, learners must have access to a well-equipped laboratory.

### Essential information for assessment decisions

#### Learning aim A

**For distinction standard,** learners will discuss the importance of documentation methods to forensic investigation. They should cover all the unit content on documentation and consider consequences of inaccurate or incomplete documentation. Learners must also analyse each personnel, crime scene and authorised personnel, by comparing and contrasting their roles when attending and processing a crime scene. Learners should explain the importance of their roles in relation to health and safety and to preserve the integrity of evidence. Learners will substantiate the use of each procedure and the crime scene personnel used in the gathering, storage and analysis of forensic evidence. This may include scenes of crime officers (SOCOs), Scientific Support Units (SSU) or other forensic specialists. It is expected that discussion will encompass a range of processes, from the first officer on the scene through to the collection and storage of evidence for analysis. Learners will discuss the significance of continuity and the chain of evidence, as well as health and safety measures and their importance in preserving the integrity of evidence for forensic analysis.

**For merit standard,** learners will justify the importance of the procedures used to preserve and gather evidence, including search patterns for forensic investigations. Learners should consider the impact that incorrectly following procedures may have when presenting evidence in court. Learners must also explain the structure and importance of SSUs and authorised personnel to forensic investigations. This should be a detailed explanation leading on from pass level, which fully clarifies their roles and why they are necessary.

**For pass standard,** learners must describe in detail the procedures used to gather evidence for forensic investigation. They are required to cover all main points on the preservation and recovery of evidence.

Learners will also need to briefly outline the roles of the first attending officer (FAO), (SOCO)/(CSI), crime scene manager, police officers, paramedics, fire and rescue service officers and forensic scientists. They should provide examples of when different authorised personnel may be needed.

#### Learning aim B

**For distinction standard,** learners are required to evaluate all the procedures they used to process their simulated crime scene. They should draw conclusions about their ability to carry out each procedure and suggest ways in which they could improve their practical work. Learners should evaluate how they maintained safety and how they ensured the integrity of evidence.

**For merit standard,** learners must justify the forensic procedures used to process their simulated crime scene, explaining why they performed each procedure and the importance of their actions in protecting the integrity of evidence for forensic analysis.

**For pass standard,** learners will process a simulated crime scene and demonstrate a clear understanding of how to gather evidence using collection methods and all other procedures that are used by a CSI. Learners must collect chemical, physical and biological evidence. They are required to document their practical and produce crime scene notes, drawings and photographs where appropriate. Learners are required to package and label evidence and show consideration for continuity of evidence. They are required to describe all the procedures they used to process their crime scene.

## Learning aims C and D

**For distinction standard,** learners will evaluate the techniques used to analyse the forensic evidence collected from a simulated crime scene. They should provide evidence of good practice and areas for improvement. When evaluating each technique, they should consider the ease of carrying out each and the type of technique, for example qualitative, quantitative or subjective. They will also consider probability – in terms of possible, probable, likely – and how probability can be described quantitatively.

**For merit standard,** learners will draw valid conclusions from the results of the analysis of the evidence collected from a simulated crime scene. They will support their conclusions with evidence and reasoning and, where appropriate, make suitable suggestions for further analysis. Learners will give a clear and logical justification for the conclusions drawn from the evidence collected during the forensic examination, and comment on its significance and the subsequent analysis. This may be presented as part of a presentation in a mock court setting or in an expert witness statement, with the same level of objectivity and clarity as appropriate to the presentation of investigational results in a forensic or scientific situation.

**For pass standard,** learners will explain the main techniques used to analyse physical, biological and chemical evidence. They will then practically analyse physical, biological and chemical evidence gathered from a simulated crime scene, and draw rational and balanced conclusions about the crime by linking the outcome of scientific investigations to the physical circumstances observed at the crime scene. The report will refer to inferences drawn in the unit and demonstrate a clear line of reasoning, and thus proof.

## Links to other units

This unit links to:

- Unit 2: Practical Scientific Procedures and Techniques
- Unit 25: Forensic Fire Investigation
- Unit 26: Forensic Traffic Collision Investigation.

## Employer involvement

Centres should develop links with local police constabulary CSI departments, universities and analytical laboratories. Specialists from these areas are usually willing to speak to learners about their work experience. Other local private forensic science agencies may also be interested in providing guest speakers. Local universities may offer the opportunity for learners to use specialist equipment.

## 4 Planning your programme

### How do I choose the right BTEC National qualification for my learners?

BTEC Nationals come in a range of sizes, each with a specific purpose. You will need to assess learners very carefully to ensure that they start on the right size of qualification to fit into their 16–19 study programme, and that they take the right pathways or optional units that allow them to progress to the next stage.

Some learners may want to take a number of complementary qualifications or keep their progression options open. These learners may be suited to taking a BTEC National Certificate or Extended Certificate. Learners who then decide to continue with a fuller vocational programme can transfer to a BTEC National Diploma or Extended Diploma, for example for their second year.

Some learners are sure of the sector they want to work in and are aiming for progression into that sector via higher education. These learners should be directed to the two-year BTEC National Extended Diploma as the most suitable qualification.

As a centre, you may want to teach learners who are taking different qualifications together. You may also wish to transfer learners between programmes to meet changes in their progression needs. You should check the qualification structures and unit combinations carefully as there is no exact match among the different sizes. You may find that learners need to complete more than the minimum number of units when transferring.

When learners are recruited, you need to give them accurate information on the title and focus of the qualification for which they are studying.

### Is there a learner entry requirement?

As a centre it is your responsibility to ensure that learners who are recruited have a reasonable expectation of success on the programme. There are no formal entry requirements but we expect learners to have qualifications at or equivalent to Level 2.

Learners are most likely to succeed if they have:

- five GCSEs at good grades and/or
- BTEC qualification(s) at Level 2
- achievement in English and mathematics through GCSE or Functional Skills.

Learners may demonstrate ability to succeed in various ways. For example, learners may have relevant work experience or specific aptitude shown through diagnostic tests or non-educational experience.

### What is involved in becoming an approved centre?

All centres must be approved before they can offer these qualifications – so that they are ready to assess learners and so that we can provide the support that is needed. Further information is given in *Section 8*.

### What level of sector knowledge is needed to teach these qualifications?

We do not set any requirements for teachers but recommend that centres assess the overall skills and knowledge of the teaching team to ensure that they are relevant and up to date. This will give learners a rich programme to prepare them for employment in the sector.

### What resources are required to deliver these qualifications?

As part of your centre approval you will need to show that the necessary material resources and work spaces are available to deliver BTEC Nationals. For some units, specific resources are required. This is indicated in the units.

### How can myBTEC help with planning for these qualifications?

myBTEC is an online toolkit that supports the delivery, assessment and quality assurance of BTECs in centres. It supports teachers with activities, such as choosing a valid combination of units, creating assignment briefs and creating assessment plans. For further information see *Section 10*.

### **Which modes of delivery can be used for these qualifications?**

You are free to deliver BTEC Nationals using any form of delivery that meets the needs of your learners. We recommend making use of a wide variety of modes, including direct instruction in classrooms or work environments, investigative and practical work, group and peer work, private study and e-learning.

### **What are the recommendations for employer involvement?**

BTEC Nationals are vocational qualifications and, as an approved centre, you are encouraged to work with employers on the design, delivery and assessment of the course to ensure that learners have a programme of study that is engaging and relevant and that equips them for progression. There are suggestions in many of the units about how employers could become involved in delivery and/or assessment but these are not intended to be exhaustive and there will be other possibilities at local level.

### **What support is available?**

We provide a wealth of support materials, including curriculum plans, delivery guides, authorised assignment briefs, additional papers for external assessments and examples of marked learner work.

You will be allocated a Standards Verifier early on in the planning stage to support you with planning your assessments. There will be extensive training programmes as well as support from our Subject Advisor team.

For further details see *Section 10*.

### **How will my learners become more employable through these qualifications?**

All BTEC Nationals are mapped to relevant occupational standards (see *Appendix 1*).

Employability skills, such as team working and entrepreneurialism, and practical hands-on skills have been built into the design of the learning aims and content. This gives you the opportunity to use relevant contexts, scenarios and materials to enable learners to develop a portfolio of evidence that demonstrates the breadth of their skills and knowledge in a way that equips them for employment.

# 5 Assessment structure and external assessment

## Introduction

BTEC Nationals are assessed using a combination of *internal assessments*, which are set and marked by teachers, and *external assessments* which are set and marked by Pearson:

- mandatory units have a combination of internal and external assessments
- all optional units are internally assessed.

We have taken great care to ensure that the assessment method chosen is appropriate to the content of the unit and in line with requirements from employers and higher education.

In developing an overall plan for delivery and assessment for the programme, you will need to consider the order in which you deliver units, whether delivery is over short or long periods and when assessment can take place. Some units are defined as synoptic units (see *Section 2*). Normally, a synoptic assessment is one that a learner would take later in a programme and in which they will be expected to apply learning from a range of units. Synoptic units may be internally or externally assessed. Where a unit is externally assessed you should refer to the sample assessment materials (SAMs) to identify where there is an expectation that learners draw on their wider learning. For internally-assessed units, you must plan the assignments so that learners can demonstrate learning from across their programme. A unit may be synoptic in one qualification and not another because of the relationship it has to the rest of the qualification.

We have addressed the need to ensure that the time allocated to final assessment of internal and external units is reasonable so that there is sufficient time for teaching and learning, formative assessment and development of transferable skills.

In administering internal and external assessment, the centre needs to be aware of the specific procedures and policies that apply, for example to registration, entries and results. An overview with signposting to relevant documents is given in *Section 7*.

## Internal assessment

Our approach to internal assessment for these qualifications will be broadly familiar to experienced centres. It offers flexibility in how and when you assess learners, provided that you meet assessment and quality assurance requirements. You will need to take account of the requirements of the unit format, which we explain in *Section 3*, and the requirements for delivering assessment given in *Section 6*.

## External assessment

A summary of the external assessment for this qualification is given in *Section 2*. You should check this information carefully, together with the unit specification and the sample assessment materials, so that you can timetable learning and assessment periods appropriately.

Learners must be prepared for external assessment by the time they undertake it. In preparing learners for assessment you will want to take account of required learning time, the relationship with other external assessments and opportunities for retaking. You should ensure that learners are not entered for unreasonable amounts of external assessment in one session. Learners may resit an external assessment to obtain a higher grade of near pass or above. If a learner has more than one attempt, then the best result will be used for qualification grading, up to the permitted maximum. It is unlikely that learners will need to or benefit from taking all assessments twice so you are advised to plan appropriately. Some assessments are synoptic and learners are likely to perform best if these assessments are taken towards the end of the programme.

## Key features of external assessment in applied science

In applied science, after consultation with stakeholders, we have developed the following:

- *Unit 1: Principles and Applications of Science I*, an exam-based assessment, in which learners will be asked to respond to a range of different question types, including multiple-choice, calculations, short-answer, and extended open-response questions demonstrating their knowledge and understanding of key areas of science. This assessment covers the core principles across the three science disciplines. Learners will also make judgements and reach conclusions by evaluating scientific information and making connections between different scientific concepts, procedures and processes.
- *Unit 3: Science Investigation Skills*, a task-based assessment in which learners will demonstrate their skills of carrying out a scientific practical investigation to collect and record data. The investigation will be from one of the content areas covered by the unit. Learners will be assessed on their skills of interpretation, analysis, planning and evaluation by using the data they have collected. They will also be required to apply their knowledge and understanding of scientific concepts, processes and procedures to plan an investigation for a different area of content and critique a method and set of results given.
- *Unit 5: Principles and Applications of Science II*, an exam-based assessment, in which learners develop and build upon the principles covered in *Unit 1* and will extend their understanding of important areas across the three science disciplines. Learners will be asked to respond to a range of different question types, including multiple-choice, calculations, short-answer, and extended open-response, demonstrating their knowledge and understanding of scientific concepts, procedures, and processes and their application.

## Units

The externally-assessed units have a specific format which we explain in *Section 3*. The content of units will be sampled across external assessments over time through appropriate papers and tasks. The ways in which learners are assessed are shown through the assessment outcomes and grading descriptors. External assessments are marked and awarded using the grade descriptors. The grades available are Distinction (D), Merit (M), Pass (P) and Near Pass (N). The Near Pass (N) grade gives learners credit below a Pass, where they have demonstrated evidence of positive performance which is worth more than an unclassified result but not yet at the Pass standard.

## Sample assessment materials

Each externally-assessed unit has a set of sample assessment materials (SAMs) that accompanies this specification. The SAMs are there to give you an example of what the external assessment will look like in terms of the feel and level of demand of the assessment. In the case of units containing synoptic assessment, the SAMs will also show where learners are expected to select and apply from across the programme.

The SAMs show the range of possible question types that may appear in the actual assessments and give you a good indication of how the assessments will be structured. While SAMs can be used for practice with learners, as with any assessment the content covered and specific details of the questions asked will change in each assessment.

A copy of each of these assessments can be downloaded from our website. An additional sample of each of the Pearson-set units will be available before the first sitting of the assessment to allow your learners further opportunities for practice.



## 6 Internal assessment

This section gives an overview of the key features of internal assessment and how you, as an approved centre, can offer it effectively. The full requirements and operational information are given in the *Pearson Quality Assurance Handbook*. All members of the assessment team need to refer to this document.

For BTEC Nationals it is important that you can meet the expectations of stakeholders and the needs of learners by providing a programme that is practical and applied. Centres can tailor programmes to meet local needs and use links with local employers and the wider vocational sector.

When internal assessment is operated effectively it is challenging, engaging, practical and up to date. It must also be fair to all learners and meet national standards.

### Principles of internal assessment

#### Assessment through assignments

For internally-assessed units, the format of assessment is an assignment taken after the content of the unit, or part of the unit if several assignments are used, has been delivered. An assignment may take a variety of forms, including practical and written types. An assignment is a distinct activity completed independently by learners that is separate from teaching, practice, exploration and other activities that learners complete with direction from, and formative assessment by, teachers.

An assignment is issued to learners as an assignment brief with a defined start date, a completion date and clear requirements for the evidence that they need to provide. There may be specific observed practical components during the assignment period. Assignments can be divided into tasks and may require several forms of evidence. A valid assignment will enable a clear and formal assessment outcome based on the assessment criteria.

#### Assessment decisions through applying unit-based criteria

Assessment decisions for BTEC Nationals are based on the specific criteria given in each unit and set at each grade level. To ensure that standards are consistent in the qualification and across the suite as a whole, the criteria for each unit have been defined according to a framework. The way in which individual units are written provides a balance of assessment of understanding, practical skills and vocational attributes appropriate to the purpose of qualifications.

The assessment criteria for a unit are hierarchical and holistic. For example, if an M criterion requires the learner to show 'analysis' and the related P criterion requires the learner to 'explain', then to satisfy the M criterion a learner will need to cover both 'explain' and 'analyse'. The unit assessment grid shows the relationships among the criteria so that assessors can apply all the criteria to the learner's evidence at the same time. In *Appendix 2* we have set out a definition of terms that assessors need to understand.

Assessors must show how they have reached their decisions using the criteria in the assessment records. When a learner has completed all the assessment for a unit then the assessment team will give a grade for the unit. This is given simply according to the highest level for which the learner is judged to have met all the criteria. Therefore:

- to achieve a Distinction, a learner must have satisfied all the Distinction criteria (and therefore the Pass and Merit criteria); these define outstanding performance across the unit as a whole
- to achieve a Merit, a learner must have satisfied all the Merit criteria (and therefore the Pass criteria) through high performance in each learning aim
- to achieve a Pass, a learner must have satisfied all the Pass criteria for the learning aims, showing coverage of the unit content and therefore attainment at Level 3 of the national framework.

The award of a Pass is a defined level of performance and cannot be given solely on the basis of a learner completing assignments. Learners who do not satisfy the Pass criteria should be reported as Unclassified.

### **The assessment team**

It is important that there is an effective team for internal assessment. There are three key roles involved in implementing assessment processes in your centre, each with different interrelated responsibilities, the roles are listed below. Full information is given in the *Pearson Quality Assurance Handbook*.

- The Lead Internal Verifier (the Lead IV) has overall responsibility for the programme, its assessment and internal verification to meet our requirements, record keeping and liaison with the Standards Verifier. The Lead IV registers with Pearson annually. The Lead IV acts as an assessor, supports the rest of the assessment team, makes sure that they have the information they need about our assessment requirements and organises training, making use of our guidance and support materials.
- Internal Verifiers (IVs) oversee all assessment activity in consultation with the Lead IV. They check that assignments and assessment decisions are valid and that they meet our requirements. IVs will be standardised by working with the Lead IV. Normally, IVs are also assessors but they do not verify their own assessments.
- Assessors set or use assignments to assess learners to national standards. Before taking any assessment decisions, assessors participate in standardisation activities led by the Lead IV. They work with the Lead IV and IVs to ensure that the assessment is planned and carried out in line with our requirements.

### **Effective organisation**

Internal assessment needs to be well organised so that the progress of learners can be tracked and so that we can monitor that assessment is being carried out in line with national standards. We support you through, for example, providing training materials and sample documentation. Our online myBTEC service can help support you in planning and record keeping. Further information on using myBTEC can be found in *Section 10* and on our website.

It is particularly important that you manage the overall assignment programme and deadlines to make sure that learners are able to complete assignments on time.

### **Learner preparation**

To ensure that you provide effective assessment for your learners, you need to make sure that they understand their responsibilities for assessment and the centre's arrangements.

From induction onwards, you will want to ensure that learners are motivated to work consistently and independently to achieve the requirements of the qualifications. Learners need to understand how assignments are used, the importance of meeting assignment deadlines, and that all the work submitted for assessment must be their own.

You will need to give learners a guide that explains how assignments are used for assessment, how assignments relate to the teaching programme, and how learners should use and reference source materials, including what would constitute plagiarism. The guide should also set out your approach to operating assessment, such as how learners must submit work and request extensions.

## Setting effective assignments

### Setting the number and structure of assignments

In setting your assignments, you need to work with the structure of assignments shown in the *Essential information for assignments* section of a unit. This shows the structure of the learning aims and criteria that you must follow and the recommended number of assignments that you should use. For some units we provide authorised assignment briefs, for all the units we give you suggestions on how to create suitable assignments. You can find these materials along with this specification on our website. In designing your own assignment briefs you should bear in mind the following points.

- The number of assignments for a unit must not exceed the number shown in *Essential information for assignments*. However, you may choose to combine assignments, for example to create a single assignment for the whole unit.
- You may also choose to combine all or parts of different units into single assignments, provided that all units and all their associated learning aims are fully addressed in the programme overall. If you choose to take this approach, you need to make sure that learners are fully prepared so that they can provide all the required evidence for assessment and that you are able to track achievement in the records.
- A learning aim must always be assessed as a whole and must not be split into two or more tasks.
- The assignment must be targeted to the learning aims but the learning aims and their associated criteria are not tasks in themselves. Criteria are expressed in terms of the outcome shown in the evidence.
- You do not have to follow the order of the learning aims of a unit in setting assignments but later learning aims often require learners to apply the content of earlier learning aims and they may require learners to draw their learning together.
- Assignments must be structured to allow learners to demonstrate the full range of achievement at all grade levels. Learners need to be treated fairly by being given the opportunity to achieve a higher grade if they have the ability.
- As assignments provide a final assessment, they will draw on the specified range of teaching content for the learning aims. The specified content is compulsory. The evidence for assessment need not cover every aspect of the teaching content as learners will normally be given particular examples, case studies or contexts in their assignments. For example, if a learner is carrying out one practical performance, or an investigation of one organisation, then they will address all the relevant range of content that applies in that instance.

### Providing an assignment brief

A good assignment brief is one that, through providing challenging and realistic tasks, motivates learners to provide appropriate evidence of what they have learned.

An assignment brief should have:

- a vocational scenario, this could be a simple situation or a full, detailed set of vocational requirements that motivates the learner to apply their learning through the assignment
- clear instructions to the learner about what they are required to do, normally set out through a series of tasks
- an audience or purpose for which the evidence is being provided
- an explanation of how the assignment relates to the unit(s) being assessed.

## Forms of evidence

BTEC Nationals have always allowed for a variety of forms of evidence to be used, provided that they are suited to the type of learning aim being assessed. For many units, the practical demonstration of skills is necessary and for others, learners will need to carry out their own research and analysis. The units give you information on what would be suitable forms of evidence to provide learners with the opportunity to apply a range of employability or transferable skills. Centres may choose to use different suitable forms for evidence to those proposed. Overall, learners should be assessed using varied forms of evidence.

Full definitions of types of assessment are given in *Appendix 2*. These are some of the main types of assessment:

- written reports
- projects
- time-constrained practical assessments with observation records and supporting evidence
- recordings of performance
- sketchbooks, working logbooks, reflective journals
- presentations with assessor questioning.

The form(s) of evidence selected must:

- allow the learner to provide all the evidence required for the learning aim(s) and the associated assessment criteria at all grade levels
- allow the learner to produce evidence that is their own independent work
- allow a verifier to independently reassess the learner to check the assessor's decisions.

For example, when you are using performance evidence, you need to think about how supporting evidence can be captured through recordings, photographs or task sheets.

Centres need to take particular care that learners are enabled to produce independent work.

For example, if learners are asked to use real examples, then best practice would be to encourage them to use their own or to give the group a number of examples that can be used in varied combinations.

## Making valid assessment decisions

### Authenticity of learner work

Once an assessment has begun, learners must not be given feedback on progress towards fulfilling the targeted criteria.

An assessor must assess only learner work that is authentic, i.e. learners' own independent work. Learners must authenticate the evidence that they provide for assessment through signing a declaration stating that it is their own work.

Assessors must ensure that evidence is authentic to a learner through setting valid assignments and supervising them during the assessment period. Assessors must take care not to provide direct input, instructions or specific feedback that may compromise authenticity.

Assessors must complete a declaration that:

- the evidence submitted for this assignment is the learner's own
- the learner has clearly referenced any sources used in the work
- they understand that false declaration is a form of malpractice.

Centres can use Pearson templates or their own templates to document authentication.

During assessment, an assessor may suspect that some or all of the evidence from a learner is not authentic. The assessor must then take appropriate action using the centre's policies for malpractice. Further information is given in *Section 7*.

### Making assessment decisions using criteria

Assessors make judgements using the criteria. The evidence from a learner can be judged using all the relevant criteria at the same time. The assessor needs to make a judgement against each criterion that evidence is present and sufficiently comprehensive. For example, the inclusion of a concluding section may be insufficient to satisfy a criterion requiring 'evaluation'.

Assessors should use the following information and support in reaching assessment decisions:

- the *Essential information for assessment decisions* section in each unit gives examples and definitions related to terms used in the criteria
- the explanation of key terms in *Appendix 2*
- examples of assessed work provided by Pearson
- your Lead IV and assessment team's collective experience, supported by the standardisation materials we provide.

Pass and Merit criteria relate to individual learning aims. The Distinction criteria as a whole relate to outstanding performance across the unit. Therefore, criteria may relate to more than one learning aim (for example A.D1) or to several learning aims (for example DE.D3). Distinction criteria make sure that learners have shown that they can perform consistently at an outstanding level across the unit and/or that they are able to draw learning together across learning aims.

### Dealing with late completion of assignments

Learners must have a clear understanding of the centre policy on completing assignments by the deadlines that you give them. Learners may be given authorised extensions for legitimate reasons, such as illness at the time of submission, in line with your centre policies.

For assessment to be fair, it is important that learners are all assessed in the same way and that some learners are not advantaged by having additional time or the opportunity to learn from others. Therefore, learners who do not complete assignments by your planned deadline or the authorised extension deadline may not have the opportunity to subsequently resubmit.

If you accept a late completion by a learner, then the assignment should be assessed normally when it is submitted using the relevant assessment criteria.

## Issuing assessment decisions and feedback

Once the assessment team has completed the assessment process for an assignment, the outcome is a formal assessment decision. This is recorded formally and reported to learners.

The information given to the learner:

- must show the formal decision and how it has been reached, indicating how or where criteria have been met
- may show why attainment against criteria has not been demonstrated
- must not provide feedback on how to improve evidence
- must be validated by an IV before it is given to the learner.

## Resubmission of improved evidence

An assignment provides the final assessment for the relevant learning aims and is normally a final assessment decision, except where the Lead IV approves one opportunity to resubmit improved evidence based on the completed assignment brief.

The Lead IV has the responsibility to make sure that resubmission is operated fairly. This means:

- checking that a learner can be reasonably expected to perform better through a second submission, for example that the learner has not performed as expected
- making sure that giving a further opportunity can be done in such a way that it does not give an unfair advantage over other learners, for example through the opportunity to take account of feedback given to other learners
- checking that the assessor considers that the learner will be able to provide improved evidence without further guidance and that the original evidence submitted remains valid.

Once an assessment decision has been given to the learner, the resubmission opportunity must have a deadline within 15 working days in the same academic year.

A resubmission opportunity must not be provided where learners:

- have not completed the assignment by the deadline without the centre's agreement
- have submitted work that is not authentic.

## Retake of internal assessment

A learner who has not achieved the level of performance required to pass the relevant learning aims after resubmission of an assignment may be offered a single retake opportunity using a new assignment. The retake may only be achieved at a pass.

The Lead Internal Verifier must only authorise a retake of an assignment in exceptional circumstances where they believe it is necessary, appropriate and fair to do so. For further information on offering a retake opportunity, you should refer to the *BTEC Centre Guide to Assessment*. We provide information on writing assignments for retakes on our website ([www.btec.co.uk/keydocuments](http://www.btec.co.uk/keydocuments)).

## Planning and record keeping

For internal processes to be effective, an assessment team needs to be well organised and keep effective records. The centre will also work closely with us so that we can quality assure that national standards are being satisfied. This process gives stakeholders confidence in the assessment approach.

The Lead IV must have an assessment plan, produced as a spreadsheet or using myBTEC. When producing a plan the assessment team may wish to consider:

- the time required for training and standardisation of the assessment team
- the time available to undertake teaching and carry out assessment, taking account of when learners may complete external assessments and when quality assurance will take place
- the completion dates for different assignments
- who is acting as IV for each assignment and the date by which the assignment needs to be verified
- setting an approach to sampling assessor decisions through internal verification that covers all assignments, assessors and a range of learners
- how to manage the assessment and verification of learners' work so that they can be given formal decisions promptly
- how resubmission opportunities can be scheduled.

The Lead IV will also maintain records of assessment undertaken. The key records are:

- verification of assignment briefs
- learner authentication declarations
- assessor decisions on assignments, with feedback given to learners
- verification of assessment decisions.

Examples of records and further information are given in the *Pearson Quality Assurance Handbook*.

# 7 Administrative arrangements

## Introduction

This section focuses on the administrative requirements for delivering a BTEC qualification. It will be of value to Quality Nominees, Lead IVs, Programme Leaders and Examinations Officers.

## Learner registration and entry

Shortly after learners start the programme of learning, you need to make sure that they are registered for the qualification and that appropriate arrangements are made for internal and external assessment. You need to refer to the *Information Manual* for information on making registrations for the qualification and entries for external assessments.

Learners can be formally assessed only for a qualification on which they are registered. If learners' intended qualifications change, for example if a learner decides to choose a different pathway specialism, then the centre must transfer the learner appropriately.

## Access to assessment

Both internal and external assessments need to be administered carefully to ensure that all learners are treated fairly, and that results and certification are issued on time to allow learners to progress to chosen progression opportunities.

Our equality policy requires that all learners should have equal opportunity to access our qualifications and assessments, and that our qualifications are awarded in a way that is fair to every learner. We are committed to making sure that:

- learners with a protected characteristic are not, when they are undertaking one of our qualifications, disadvantaged in comparison to learners who do not share that characteristic
- all learners achieve the recognition they deserve for undertaking a qualification and that this achievement can be compared fairly to the achievement of their peers.

Further information on access arrangements can be found in the Joint Council for Qualifications (JCQ) document *Access Arrangements, Reasonable Adjustments and Special Consideration for General and Vocational Qualifications*.



## Administrative arrangements for internal assessment

### Records

You are required to retain records of assessment for each learner. Records should include assessments taken, decisions reached and any adjustments or appeals. Further information can be found in the *Information Manual*. We may ask to audit your records so they must be retained as specified.

### Reasonable adjustments to assessment

A reasonable adjustment is one that is made before a learner takes an assessment to ensure that they have fair access to demonstrate the requirements of the assessments. You are able to make adjustments to internal assessments to take account of the needs of individual learners. In most cases this can be achieved through a defined time extension or by adjusting the format of evidence. We can advise you if you are uncertain as to whether an adjustment is fair and reasonable. You need to plan for time to make adjustments if necessary.

Further details on how to make adjustments for learners with protected characteristics are given on our website in the document *Supplementary guidance for reasonable adjustment and special consideration in vocational internally-assessed units*.

### Special consideration

Special consideration is given after an assessment has taken place for learners who have been affected by adverse circumstances, such as illness. You must operate special consideration in line with our policy (see previous paragraph). You can provide special consideration related to the period of time given for evidence to be provided or for the format of the assessment if it is equally valid. You may not substitute alternative forms of evidence to that required in a unit, or omit the application of any assessment criteria to judge attainment. Pearson can consider applications for special consideration in line with the policy.

### Appeals against assessment

Your centre must have a policy for dealing with appeals from learners. These appeals may relate to assessment decisions being incorrect or assessment not being conducted fairly. The first step in such a policy could be a consideration of the evidence by a Lead IV or other member of the programme team. The assessment plan should allow time for potential appeals after assessment decisions have been given to learners. If there is an appeal by a learner, you must document the appeal and its resolution. Learners have a final right of appeal to Pearson but only if the procedures that you have put in place have not been followed. Further details are given in the document *Enquiries and appeals about Pearson vocational qualifications and end point assessment policy*.

## Administrative arrangements for external assessment

### Entries and resits

For information on the timing of assessment and entries, please refer to the annual examinations timetable on our website.

### Access arrangements requests

Access arrangements are agreed with Pearson before an assessment. They allow students with special educational needs, disabilities or temporary injuries to:

- access the assessment
- show what they know and can do without changing the demands of the assessment.

Access arrangements should always be processed at the time of registration. Learners will then know what type of arrangements are available in place for them.

### Granting reasonable adjustments

For external assessment, a reasonable adjustment is one that we agree to make for an individual learner. A reasonable adjustment is defined for the individual learner and informed by the list of available access arrangements.

Whether an adjustment will be considered reasonable will depend on a number of factors, to include:

- the needs of the learner with the disability
- the effectiveness of the adjustment
- the cost of the adjustment; and
- the likely impact of the adjustment on the learner with the disability and other learners.

Adjustment may be judged unreasonable and not approved if it involves unreasonable costs, timeframes or affects the integrity of the assessment.

### Special consideration requests

Special consideration is an adjustment made to a student's mark or grade after an external assessment to reflect temporary injury, illness or other indisposition at the time of the assessment. An adjustment is made only if the impact on the learner is such that it is reasonably likely to have had a material effect on that learner being able to demonstrate attainment in the assessment.

Centres are required to notify us promptly of any learners who they believe have been adversely affected and request that we give special consideration. Further information can be found in the special requirements section on our website.

## Conducting external assessments

Centres must make arrangements for the secure delivery of external assessments. External assessments for BTEC qualifications include examinations, set tasks and performance.

Each external assessment has a defined degree of control under which it must take place. Some external assessments may have more than one part and each part may have a different degree of control. We define degrees of control as follows.

### High control

This is the completion of assessment in formal invigilated examination conditions.

### Medium control

This is completion of assessment, usually over a longer period of time, which may include a period of controlled conditions. The controlled conditions may allow learners to access resources, prepared notes or the internet to help them complete the task.

### Low control

These are activities completed without direct supervision. They may include research, preparation of materials and practice. The materials produced by learners under low control will not be directly assessed.

Further information on responsibilities for conducting external assessment is given in the document *Instructions for Conducting External Assessments*, available on our website.

## Dealing with malpractice in assessment

Malpractice means acts that undermine the integrity and validity of assessment, the certification of qualifications, and/or that may damage the authority of those responsible for delivering the assessment and certification.

Pearson does not tolerate actions (or attempted actions) of malpractice by learners, centre staff or centres in connection with Pearson qualifications. Pearson may impose penalties and/or sanctions on learners, centre staff or centres where incidents (or attempted incidents) of malpractice have been proven.

Malpractice may arise or be suspected in relation to any unit or type of assessment within the qualification. For further details regarding malpractice and advice on preventing malpractice by learners, please see Pearson's *Centre guidance: Dealing with malpractice and maladministration in vocational qualifications*, available on our website.

The procedures we ask you to adopt vary between units that are internally-assessed and those that are externally assessed.

### Internally-assessed units

Centres are required to take steps to prevent malpractice and to investigate instances of suspected malpractice. Learners must be given information that explains what malpractice is for internal assessment and how suspected incidents will be dealt with by the centre. The *Centre Guidance: Dealing with Malpractice* document gives full information on the actions we expect you to take.

Pearson may conduct investigations if we believe that a centre is failing to conduct internal assessment according to our policies. The above document gives further information, examples and details the penalties and sanctions that may be imposed.

In the interests of learners and centre staff, centres need to respond effectively and openly to all requests relating to an investigation into an incident of suspected malpractice.

### Externally-assessed units

External assessment means all aspects of units that are designated as external in this specification, including preparation for tasks and performance. For these assessments centres must follow the JCQ procedures set out in the latest version of *JCQ Suspected Malpractice in Examinations and Assessments Policies and Procedures* ([www.jcq.org.uk](http://www.jcq.org.uk)).

In the interests of learners and centre staff, centres need to respond effectively and openly to all requests relating to an investigation into an incident of suspected malpractice.

### Learner malpractice

Heads of Centres are required to report incidents of any suspected learner malpractice that occur during Pearson external assessments. We ask that centres do so by completing a *JCQ Form M1* (available at [www.jcq.org.uk/exams-office/malpractice](http://www.jcq.org.uk/exams-office/malpractice)) and emailing it and any accompanying documents (signed statements from the learner, invigilator, copies of evidence, etc.) to the Investigations Team at [candidatemalpractice@pearson.com](mailto:candidatemalpractice@pearson.com). The responsibility for determining appropriate sanctions or penalties to be imposed on learners lies with Pearson.

Learners must be informed at the earliest opportunity of the specific allegation and the centre's malpractice policy, including the right of appeal. Learners found guilty of malpractice may be disqualified from the qualification for which they have been entered with Pearson.

## Teacher/centre malpractice

Heads of Centres are required to inform Pearson's Investigations Team of any incident of suspected malpractice by centre staff, before any investigation is undertaken. Heads of centres are requested to inform the Investigations Team by submitting a *JCQ Form M2(a)* (available at [www.jcq.org.uk/exams-office/malpractice](http://www.jcq.org.uk/exams-office/malpractice)) with supporting documentation to [pqsmalpractice@pearson.com](mailto:pqsmalpractice@pearson.com). Where Pearson receives allegations of malpractice from other sources (for example Pearson staff or anonymous informants), the Investigations Team will conduct the investigation directly or may ask the head of centre to assist.

Incidents of maladministration (accidental errors in the delivery of Pearson qualifications that may affect the assessment of learners) should also be reported to the Investigations Team using the same method.

Heads of Centres/Principals/Chief Executive Officers or their nominees are required to inform learners and centre staff suspected of malpractice of their responsibilities and rights; see Section 6.15 of the *JCQ Suspected Malpractice in Examinations and Assessments Policies and Procedures* document.

Pearson reserves the right in cases of suspected malpractice to withhold the issuing of results and/or certificates while an investigation is in progress. Depending on the outcome of the investigation results and/or certificates may be released or withheld.

You should be aware that Pearson may need to suspend certification when undertaking investigations, audits and quality assurances processes. You will be notified within a reasonable period of time if this occurs.

## Sanctions and appeals

Where malpractice is proven we may impose sanctions or penalties.

Where learner malpractice is evidenced, penalties may be imposed such as:

- mark reduction for external assessments
- disqualification from the qualification
- being barred from registration for Pearson qualifications for a period of time.

If we are concerned about your centre's quality procedures we may impose sanctions such as:

- working with you to create an improvement action plan
- requiring staff members to receive further training
- placing temporary blocks on your certificates
- placing temporary blocks on registration of learners
- debarring staff members or the centre from delivering Pearson qualifications
- suspending or withdrawing centre approval status.

The centre will be notified if any of these apply.

Pearson has established procedures for centres that are considering appeals against penalties and sanctions arising from malpractice. Appeals against a decision made by Pearson will normally be accepted only from Heads of Centres (on behalf of learners and/or members of staff) and from individual members (in respect of a decision taken against them personally). Further information on appeals can be found in our *Enquiries and appeals about Pearson vocational qualifications and end point assessment policy*, which is on our website. In the initial stage of any aspect of malpractice, please notify the Investigations Team by email via [pqsmalpractice@pearson.com](mailto:pqsmalpractice@pearson.com) who will inform you of the next steps.

## Certification and results

Once a learner has completed all the required components for a qualification, even if final results for external assessments have not been issued, then the centre can claim certification for the learner, provided that quality assurance has been successfully completed. For the relevant procedures please refer to our *Information Manual*. You can use the information provided on qualification grading to check overall qualification grades.

### Results issue

After the external assessment session, learner results will be issued to centres. The result will be in the form of a grade. You should be prepared to discuss performance with learners, making use of the information we provide and post-results services.

### Post-assessment services

Once results for external assessments are issued, you may find that the learner has failed to achieve the qualification or to attain an anticipated grade. It is possible to transfer or reopen registration in some circumstances. The *Information Manual* gives further information.

### Changes to qualification requests

Where a learner who has taken a qualification wants to resit an externally-assessed unit to improve their qualification grade, you firstly need to decline their overall qualification grade. You may decline the grade before the certificate is issued. For a learner receiving their results in August, you should decline the grade by the end of September if the learner intends to resit an external assessment.

## Additional documents to support centre administration

As an approved centre you must ensure that all staff delivering, assessing and administering the qualifications have access to this documentation. These documents are reviewed annually and are reissued if updates are required.

- *Pearson Quality Assurance Handbook*: this sets out how we will carry out quality assurance of standards and how you need to work with us to achieve successful outcomes.
- *Information Manual*: this gives procedures for registering learners for qualifications, transferring registrations, entering for external assessments and claiming certificates.
- *Lead Examiners' Reports*: these are produced after each series for each external assessment and give feedback on the overall performance of learners in response to tasks or questions set.
- *Instructions for Conducting External Assessments (ICEA)*: this explains our requirements for the effective administration of external assessments, such as invigilation and submission of materials.
- *Regulatory policies*: our regulatory policies are integral to our approach and explain how we meet internal and regulatory requirements. We review the regulated policies annually to ensure that they remain fit for purpose. Policies related to this qualification include:
  - adjustments for candidates with disabilities and learning difficulties, access arrangements and reasonable adjustments for general and vocational qualifications
  - age of learners
  - centre guidance for dealing with malpractice
  - recognition of prior learning and process.

This list is not exhaustive and a full list of our regulatory policies can be found on our website.

## 8 Quality assurance

### Centre and qualification approval

As part of the approval process, your centre must make sure that the resource requirements listed below are in place before offering the qualification.

- Centres must have appropriate physical resources (for example, equipment, IT, learning materials, teaching rooms) to support the delivery and assessment of the qualification.
- Staff involved in the assessment process must have relevant expertise and/or occupational experience.
- There must be systems in place to ensure continuing professional development for staff delivering the qualification.
- Centres must have in place appropriate health and safety policies relating to the use of equipment by learners.
- Centres must deliver the qualification in accordance with current equality legislation.
- Centres should refer to the teacher guidance section in individual units to check for any specific resources required.

### Continuing quality assurance and standards verification

On an annual basis, we produce the *Pearson Quality Assurance Handbook*. It contains detailed guidance on the quality processes required to underpin robust assessment and internal verification.

The key principles of quality assurance are that:

- a centre delivering BTEC programmes must be an approved centre, and must have approval for the programmes or groups of programmes that it is delivering
- the centre agrees, as part of gaining approval, to abide by specific terms and conditions around the effective delivery and quality assurance of assessment; it must abide by these conditions throughout the period of delivery
- Pearson makes available to approved centres a range of materials and opportunities, through online standardisation, intended to exemplify the processes required for effective assessment, and examples of effective standards. Approved centres must use the materials and services to ensure that all staff delivering BTEC qualifications keep up to date with the guidance on assessment
- an approved centre must follow agreed protocols for standardisation of assessors and verifiers, for the planning, monitoring and recording of assessment processes, and for dealing with special circumstances, appeals and malpractice.

The approach of quality-assured assessment is through a partnership between an approved centre and Pearson. We will make sure that each centre follows best practice and employs appropriate technology to support quality-assurance processes, where practicable. We work to support centres and seek to make sure that our quality-assurance processes do not place undue bureaucratic processes on centres. We monitor and support centres in the effective operation of assessment and quality assurance.

The methods we use to do this for BTEC Level 3 include:

- making sure that all centres complete appropriate declarations at the time of approval
- undertaking approval visits to centres
- making sure that centres have effective teams of assessors and verifiers who are trained to undertake assessment
- assessment sampling and verification, through requested samples of assessments, completed assessed learner work and associated documentation
- an overarching review and assessment of a centre's strategy for delivering and quality assuring its BTEC programmes, for example making sure that synoptic units are placed appropriately in the order of delivery of the programme.

Centres that do not fully address and maintain rigorous approaches to delivering, assessing and quality assurance cannot seek certification for individual programmes or for all BTEC Level 3 programmes. An approved centre must make certification claims only when authorised by us and strictly in accordance with requirements for reporting.

Centres that do not comply with remedial action plans may have their approval to deliver qualifications removed.

## 9 Understanding the qualification grade

### Awarding and reporting for the qualification

This section explains the rules that we apply in awarding a qualification and in providing an overall qualification grade for each learner. It shows how all the qualifications in this sector are graded.

The awarding and certification of these qualifications will comply with regulatory requirements.

### Eligibility for an award

In order to be awarded a qualification, a learner must complete all units, achieve a Near Pass (N) or above in all external units and a pass or above in all mandatory units unless otherwise specified. Refer to the structure in *Section 2*.

To achieve any qualification grade, learners must:

- complete and **have an outcome** (D, M, P, N or U) for all units within a valid combination
- achieve the **required units at Pass or above** shown in *Section 2*, and for the Extended Diploma achieve a minimum 900 GLH at Pass or above (or N or above in external units)
- achieve the **minimum number of points** at a grade threshold.

It is the responsibility of a centre to ensure that a correct unit combination is adhered to.

Learners who do not achieve the required minimum grade (N or P) in units shown in the structure will not achieve a qualification.

Learners who do not achieve sufficient points for a qualification or who do not achieve all the required units may be eligible to achieve a smaller qualification in the same suite provided they have completed and achieved the correct combination of units and met the appropriate qualification grade points threshold.

### Calculation of the qualification grade

The final grade awarded for a qualification represents an aggregation of a learner's performance across the qualification. As the qualification grade is an aggregate of the total performance, there is some element of compensation in that a higher performance in some units may be balanced by a lower outcome in others.

In the event that a learner achieves more than the required number of optional units, the mandatory units along with the optional units with the highest grades will be used to calculate the overall result, subject to the eligibility requirements for that particular qualification title.

BTEC Nationals are Level 3 qualifications and are awarded at the grade ranges shown in the table below.

Qualification	Available grade range
Certificate, Extended Certificate, Foundation Diploma	P to D*
Diploma	PP to D*D*
Extended Diploma	PPP to D*D*D*

The *Calculation of qualification grade* table, shown further on in this section, shows the minimum thresholds for calculating these grades. The table will be kept under review over the lifetime of the qualification. The most up to date table will be issued on our website.

Pearson will monitor the qualification standard and reserves the right to make appropriate adjustments.

Learners who do not meet the minimum requirements for a qualification grade to be awarded will be recorded as Unclassified (U) and will not be certificated. They may receive a Notification of Performance for individual units. The *Information Manual* gives full information.



### Points available for internal units

The table below shows the number of **points** available for internal units. For each internal unit, points are allocated depending on the grade awarded.

	Unit size	
	60 GLH	90 GLH
U	0	0
Pass	6	9
Merit	10	15
Distinction	16	24

### Points available for external units

Raw marks from the external units will be awarded **points** based on performance in the assessment. The table below shows the **minimum number of points** available for each grade in the external units.

	Unit size	
	90 GLH	120 GLH
U	0	0
Near Pass	6	8
Pass	9	12
Merit	15	20
Distinction	24	32

Pearson will automatically calculate the points for each external unit once the external assessment has been marked and grade boundaries have been set. For more details about how we set grade boundaries in the external assessment please go to our website.

### Claiming the qualification grade

Subject to eligibility, Pearson will automatically calculate the qualification grade for your learners when the internal unit grades are submitted and the qualification claim is made. Learners will be awarded qualification grades for achieving the sufficient number of points within the ranges shown in the relevant *Calculation of qualification grade* table for the cohort.

## Calculation of qualification grade

Applicable for registration from 1 September 2016.

Certificate		Extended Certificate		Foundation Diploma		Diploma		Extended Diploma	
180 GLH		360 GLH		510 GLH		720 GLH		1080 GLH	
Grade	Points threshold	Grade	Points threshold	Grade	Points threshold	Grade	Points threshold	Grade	Points threshold
U	0	U	0	U	0	U	0	U	0
Pass	18	P	36	P	51	PP	72	PPP	108
						MP	88	MPP	124
								MMP	140
Merit	26	M	52	M	73	MM	104	MMM	156
						DM	124	DMM	176
								DDM	196
Distinction	42	D	74	D	104	DD	144	DDD	216
						D*D	162	D*DD	234
								D*D*D	252
Distinction*	48	D*	90	D*	130	D*D*	180	D*D*D*	270

The table is subject to review over the lifetime of the qualification. The most up-to-date version will be issued on our website.

## Examples of grade calculations based on table applicable to registrations from September 2016

### Example 1: Achievement of a Diploma with a PP grade

	GLH	Type (Int/Ext)	Grade	Unit points
Unit 1	90	Ext	Pass	9
Unit 2	90	Int	Pass	9
Unit 3	120	Ext	Pass	12
Unit 4	90	Int	Pass	9
Unit 5	120	Ext	Pass	12
Unit 6	90	Int	Merit	15
Unit 8	60	Int	U	0
Unit 9	60	Int	Merit	10
<b>Totals</b>	<b>720</b>		<b>PP</b>	<b>76</b>

The learner has achieved N or higher in Units 1, 3 and 5, P or higher in Unit 6 and a P or higher in at least one of Units 2 and 4

The learner has sufficient points for a PP grade

### Example 2: Achievement of a Diploma with a DD grade

	GLH	Type (Int/Ext)	Grade	Unit points
Unit 1	90	Ext	Distinction	24
Unit 2	90	Int	Merit	15
Unit 3	120	Ext	Near Pass	8
Unit 4	90	Int	Distinction	24
Unit 5	120	Ext	Distinction	32
Unit 6	90	Int	Merit	15
Unit 8	60	Int	Merit	10
Unit 9	60	Int	Distinction	16
<b>Totals</b>	<b>720</b>		<b>DD</b>	<b>144</b>

The learner has sufficient points for a DD grade

### Example 3: An Unclassified result for a Diploma

	GLH	Type (Int/Ext)	Grade	Unit points
Unit 1	90	Ext	Pass	9
Unit 2	90	Int	U	0
Unit 3	120	Ext	U	0
Unit 4	90	Int	Pass	9
Unit 5	120	Ext	Distinction	32
Unit 6	90	Int	Merit	15
Unit 8	60	Int	Pass	6
Unit 9	60	Int	Merit	10
<b>Totals</b>	<b>720</b>		<b>U</b>	<b>81</b>

The learner has a U in Units 2 and 3.

The learner has sufficient points for a PP grade but has not met the minimum requirement for N or higher in Units 1, 3, 5 and P or higher in Unit 6.

# 10 Resources and support

Our aim is to give you a wealth of resources and support to enable you to deliver BTEC National qualifications with confidence. On our website you will find a list of resources to support teaching and learning, and professional development.

## Support for setting up your course and preparing to teach

### Specification

This **specification** (for teaching from September 2016) includes details on the administration of qualifications and information on all the units for the qualification.

### Delivery Guide

This free guide gives you important advice on how to choose the right course for your learners and how to ensure you are fully prepared to deliver the course. It explains the key features of BTEC Nationals (for example employer involvement and employability skills). It also covers guidance on assessment (internal and external) and quality assurance. The guide tells you where you can find further support and gives detailed unit-by-unit delivery guidance. It includes teaching tips and ideas, assessment preparation and suggestions for further resources.

### Schemes of work

Free sample schemes of work are provided for each mandatory unit. These are available in Word™ format for ease of customisation.

### Curriculum models

These show how the BTECs in the suite fit into a 16–19 study programme, depending on their size and purpose. The models also show where other parts of the programme, such as work experience, maths and English, tutorial time and wider study, fit alongside the programme.

### Study skills activities

A range of case studies and activities is provided; they are designed to help learners develop the study skills they need to successfully complete their BTEC course. The case studies and activities are provided in Word™ format for easy customisation.

### myBTEC

myBTEC is a free, online toolkit that lets you plan and manage your BTEC provision from one place. It supports the delivery, assessment and quality assurance of BTECs in centres and supports teachers with the following activities:

- checking that a programme is using a valid combination of units
- creating and verifying assignment briefs (including access to a bank of authorised assignment briefs that can be customised)
- creating assessment plans and recording assessment decisions
- tracking the progress of every learner throughout their programme.

To find out more about myBTEC, visit the myBTEC page on the support services section of our website. We will add the new BTEC National specifications to myBTEC as soon possible.

## Support for teaching and learning

Pearson Learning Services provides a range of engaging resources to support BTEC Nationals, including:

- textbooks in e-book and print formats
- revision guides and revision workbooks in e-book and print formats
- teaching and assessment packs, including e-learning materials via the Active Learn Digital Service.

Teaching and learning resources are also available from a number of other publishers. Details of Pearson's own resources and of all endorsed resources can be found on our website.

## Support for assessment

### Sample assessment materials for externally-assessed units

Sample assessments are available for the Pearson-set units. One copy of each of these assessments can be downloaded from the website/available in print. For each suite an additional sample for one of the Pearson-set units is also available, allowing your learners further opportunities for practice.

Further sample assessments will be made available through our website on an ongoing basis.

### Sample assessment materials for internally-assessed units

We do not prescribe the assessments for the internally-assessed units. Rather, we allow you to set your own, according to your learners' preferences and to link with your local employment profile.

We do provide a service in the form of Authorised Assignment Briefs, which are approved by Pearson Standards Verifiers. They are available via our website or free on myBTEC.

### Sample marked learner work

To support you in understanding the expectation of the standard at each grade, examples of marked learner work at PM/MD grades are linked to the Authorised Assignment Briefs.

## Training and support from Pearson

### People to talk to

There are many people who are available to support you and provide advice and guidance on delivery of your BTEC Nationals. These include:

- Subject Advisors – available for all sectors. They understand all Pearson qualifications in their sector and so can answer sector-specific queries on planning, teaching, learning and assessment
- Standards Verifiers – they can support you with preparing your assignments, ensuring that your assessment plan is set up correctly, and support you in preparing learner work and providing quality assurance through sampling
- Curriculum Development Managers (CDMs) – they are regionally based and have a full overview of the BTEC qualifications and of the support and resources that Pearson provides. CDMs often run network events
- Customer Services – the ‘Support for You’ section of our website gives the different ways in which you can contact us for general queries. For specific queries, our service operators can direct you to the relevant person or department.

### Training and professional development

Pearson provides a range of training and professional development events to support the introduction, delivery, assessment and administration of BTEC National qualifications. These sector-specific events, developed and delivered by specialists, are available both face to face and online.

#### **‘Getting Ready to Teach’**

These events are designed to get teachers ready for delivery of the BTEC Nationals. They include an overview of the qualifications’ structures, planning and preparation for internal and external assessment, and quality assurance.

#### **Teaching and learning**

Beyond the ‘Getting Ready to Teach’ professional development events, there are opportunities for teachers to attend sector- and role-specific events. These events are designed to connect practice to theory; they provide teacher support and networking opportunities with delivery, learning and assessment methodology.

Details of our training and professional development programme can be found on our website.





## Appendix 1 Links to industry standards

BTEC Nationals have been developed in consultation with industry and appropriate sector bodies to ensure that the qualification content and approach to assessment aligns closely to the needs of employers. Where they exist, and are appropriate, National Occupational Standards (NOS) and professional body standards have been used to establish unit content.

In the applied science sector, the following approach has been used:

- use of Registered Science Technician competencies in the assessment criteria and guidance in units.

## Appendix 2 Glossary of terms used for internally-assessed units

This is a summary of the key terms used to define the requirements in the units.

Term	Definition
Examine	Knowledge with application where learners are expected to select and apply knowledge to less familiar contexts.
Explore	Skills and/or knowledge involving practical testing or trialling.
Review	Process for learning (knowledge or skills).
Undertake	Skills, often referring to given processes or techniques.
Understand	For defined knowledge in familiar contexts.
Analyse	Learners present the outcome of methodical and detailed examination either: <ul style="list-style-type: none"> <li>• breaking down a theme, topic or situation in order to interpret and study the interrelationships between the parts and/or</li> <li>• of information or data to interpret and study key trends and interrelationships.</li> </ul> Analysis can be through performance, practice, written or, less commonly, verbal presentation.
Apply	Application of skills, knowledge and understanding to or within context/situation.
Assess	Learners present a careful consideration of varied factors or events that apply to a specific situation or, to identify those which are the most important or relevant and arrive at a conclusion.
Calculate	Learners manipulate quantitative data to help analyse and compare findings.
Compare	Learners identify the main factors relating to two or more items/situations or aspects of a subject that is extended to explain the similarities, differences, advantages and disadvantages.  This is used to show depth of knowledge through selection and isolation of characteristics.
Conduct/use (of)/carry out	Related to use and demonstration of practical equipment/techniques/procedures.
Construct	Used with a standard to demonstrate competence in set up of practical equipment.

Term	Definition
Describe	<p>Learners' work gives a clear, objective account in their own words showing recall and, in some cases application, of the relevant features and information about a subject.</p> <p>Use of this verb normally requires breadth of content coverage.</p> <p>Evidence will normally be written but could be through presentation or, less frequently, performance or practice.</p>
Determine	<p>Learners use quantitative and/or qualitative information to help analyse and compare findings.</p>
Discuss	<p>Learners consider different aspects of:</p> <ul style="list-style-type: none"> <li>• a theme or topic;</li> <li>• how they interrelate; and</li> <li>• the extent to which they are important.</li> </ul> <p>A conclusion is not required.</p>
Evaluate	<p>Learners' work draws on varied information, themes or concepts to consider aspects such as:</p> <ul style="list-style-type: none"> <li>• strengths or weaknesses</li> <li>• advantages or disadvantages</li> <li>• alternative actions</li> <li>• relevance or significance.</li> </ul> <p>Learners' inquiries should lead to a supported judgement showing relationship to its context. This will often be in a conclusion.</p>
Explain	<p>Learners' work shows clear details and gives reasons and/or evidence to support an opinion, view or argument. It could show how conclusions are drawn (arrived at). Learners are able to show that they comprehend the origins, functions and objectives of a subject, and its suitability for purpose.</p>
Illustrate	<p>Learners include examples, images or diagrams to show what is meant in a specific context.</p>
Investigate	<p>Knowledge based on personal research and development.</p>
Justify	<p>Learners give reasons or evidence to:</p> <ul style="list-style-type: none"> <li>• support an opinion</li> <li>• prove something right or reasonable.</li> </ul>
Predict (make predictions)	<p>Learners can synthesise predictions using applications of relevant knowledge and understanding in a given context.</p>
Prepare	<p>Used with a standard to demonstrate competence in preparation of testing materials, for example organic and inorganic substances/solutions.</p>

This is a key summary of the types of evidence used for BTEC Nationals.

<b>Type of evidence</b>	<b>Definition and purpose</b>
Case study	A specific example to which all learners must select and apply knowledge. Used to show application to a realistic context where direct experience cannot be gained.
Individual project	A self-directed, large-scale activity requiring planning, research, exploration, outcome and review. Used to show self-management, project management and/or deep learning, including synopticity.
Development log	A record kept by learners to show the process of development. Used to show method, self-management and skill development.
Report writing	A report, consisting of analysis of findings could be through research or primary investigations conducted.
Presentation	A visual or audio presentation of findings that demonstrates knowledge and understanding of a concept.



# Pearson

# BTEC Level 3 Nationals

# in

# Applied Science

Certificate in Applied Science

Extended Certificate in Applied Science

Foundation Diploma in Applied Science

**Diploma in Applied Science**

Extended Diploma in Applied Science

For more information about Edexcel, BTEC or LCCI qualifications  
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