

CONDITIONS AND REQUIREMENTS

# GCE Subject Level Conditions and Requirements for Science (Biology, Chemistry, Physics) and Certificate Requirements (2021)

November 2020

**ofqual**

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## Introduction

### About this document

This document is part of a suite of documents which sets out the regulatory requirements for awarding organisations offering reformed A levels and AS qualifications in 2021.

We have developed all our requirements for GCE qualifications with the intention that AS and A level qualifications should fulfil the purposes set out in the table below:

A levels	AS qualifications
<ul style="list-style-type: none"><li>■ define and assess achievement of the knowledge, skills and understanding which will be needed by students planning to progress to undergraduate study at a UK higher education establishment, particularly (although not only) in the same subject area;</li><li>■ set out a robust and internationally comparable post-16 academic course of study to develop that knowledge, skills and understanding;</li><li>■ permit UK universities to accurately identify the level of attainment of students;</li><li>■ provide a basis for school and college accountability measures at age 18; and</li><li>■ provide a benchmark of academic ability for employers.</li></ul>	<ul style="list-style-type: none"><li>■ provide evidence of students' achievements in a robust and internationally comparable post-16 course of study that is a sub-set of A level content;</li><li>■ enable students to broaden the range of subjects they study.</li></ul>

### Requirements set out in this document

This document sets out the GCE Subject Level Conditions for Science subjects (Biology, Chemistry and Physics) in 2021. These conditions will come into effect at 09:30 on 5 November 2020 for the following qualifications:

- All GCE A levels in Science subjects (Biology, Chemistry and Physics); and
- All standalone GCE AS qualifications in Science subjects (Biology, Chemistry and Physics)

for Learners completing the qualification in 2021, except where the GQCov Framework applies.

It also sets out our:

- interpretation of the content document - an awarding organisation must comply with these requirements under Condition GCE(Science)1.1(c);
- assessment objectives - awarding organisations must comply with these assessment objectives under Condition GCE(Science)1.2;
- requirements in relation to practical assessments - awarding organisations must comply with these requirements under Condition GCE(Science)3.2; and
- certificate requirements - awarding organisations must comply with these requirements under Condition GCE(Science)4.3 and General Condition I3.1.

Appendix 1 reproduces the subject content requirements for GCE Science qualifications in Biology, Chemistry and Physics, as published by the Department for Education. Awarding organisations must comply with these requirements under Condition GCE(Science)1.1.

With respect to the qualifications listed above, awarding organisations must also comply with:

- our [General Conditions of Recognition](#), which apply to all awarding organisations and qualifications;
- our [GCE Qualification Level Conditions](#); and
- all [relevant Regulatory Documents](#).

With respect to all other GCE qualifications in Biology, Chemistry and Physics, taken by Learners completing the qualification in 2022 and after, an awarding organisation must continue to comply with the [GCE Subject Level Conditions and Requirements for Science \(Biology, Chemistry, Physics\)](#).

## Subject Level Conditions

### GCE Subject Level Conditions for Science (Biology, Chemistry and Physics)

#### *Condition GCE(Science) 1: Compliance with content requirements*

##### **GCE (Science)1.1**

In respect of each GCE Qualification in Biology, Chemistry or Physics which it makes available, or proposes to make available, an awarding organisation must -

- (a) comply with the requirements relating to that qualification set out in the document published by the Secretary of State entitled '[GCE AS and A level subject content for biology, chemistry, physics and psychology](#)' DFE-00356-2014,
- (b) have regard to any recommendations or guidelines relating to that qualification set out in that document, and
- (c) interpret that document in accordance with any requirements, and having regard to any guidance, which may be published by Ofqual and revised from time to time.

##### **GCE (Science)1.2**

In respect of each GCE Qualification in Biology, Chemistry or Physics which it makes available, or proposes to make available, an awarding organisation must comply with any requirements, and have regard to any guidance, relating to the objectives to be met by any assessment for that qualification which may be published by Ofqual and revised from time to time.

## **Condition GCE(Science) 2: Practical skills**

### **GCE (Science)2.1**

In respect of each GCE A level qualification in Biology, Chemistry or Physics which it makes available, or proposes to make available, an awarding organisation must -

- (a) require each Learner to complete practical activities, and
- (b) ensure that, taken together, those practical activities provide opportunities for each Learner to -
  - (i) develop all of the skills specified in relation to the qualification in appendix 5a to the content document, and
  - (ii) use and be assessed in relation to some or all of the skills, apparatus and techniques specified in relation to the qualification in appendices 5b and 5c to the content document.

### **GCE (Science)2.2**

In respect of each GCE A level qualification in Biology, Chemistry or Physics which it makes available, or proposes to make available, an awarding organisation must -

- (a) review the practical activities which it requires each Learner to complete following any revision by the Secretary of State to the skills, apparatus or techniques specified in respect of that qualification, and
- (b) revise those practical activities if appropriate.

### **GCE (Science)2.3**

In respect of each GCE A level qualification in Biology, Chemistry or Physics which it makes available, or proposes to make available, an awarding organisation must -

- (a) set out in the specification for that qualification -
  - (i) the practical activities which each Learner must complete, and
  - (ii) in particular, the skills and techniques which those practical activities must allow each Learner to develop or demonstrate, and the apparatus which those practical activities must allow each Learner to use, and
- (b) promptly amend that specification when the awarding organisation makes any revision to those skills, techniques or apparatus, or those practical activities, and
- (c) where such an amendment has been made to the specification, publish that specification as amended.

### **GCE (Science)2.4**

In respect of each assessment cycle for each GCE A level qualification in Biology, Chemistry or Physics which it makes available, an awarding organisation must -

- (a) require each Centre to provide a practical science statement to the awarding organisation, and
- (b) treat any failure by a Centre to provide a practical science statement to the awarding organisation in a timely manner as malpractice and/or maladministration (under General Condition A8 (Malpractice and maladministration)).

### **GCE (Science)2.5**

For the purposes of this condition, the content document is the document specified in Condition GCE(Science)1.1(a).

### **GCE (Science)2.6**

For the purposes of this condition, a 'practical science statement' is a true and accurate written statement made by a Centre to an awarding organisation which confirms that it has taken reasonable steps to secure that each Learner to which that Centre has delivered the assessments to be taken in a particular assessment cycle for each A level qualification in Biology, Chemistry or Physics which the awarding organisation makes available has -

- (a) completed practical activities as required by the awarding organisation, and
- (b) made a contemporaneous record of the work which that Learner has undertaken during those practical activities.

## **Condition GCE(Science) 3: Practical Science Assessments**

### **GCE(Science)3.1**

In respect of a practical science assessment for each GCE A level qualification in Biology, Chemistry or Physics that an awarding organisation makes available or proposes to make available -

- (a) Condition H2 does not apply,
- (b) Condition GCE4.1 does not apply, and
- (c) that assessment must not be an Assessment by Examination.

### **GCE(Science)3.2**

An awarding organisation must ensure that in respect of each practical science assessment for each GCE A level qualification in Biology, Chemistry or Physics which it makes available it complies with any requirements, and has regard to any guidance, which may be published by Ofqual and revised from time to time.

### **GCE(Science)3.3**

For the purposes of this condition, a 'practical science assessment' is an assessment -

- (a) of a Learner's competency in the skills outlined in appendix 5b, and the use of some or all of the apparatus and techniques outlined in the relevant section of appendix 5c, to the document published by the Secretary of State entitled ['GCE AS and A level subject content for biology, chemistry, physics and psychology'](#), document reference DFE- 00356-2014,
- (b) as evidenced by the Learner's performance in practical activities as required by the awarding organisation under Condition GCE(Science)2.1.

## **Condition GCE(Science) 4: Marking and results**

### **GCE(Science)4.1**

In respect of each GCE A level qualification in Biology, Chemistry or Physics which it makes available an awarding organisation must calculate and publish the following two separate results for each Learner -

- (a) a result for the Assessments by Examination to be taken for that qualification, and
- (b) a result for the practical science assessment.

### **GCE(Science)4.2**

In respect of each GCE A level qualification in Biology, Chemistry or Physics which it makes available, an awarding organisation must ensure that an Assessor does not have any regard to a Learner's

-

- (a) result for the practical science assessment in calculating that Learner's final mark and result for the Assessments by Examination, and/or
- (b) final mark or result for the Assessments by Examination in determining that Learner's result for the practical science assessment.

### **GCE(Science)4.3**

In respect of each practical science assessment an awarding organisation must ensure that it complies with any Certificate Requirements in relation to that assessment which may be published by Ofqual and revised from time to time.

### **GCE(Science)4.4**

In respect of each GCE A level qualification in Biology, Chemistry or Physics which it makes available, an awarding organisation must ensure that

-

- (a) a Learner may use the result for a practical science assessment which he or she has taken for a GCE A level qualification in the same science subject made available by the awarding organisation or another awarding organisation, and
- (a) that Learner is not required to take a further practical science assessment before being awarded the qualification.

### **GCE(Science)4.5**

For the purposes of this condition, a practical science assessment' has the same meaning as in Condition GCE(Science)3.3.

## Subject content requirements

### Requirements in relation to subject content for GCE Science

The subject content for GCE Qualifications in Science (Biology, Chemistry and Physics) is set out in the Department for Education's [GCE AS and A level subject content](#), document reference DFE-00356- 2014 (the 'Content Document').

Condition GCE(Science)1.1(c) requires awarding organisations to interpret the Content Document in line with any requirements, and having regard to any guidance, published by Ofqual.

We set out our requirements for the purposes of Condition GCE(Science)1.1(c) below.

#### *Practical activities*

An awarding organisation must interpret the Content Document as if -

- (b) the requirement for a Learner to complete 12 practical activities has been disapplied, and
- (c) the Common Practical Assessment Criteria are assessed using the minimum number of practical activities required to demonstrate competence.

## Requirements in relation to practical science assessments

### Requirements in relation to practical science assessments

Condition GCE(Science)3.2 allows us to specify requirements and guidance in relation to practical science assessments (as defined in Condition GCE(Science)3.3) for GCE Science qualifications in Biology, Chemistry and Physics.

We set out our requirements for the purposes of Condition GCE(Science)3.2 below.

#### *Form of the practical science assessment*

An awarding organisation must ensure that each practical science assessment is designed and set in such a way as to allow a Learner who has demonstrated the competencies outlined in Table 1 below to reach a Pass.

#### *Marking of practical science assessments*

Evidence generated by a Learner in a practical science assessment may be marked

- (a) by a Centre,
- (b) by the awarding organisation or a person connected to the awarding organisation, or
- (c) through a combination of (a) and (b).

In any event, the awarding organisation must demonstrate to Ofqual's satisfaction in its assessment strategy that -

- (a) it has taken all reasonable steps to identify the risk of any Adverse Effect which may result from its approach to marking practical science assessments, and
- (b) where such a risk is identified, it has taken all reasonable steps to prevent that Adverse Effect or, where it cannot be prevented, to mitigate that Adverse Effect.

#### *The specified level of attainment in practical science assessments*

In relation to each practical science assessment, an awarding organisation must ensure that -

- (a) the only specified level of attainment is a Pass,
- (b) the criteria used by Assessors to determine whether each Learner will be awarded a Pass are those set out in Table 1 below, and
- (c) a Learner who does not meet the criteria to be awarded a Pass, or who has not been exempted on grounds of disability from the assessment but who does not take that assessment, is issued a result of Not Classified .

Under Condition H1.1, an awarding organisation must have in place arrangements to ensure that, as far as possible, the criteria set out in Table 1 are -

- (a) understood by Assessors and accurately applied, and
- (b) applied consistently by Assessors, regardless of the identity of the Assessor, Learner or Centre.

### ***The criteria for a Pass***

In order to be awarded a Pass a Learner must, by the end of the practical science assessment, consistently and routinely meet the criteria in respect of each competency listed below. A Learner may demonstrate the competencies in any practical activity undertaken as part of that assessment throughout the course of study.

Learners may undertake practical activities in groups. However, the evidence generated by each Learner must demonstrate that he or she independently meets the criteria outlined below in respect of each competency. Such evidence -

- (a) will comprise both the Learner's performance during each practical activity and his or her contemporaneous record of the work that he or she has undertaken during that activity, and
- (b) must include evidence of independent application of investigative approaches and methods to practical work.

*Table 1: The criteria for a Pass*

<b>Competency</b>	<b>Assessment criteria</b>
1 – Follows written procedures	a) Correctly follows written instructions to carry out experimental techniques or procedures
2 – Applies investigative approaches and methods when using instruments and equipment	<ul style="list-style-type: none"> <li>a) Correctly uses appropriate instrumentation, apparatus and materials (including ICT) to carry out investigative activities, experimental techniques and procedures with minimal assistance or prompting.</li> <li>b) Carries out techniques or procedures methodically, in sequence and in combination, identifying practical issues and making adjustments where necessary.</li> <li>c) Identifies and controls significant quantitative variables where applicable, and plans approaches to take account of variables that cannot readily be controlled.</li> <li>d) Selects appropriate equipment and measurement strategies in order to ensure suitably accurate</li> </ul>

Competency	Assessment criteria
	results.
3 – Safely uses a range of practical equipment and materials	a) Identifies hazards and assesses risks associated with those hazards, making safety adjustments as necessary, when carrying out experimental techniques and procedures in the lab or field.  b) Uses appropriate safety equipment and approaches to minimise risks with minimal prompting.
4 – Makes and records observations	a) Makes accurate observations relevant to the experimental or investigative procedure.  b) Obtains accurate, precise and sufficient data for experimental and investigative procedures and records this methodically using appropriate units and conventions.
5 – Researches, references and reports	c) Uses appropriate software and/or tools to process data, carry out research and report findings.  d) Cites sources of information demonstrating that research has taken place, supporting planning and conclusions.

### ***Monitoring of practical science assessments***

In respect of each GCE A level qualification in Biology, Chemistry or Physics which it makes available, an awarding organisation must have in place clear and effective arrangements to monitor the delivery and, where relevant, the marking of practical science assessments by Centres.

As part of those arrangements, an awarding organisation must ensure that each Centre which delivers practical science assessments receives a monitoring visit at least every two years (a 'Monitoring Visit').

This requirement may be met by way of a Monitoring Visit conducted by another awarding organisation which makes available a GCE A level qualification in Biology, Chemistry or Physics. Such a Monitoring Visit conducted by another awarding organisation may relate to practical science assessments in any of Biology, Chemistry or Physics. An awarding organisation must ensure that, over time, the practical science assessments for the GCE A level qualification in Biology, Chemistry or Physics which it makes available are the subject of a Monitoring Visit.

An awarding organisation may only rely on a Monitoring Visit undertaken by another awarding organisation where it has reasonable grounds to believe that the Monitoring Visit has included the activities outlined at (a) - (e) below. Where an awarding organisation does not have reasonable grounds for such a belief it must take action to ensure that it satisfies its obligations in respect of the monitoring of practical science assessments.

An awarding organisation must take reasonable steps to ensure that each Monitoring Visit it conducts, and must have reasonable grounds to believe that each Monitoring Visit undertaken by another awarding organisation on which it wishes to rely, includes the following activities -

- (a) Observation of one or more practical activities being undertaken.
- (b) Steps to ensure that, where evidence generated by a Learner in the practical science assessment is marked by the Centre, Teachers are applying the criteria outlined above accurately and consistently.
- (c) Steps to ensure that Learners have been provided with opportunities to undertake practical activities.
- (d) A review of samples of records of Learners' practical activities and Centres' documentation in relation to those activities to ensure that all relevant requirements in relation to the practical activities and practical science assessments are being met.
- (e) Where appropriate, the provision of advice and guidance to the Centre.

Where, during a Monitoring Visit, an awarding organisation identifies an Adverse Effect, or a risk of an Adverse Effect, relating to the delivery or marking of practical science assessments, it must ensure all other awarding organisations for whom that Centre delivers practical assessments for GCE A level qualifications in Biology, Chemistry, Geology or Physics are informed.

An awarding organisation must set out its approach to monitoring, and in particular how it will meet the above requirements, in its assessment strategy for each GCE A level qualification in Biology, Chemistry or Physics which it makes available, or proposes to make available.

An awarding organisation may carry out Monitoring Visits remotely in 2020/21.

# Certificate Requirements

## Certificate Requirements

Condition GCE(Science)4.3 allows us to specify Certificate Requirements in relation to the way in which a Learner's attainment in a practical science assessment is reflected on that Learner's certificate for the qualification.

In addition, under Condition I3.1, an awarding organisation is required to ensure that the design of each certificate in relation to a qualification which it makes available complies with the Certificate Requirements which may be published by Ofqual and revised from time to time.

We set out our Certificate Requirements for the purposes of Condition GCE(Science)4.3 and Condition I3.1 below.

These requirements must be followed together with the [Additional Certificate Requirements](#) which apply to all qualifications.

### *Certificate requirements for practical science assessments*

A certificate will only be issued for a GCE A level Science qualification in Biology, Chemistry or Physics where a Learner has been awarded a grade A\* - E in respect of the level of attainment he or she has demonstrated in the Assessments by Examination to be taken for that qualification.

Where a Learner has not been awarded a grade A\* - E in respect of those Assessments by Examination, an awarding organisation must ensure that no certificate is issued in respect of that Learner's practical science assessment, regardless of the result for that assessment.

For clarity, the result for that Learner's practical science assessment must still be issued, together with the Learner's result in respect of the Assessments by Examination, under Condition H6.1.

Where a certificate will be issued to a Learner in respect of the Assessments by Examination, an awarding organisation must ensure that it meets the following requirements in recording the outcome of the practical science assessment on that certificate -

- (a) Where the Learner has been awarded a Pass, that outcome must be recorded on the certificate.
- (b) Where the Learner -
  - (i) has taken the practical science assessment but has not been awarded a Pass, or
  - (ii) has not been granted an exemption on grounds of disability from taking the practical science assessment, but has not taken it,the outcome reported on the certificate must be Not Classified.
- (c) Where the Learner has been granted an exemption from taking the practical science assessment on grounds of disability, the outcome reported on the certificate must be in line with any requirements which may be published by Ofqual and revised from time to time.

In all cases an awarding organisation must ensure that it is clear that the above outcomes are in relation to the practical science assessment.

## Assessment objectives

### Assessment objectives - GCE AS and A level qualifications in Science (Biology, Chemistry and Physics)

Condition GCE(Science)1.2 allows us to specify requirements relating to the objectives to be met by any assessment for GCE Science Qualifications in Biology, Chemistry or Physics.

The assessment objectives set out below constitute requirements for the purposes of Condition GCE(Science)1.2. Awarding organisations must comply with these requirements in relation to all GCE AS and A level Science qualifications in Biology, Chemistry or Physics they make available.

	Objective	A level	AS
AO1	Demonstrate knowledge and understanding of scientific ideas, processes, techniques and procedures	30-35%	35-40%
AO2	Apply knowledge and understanding of scientific ideas, processes, techniques and procedures: <ul style="list-style-type: none"><li>■ in a theoretical context</li><li>■ in a practical context</li><li>■ when handling qualitative data</li><li>■ when handling quantitative data</li></ul>	40-45%	40-45%
AO3	Analyse, interpret and evaluate scientific information, ideas and evidence, including in relation to issues, to: <ul style="list-style-type: none"><li>■ make judgements and reach conclusions</li><li>■ develop and refine practical design and procedures</li></ul>	25-30%	20-25%

The ability to use mathematical skills at a level appropriate for GCE Qualifications in Biology, Chemistry or Physics must be tested across the assessment objectives. The weighting of mathematical skills must be at least -

- in respect of GCE Qualifications in Biology, 10 per cent
- in respect of GCE Qualifications in Chemistry, 20 per cent
- in respect of GCE Qualifications in Physics, 40 per cent

The ability to select, organise and communicate information and ideas coherently using appropriate scientific conventions and vocabulary must be tested across the assessment objectives. The following definitions apply in relation to the assessment objectives:

- Knowledge includes facts, specialist vocabulary, principles, concepts, theories, models, practical techniques, studies and methods.
- Processes include collecting evidence, explaining, theorising, modelling, validating, interpreting, planning to test an idea and peer reviewing.
- Issues include those that are ethical, social, economic, environmental, cultural, political and technological.

## **Appendix 1 – Subject content (published by Department for Education)**



Department  
for Education

# **GCE AS and A level subject content for biology, chemistry, physics and psychology**

**April 2014**

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# GCE AS and A level subject content for biology, chemistry, physics and psychology

## Introduction

1. AS and A level subject content sets out the knowledge, understanding and skills common to all AS and A level specifications in biology, chemistry, physics and psychology.

## Aims and objectives

2. AS and A level specifications in a science subject must encourage students to:
- develop essential knowledge and understanding of different areas of the subject and how they relate to each other
  - develop and demonstrate a deep appreciation of the skills, knowledge and understanding of scientific methods
  - develop competence and confidence in a variety of practical, mathematical and problem solving skills
  - develop their interest in and enthusiasm for the subject, including developing an interest in further study and careers associated with the subject
  - understand how society makes decisions about scientific issues and how the sciences contribute to the success of the economy and society

## Subject content

3. AS and A level science specifications must build on the skills, knowledge and understanding set out in the GCSE criteria/content for science.

4. The skills, knowledge and understanding set out in the appendices for AS in each science subject must comprise approximately 60 per cent of AS specifications. The skills, knowledge and understanding for A level must comprise approximately 60 per cent of an A level specification. For A level this would include all the practical requirements in Appendix 5, while for AS it would include those from Appendix 5a. For both AS and A level it would include the mathematical requirements on Appendix 6.

5. The remainder of both AS and A level specifications allows both for:
- further consideration of applications and implications of science and the development of scientific ideas

- the introduction of different areas of study
6. AS and A level specifications must include a range of contemporary and other contexts.
7. AS and A level specifications must require students to cover the areas of the subject as illustrated in the relevant appendix.
8. The skills, knowledge and understanding of each specification in the subject must, where appropriate, include the requirements set out below, and be integrated into the mandatory content indicated in the relevant appendix and any content added by the awarding organisation, where appropriate:
- use theories, models and ideas to develop scientific explanations
  - use knowledge and understanding to pose scientific questions, define scientific problems, present scientific arguments and scientific ideas
  - use appropriate methodology, including information and communication technology (ICT), to answer scientific questions and solve scientific problems
  - carry out experimental and investigative activities, including appropriate risk management, in a range of contexts
  - analyse and interpret data to provide evidence, recognising correlations and causal relationships
  - evaluate methodology, evidence and data, and resolve conflicting evidence
  - know that scientific knowledge and understanding develops over time
  - communicate information and ideas in appropriate ways using appropriate terminology
  - consider applications and implications of science and evaluate their associated benefits and risks
  - consider ethical issues in the treatment of humans, other organisms and the environment
  - evaluate the role of the scientific community in validating new knowledge and ensuring integrity
  - evaluate the ways in which society uses science to inform decision making

## Appendix 1 - biology – knowledge and understanding

9. This appendix must be read in conjunction with sections 3 - 8 of this content.

10. The A level knowledge and understanding combined must comprise approximately 60 per cent of an A level specification. All of the content below is required for the A level. The AS knowledge and understanding set out in this appendix must comprise approximately 60 per cent of the AS specification, and is shown below in normal (non-bold) text.

11. Biology specifications must ensure that there is an appropriate balance between plant biology, animal biology and microbiology and include an appreciation of the relevance of sustainability to all aspects of scientific developments.

12. Living organisms, including plants, animals and microorganisms, interact with each other and with the non-living world. The living world can be studied at population, organism, cell and molecular levels. There are fundamental similarities as well as differences between plants, animals and microorganisms.

13. Biodiversity

- the variety of life, both past and present, is extensive, but the biochemical basis of life is similar for all living things
- biodiversity refers to the variety and complexity of life and may be considered at different levels
- biodiversity can be measured, for example within a habitat or at the genetic level
- classification is a means of organising the variety of life based on relationships between organisms and is built around the concept of species
- originally classification systems were based on observable features but more recent approaches draw on a wider range of evidence to clarify relationships between organisms
- adaptations of organisms to their environments can be behavioural, physiological and anatomical
- adaptation and selection are major factors in evolution and make a significant contribution to the diversity of living organisms

14. Exchange and transport

- organisms need to exchange substances selectively with their environment and this takes place at exchange surfaces

- factors such as size or metabolic rate affect the requirements of organisms and this gives rise to adaptations such as specialised exchange surfaces and mass transport systems
- substances are exchanged by passive or active transport across exchange surfaces
- the structure of the plasma membrane enables control of the passage of substances into and out of cells

#### 15. Cells

- the cell theory is a unifying concept in biology
- prokaryotic and eukaryotic cells can be distinguished on the basis of their structure and ultrastructure
- in complex multicellular organisms cells are organised into tissues, tissues into organs and organs into systems
- during the cell cycle genetic information is copied and passed to daughter cells
- daughter cells formed during mitosis have identical copies of genes while cells formed during meiosis are not genetically identical

#### 16. Biological molecules

- biological molecules are often polymers and are based on a small number of chemical elements
- in living organisms nucleic acids (DNA and RNA), carbohydrates, proteins, lipids, inorganic ions and water all have important roles and functions related to their properties
- the sequence of bases in the DNA molecule determines the structure of proteins, including enzymes
- enzymes catalyse the reactions that determine structures and functions from cellular to whole-organism level
- enzymes are proteins with a mechanism of action and other properties determined by their tertiary structure
- enzymes catalyse a wide range of intracellular reactions as well as extracellular ones
- ATP provides the immediate source of energy for biological processes

#### 17. Ecosystems

- **ecosystems range in size from the very large to the very small**

- **biomass transfers through ecosystems and the efficiency of transfer through different trophic levels can be measured**
- **microorganisms play a key role in recycling chemical elements**
- **ecosystems are dynamic systems, usually moving from colonisation to climax communities in a process known as succession**
- **the dynamic equilibrium of populations is affected by a range of factors**
- **humans are part of the ecological balance and their activities affect it both directly and indirectly**
- **effective management of the conflict between human needs and conservation help to maintain sustainability of resources**

18. Control systems

- **homeostasis is the maintenance of a constant internal environment**
- **negative feedback helps maintain an optimal internal state in the context of a dynamic equilibrium. Positive feedback also occurs**
- **stimuli, both internal and external, are detected leading to responses**
- **the genome is regulated by a number of factors**
- **coordination may be chemical or electrical in nature**

19. Genetics and evolution

- **transfer of genetic information from one generation to the next can ensure continuity of species or lead to variation within a species and possible formation of new species**
- **reproductive isolation can lead to accumulation of different genetic information in populations potentially leading to formation of new species**
- **sequencing projects have read the genomes of organisms ranging from microbes and plants to humans. This allows the sequences of the proteins that derive from the genetic code to be predicted**
- **gene technologies allow study and alteration of gene function in order to better understand organism function and to design new industrial and medical processes**

20. Energy for biological processes

- **in cellular respiration, glycolysis takes place in the cytoplasm and the remaining steps in the mitochondria**
- **ATP synthesis is associated with the electron transfer chain in the membranes of mitochondria and chloroplasts**

- **in photosynthesis energy is transferred to ATP in the light- dependent stage and the ATP is utilised during synthesis in the light-independent stage**

## Appendix 2 - chemistry – knowledge and understanding

21. This appendix must be read in conjunction with sections 3 - 8 of this content.
22. The A level knowledge and understanding combined must comprise approximately 60 per cent of an A level specification. All of the content below is required for the A level. The AS knowledge and understanding set out in this appendix must comprise approximately 60 per cent of the AS specification, and is shown below in normal (non-bold) text.
23. Chemistry specifications must ensure that there is an appreciation of the relevance of sustainability to all aspects of scientific developments.
24. Formulae, equations and amounts of substance
- empirical and molecular formulae
  - balanced chemical equations (full and ionic)
  - the Avogadro constant and the amount of substance (mole)
  - relative atomic mass and relative isotopic mass
  - calculation of reacting masses, mole concentrations, volumes of gases, per cent yields and atom economies
  - simple acid–base titrations
  - **non-structured titration calculations, based solely on experimental results**
25. Atomic structure
- structure and electronic configuration of atoms (up to  $Z = 36$ ) in terms of main energy levels and s, p and d orbitals
  - ions and isotopes; use of mass spectrometry in determining relative atomic mass and relative abundance of isotopes
26. Bonding and structure
- interpretation of ionic and covalent bonding in terms of electron arrangements. Examples of simple covalent, giant covalent, ionic and metallic structures
  - permanent and induced dipole–dipole interactions between molecules, including hydrogen bonding. Electronegativity and its application to bond type. Interpretation of the physical properties of materials in terms of structure and bonding
  - shapes of simple molecules and ions with up to six outer pairs of electrons (any combination of bonding pairs and lone pairs). Interpretation in terms of electron pair repulsion theory
27. Energetics

- enthalpy changes, including standard enthalpy changes of reaction, formation and combustion. Average bond enthalpies
- use of Hess's law to calculate enthalpy changes
- **use of energetics, including entropy, to predict the feasibility of reactions**

#### 28. Kinetics

- a qualitative understanding of collision theory. Activation energy and its relationship to the qualitative effect of temperature changes on rate of reaction. Boltzman distribution
- the role of catalysts in providing alternative routes of lower activation energy
- **determination and use of rate equations of the form:  $Rate = k[A]^m[B]^n$ , where  $m$  and  $n$  are integers. Using orders of reactions where appropriate, which may give information about a rate-determining/limiting step**

#### 29. Equilibria

- the dynamic nature of equilibria. For homogeneous reactions, the qualitative effects of temperature, pressure and concentration changes on the position of equilibrium
- equilibrium constants,  $K_c$
- **calculation of  $K_c$  and reacting quantities**
- **the effect of temperature changes on  $K_c$**
- **the Bronsted–Lowry theory of acid–base reactions. The ionic product of water,  $K_w$ ; pH and its calculation for strong acids and strong bases**
- **dissociation constants of weak acids,  $K_a$ . Calculation of pH for weak acids. Buffer solutions and their applications**

#### 30. Redox

- oxidation states and their calculation
- oxidation and reduction as electron transfer, applied to reactions of s, p and d block elements
- **electrode potentials and their applications**

#### 31. Inorganic chemistry and the periodic table

- the organisation of elements according to their proton number and electronic structures. Classification of elements into s, p and d blocks
- the characteristic reactions of the elements and compounds of a metallic group and a non-metallic group. Trends in properties of elements and compounds within these groups

- trends in properties of elements across a period including:
  - melting point
  - ionisation energy
- **the transition metals as d block elements forming one or more stable ions that have incompletely filled d orbitals. At least two transition metals, chosen from titanium to copper, to illustrate:**
  - **the existence of more than one oxidation state for each element in its compounds**
  - **the formation of coloured ions in solution and simple precipitation reactions of these**
  - **reactions with ligands to form complexes and reactions involving ligand substitution**
  - **the catalytic behaviour of the elements and their compounds**

### 32. Organic chemistry

- functional groups. Structural isomers and stereoisomers (to include geometric (E–Z) isomerism as a result of restricted rotation about a carbon–carbon double bond **and optical isomerism as a result of chirality in molecules with a single chiral centre**)
- reactions classified as addition, elimination, substitution, oxidation, **reduction, hydrolysis**, addition polymerisation **and condensation polymerisation**
- mechanisms classified as radical substitution, electrophilic addition, nucleophilic substitution, **electrophilic substitution and nucleophilic addition**
- single and double covalent bonds, bond polarity and bond enthalpy as factors influencing reactivity, illustrated by reference to appropriate reactions
- **the structure of, and the bonding in, benzene**
- organic synthesis, including characteristic reactions of alkanes, alkenes, halogenoalkanes, alcohols, **arenes, aldehydes, ketones, carboxylic acids, esters, amines, amino acids and amides**

### 33. Modern analytical techniques

- the use of mass spectrometry, infrared spectroscopy, **nuclear magnetic resonance spectroscopy and chromatography** in analysis, including techniques for the elucidation of structure

## Appendix 3 - physics – knowledge and understanding

34. This appendix must be read in conjunction with sections 3 - 8 of this content.
35. The A level knowledge and understanding combined must comprise approximately 60 per cent of an A level specification. All of the content below is required for the A level. The AS knowledge and understanding set out in this appendix must comprise approximately 60 per cent of the AS specification, and is shown below in normal (non-bold) text.
36. All physics specifications must ensure that there is an appropriate balance between mathematical calculations and written explanations. They also need to ensure that practical skills are developed.
37. All physics specifications must require knowledge and understanding of:
- the use of SI units and their prefixes
  - Newton's laws of motion
  - the estimation of physical quantities
  - the limitations of physical measurements
38. Vectors and scalars
- the distinction between vector and scalar quantities
  - resolution of vectors into two components at right angles
  - addition rule for two vectors
  - calculations for two perpendicular vectors
39. Mechanics
- kinematics:
    - use of kinematic equations in one dimension with constant velocity or acceleration
    - graphical representation of accelerated motion
    - interpretation of velocity-time and displacement-time graphs
  - dynamics:
    - use of  $F = ma$  when mass is constant
    - one- and two-dimensional motion under constant force
    - independent effect of perpendicular components with uniform acceleration, projectile motion

- energy:
  - calculation of work done for constant forces, including force not along the line of motion
  - calculation of exchanges between gravitational potential energy and kinetic energy
  - principle of conservation of energy
- momentum:
  - definition
  - principle of conservation of momentum
  - calculations for one-dimensional problems
- **circular motion:**
  - **radian measure of angle and angular velocity**
  - **application of  $F = ma = mv^2/r = mr\omega^2$  to motion in a circle at constant speed**
- **oscillations:**
  - **simple harmonic motion**
  - **quantitative treatment using  $a = -\omega^2x$  and its solution  $x = A \cos \omega t$ .**

#### 40. Mechanical properties of matter

- stress, strain, Young modulus
- force-extension graphs, energy stored

#### 41. Electric circuits

- current:
  - electric current as rate of flow of charge,  $I = \Delta q/\Delta t$
- emf and potential difference:
  - definition of emf and concept of internal resistance
  - potential difference in terms of energy transfer
- resistance:
  - definition
  - resistivity
  - Ohm's law

- DC Circuits:
  - conservation of charge and energy in circuits
  - relationships between currents, voltages and resistances in series and parallel circuits
  - power dissipated
  - potential divider circuits
- **capacitance:**
  - **definition**
  - **energy of a capacitor**
  - **quantitative treatment of charge and discharge curves**

#### 42. Waves

- qualitative treatment of polarisation and diffraction
- path difference, phase and coherence, interference
- graphical treatment of superposition and stationary waves

#### 43. Matter

- **molecular kinetic theory:**
  - **ideal gases;  $pV = NkT$**
  - **absolute zero**
  - **relationship between temperature and average molecular kinetic energy**
- **internal energy:**
  - **idea of internal energy**
  - **energy required for temperature change =  $mc\Delta\theta$**

#### 44. Quantum and nuclear physics

- photons and particles:
  - photon model to explain observable phenomena
  - evidence supporting the photon model
  - wave-particle duality, particle diffraction
- **nuclear decay:**
  - **connections between nature, penetration and range of emissions from radioactive substances**

- evidence for existence of nucleus
- activity of radioactive sources and idea of half-life
- modelling with constant decay probability leading to exponential decay
- nuclear changes in decay
- nuclear energy:
  - fission and fusion processes
  - $E = mc^2$  applied to nuclear processes
  - calculations relating mass difference to energy change

#### 45. Fields

- force fields:
  - concept and definition
  - gravitational force and inverse square field for point (or spherical) masses
  - electric force and field for point (or spherical) charges in a vacuum
  - electric and gravitational potential and changes in potential energy
  - uniform electric field
  - similarities and differences between electric and gravitational fields
- B-fields:
  - force on a straight wire and force on a moving charge in a uniform field
- flux and electromagnetic induction:
  - concept and definition
  - Faraday's and Lenz's laws
  - emf equals rate of change of magnetic flux linkage

## Appendix 4 - psychology – knowledge and understanding

46. This appendix must be read in conjunction with sections 3 - 8 of this content.

47. The A level knowledge and understanding combined must comprise approximately 60 per cent of an A level specification. All of the content below is required for the A level. The AS knowledge and understanding set out in this appendix must comprise approximately 60 per cent of the AS specification, and is set out in normal (non-bold) type below.

48. No prior knowledge of psychology is required for AS and A level specifications in psychology.

49. AS and A level specifications must require students to have a basic understanding of the scope of different areas in psychology and the breadth of different approaches used in psychology.

50. Students are expected to carry out ethical, investigative activities appropriate for the study of psychology at this level, but they will not be directly assessed on these activities.

51. AS specifications must require students to develop knowledge and understanding from all of the following areas of psychology:

- cognitive
- social
- developmental
- individual differences
- biological

52. AS specifications must also require students to develop knowledge and understanding of research in psychology including:

- methods and techniques for collection of quantitative and qualitative data including experimentation, observation, self-report and correlational analysis
- experimental design including independent measures and repeated measures
- descriptive statistics including measures of central tendency, dispersion and graphical presentation of results

53. In 51 and 52 above, there is a minimum requirement for specifications to cover the following:

- specialist vocabulary and terminology

- psychological theories, concepts and studies
- ethical issues in psychology
- the collection and analysis of both quantitative and qualitative data in psychology, including the use of descriptive statistics
- the strengths and weaknesses of methods of research and investigation in psychology
- the contribution of psychology to an understanding of individual, social and cultural diversity

**54. In addition to the AS content, A level specifications must require students to develop further knowledge, understanding and skills from at least two of the core areas (from cognitive, social, developmental, individual differences and biological psychology).**

**55. Students must have an understanding of different approaches used in psychology including cognitive, biological, behavioural and psychodynamic. Knowledge and understanding must be related to:**

- the applications and implications of psychology to cultural, social and contemporary issues
- the interrelationship between different areas of psychology
- the scientific nature of psychology
- the application of theories, concepts and approaches to the solution of problems
- the design and reporting of investigations and drawing valid conclusions from them
- the collection and analysis of both quantitative and qualitative data including the use of inferential statistics
- the application of principles and perspectives
- an appreciation of issues and debates in psychology

## Appendix 5 - working scientifically

Specifications in biology, chemistry and physics must encourage the development of the skills, knowledge and understanding in science through teaching and learning opportunities for regular hands-on practical work.

In order to develop the necessary skills, knowledge and understanding, students studying A levels in biology, chemistry and physics will be required to have carried out a minimum of 12 practical activities, which will contribute towards the Practical Endorsement. These skills, knowledge and understanding will also be assessed in A level written examinations in the context of these, and other, practical activities. The written examination for AS will also assess students in relation to their practical skills, knowledge and understanding.

The practical skills can be split into those which can be assessed through written examinations for AS and A level (Appendix 5a); and those for A levels that will be assessed directly through appropriate practical activities (Appendix 5b).

The practical activities highlighted as the minimum requirement within specifications must cover the use of apparatus and practical techniques identified for each science (Appendix 5c).

## **Appendix 5a - practical skills identified for indirect assessment and developed through teaching and learning**

Question papers for AS and A level qualifications will assess student's abilities to:

### **Independent thinking**

- solve problems set in practical contexts
- apply scientific knowledge to practical contexts

### **Use and application of scientific methods and practices**

- comment on experimental design and evaluate scientific methods
- present data in appropriate ways
- evaluate results and draw conclusions with reference to measurement uncertainties and errors
- identify variables including those that must be controlled

### **Numeracy and the application of mathematical concepts in a practical context**

- plot and interpret graphs
- process and analyse data using appropriate mathematical skills as exemplified in the mathematical appendix for each science
- consider margins of error, accuracy and precision of data

### **Instruments and equipment**

- know and understand how to use a wide range of experimental and practical instruments, equipment and techniques appropriate to the knowledge and understanding included in the specification

## **Appendix 5b - practical skills identified for direct assessment and developed through teaching and learning**

Practical work carried out throughout each A level course will enable students to develop the following skills. Students will be directly assessed in relation to these skills based on their completion of at least 12 practical activities during the A level course.

### **Independent thinking**

- apply investigative approaches and methods to practical work

### **Use and apply scientific methods and practices**

- safely and correctly use a range of practical equipment and materials
- follow written instructions
- make and record observations
- keep appropriate records of experimental activities
- present information and data in a scientific way
- use appropriate software and tools to process data, carry out research and report findings

### **Research and referencing**

- use online and offline research skills including websites, textbooks and other printed scientific sources of information
- correctly cite sources of information

### **Instruments and equipment**

- use a wide range of experimental and practical instruments, equipment and techniques appropriate to the knowledge and understanding included in the specification

## Appendix 5c -

### Use of apparatus and techniques - biology

Specifications for biology must give students opportunities to use relevant apparatus to develop and demonstrate these techniques.

For A level, all of the techniques listed below will be assessed through a minimum of 12 identified practical activities within each specification. These 'core' practicals must allow students to demonstrate all of the practical skills given in appendix 5b.

#### Practical techniques to be completed by candidates

- use appropriate apparatus to record a range of quantitative measurements (to include mass, time, volume, temperature, length and pH)
- use appropriate instrumentation to record quantitative measurements, such as a colorimeter or potometer
- use laboratory glassware apparatus for a variety of experimental techniques to include serial dilutions
- use of light microscope at high power and low power, including use of a graticule
- produce scientific drawing from observation with annotations
- use qualitative reagents to identify biological molecules
- separate biological compounds using thin layer/paper chromatography or electrophoresis
- safely and ethically use organisms to measure:
  - plant or animal responses
  - physiological functions
- use microbiological aseptic techniques, including the use of agar plates and broth
- safely use instruments for dissection of an animal organ, or plant organ
- use sampling techniques in fieldwork
- use ICT such as computer modelling, or data logger to collect data, or use software to process data

## Use of apparatus and techniques - chemistry

Specifications for chemistry must give students opportunities to use relevant apparatus to develop and demonstrate these techniques.

All of the techniques listed below will be assessed through a minimum of 12 identified practical activities within each specification. These 'core' practicals must allow students to demonstrate all of the practical skills given in appendix 5b.

### Practical techniques to be gained by candidate

- use appropriate apparatus to record a range of measurements (to include mass, time, volume of liquids and gases, temperature)
- use water bath or electric heater or sand bath for heating
- measure pH using pH charts, or pH meter, or pH probe on a data logger
- use laboratory apparatus for a variety of experimental techniques including:
  - titration, using burette and pipette
  - distillation and heating under reflux, including setting up glassware using retort stand and clamps
  - qualitative tests for ions and organic functional groups
  - filtration, including use of fluted filter paper, or filtration under reduced pressure
- use volumetric flask, including accurate technique for making up a standard solution
- use acid-base indicators in titrations of weak/strong acids with weak/strong alkalis
- purify:
  - a solid product by recrystallization
  - a liquid product, including use of separating funnel
- use melting point apparatus
- use thin-layer or paper chromatography
- set up electrochemical cells and measuring voltages
- safely and carefully handle solids and liquids, including corrosive, irritant, flammable and toxic substances
- measure rates of reaction by at least two different methods, for example:
  - an initial rate method such as a clock reaction
  - a continuous monitoring method

## Use of apparatus and techniques - physics

Specifications for physics must give students opportunities to use relevant apparatus to develop and demonstrate these techniques.

All of the techniques listed below will be assessed through a minimum of 12 identified practical activities within each specification. These 'core' practicals must allow students to demonstrate all of the practical skills given in appendix 5b.

### Practical techniques to be gained by candidate

- use appropriate analogue apparatus to record a range of measurements (to include length/distance, temperature, pressure, force, angles, volume) and to interpolate between scale markings
- use appropriate digital instruments, including electrical multimeters, to obtain a range of measurements (to include time, current, voltage, resistance, mass)
- use methods to increase accuracy of measurements, such as timing over multiple oscillations, or use of fiducial marker, set square or plumb line
- use stopwatch or light gates for timing
- use calipers and micrometers for small distances, using digital or vernier scales
- correctly construct circuits from circuit diagrams using DC power supplies, cells, and a range of circuit components, including those where polarity is important
- design, construct and check circuits using DC power supplies, cells, and a range of circuit components
- use signal generator and oscilloscope, including volts/division and time-base
- generate and measure waves, using microphone and loudspeaker, or ripple tank, or vibration transducer, or microwave / radio wave source
- use laser or light source to investigate characteristics of light, including interference and diffraction
- use ICT such as computer modelling, or data logger with a variety of sensors to collect data, or use of software to process data
- use ionising radiation, including detectors

## Appendix 6 - mathematical requirements and exemplifications

In order to be able to develop their skills, knowledge and understanding in science, students need to have been taught, and to have acquired competence in, the appropriate areas of mathematics relevant to the subject as indicated in the table of coverage below.

The assessment of quantitative skills will include at least 10% level 2 or above mathematical skills for biology and psychology, 20% for chemistry and 40% for physics, these skills will be applied in the context of the relevant science A level.

All mathematical content must be assessed within the lifetime of the specification.

The following tables illustrate where these mathematical skills may be developed and could be assessed in each of the sciences. Those shown in bold type would only be tested in the full A Level course.

This list of examples is not exhaustive. These skills could be developed in other areas of specification content.

### 6a - biology

	<b>Mathematical skills</b>	<b>Exemplification of mathematical skill in the context of A level biology (assessment is not limited to the examples given below)</b>
<b>A.0 - arithmetic and numerical computation</b>		
A.0.1	Recognise and make use of appropriate units in calculations	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>• convert between units, e.g. <math>\text{mm}^3</math> to <math>\text{cm}^3</math> as part of volumetric calculations</li> <li>• work out the unit for a rate e.g. breathing rate</li> </ul>
A.0.2	Recognise and use expressions in decimal and standard form	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>• use an appropriate number of decimal places in calculations, e.g. for a mean</li> <li>• carry out calculations using numbers in standard and ordinary form, e.g. use of magnification</li> <li>• understand standard form when applied to areas such as size of organelles</li> <li>• convert between numbers in standard</li> </ul>

		<p>and ordinary form</p> <ul style="list-style-type: none"> <li>understand that significant figures need retaining when making conversions between standard and ordinary form, e.g. <math>0.0050 \text{ mol dm}^{-3}</math> is equivalent to <math>5.0 \times 10^{-3} \text{ mol dm}^{-3}</math></li> </ul>
A.0.3	Use ratios, fractions and percentages	<p>Candidates may be tested on their ability to:</p> <ul style="list-style-type: none"> <li>calculate percentage yields</li> <li>calculate surface area to volume ratio</li> <li>use scales for measuring</li> <li>represent phenotypic ratios (monohybrid and dihybrid crosses)</li> </ul>
A.0.4	Estimate results	<p>Candidates may be tested on their ability to:</p> <ul style="list-style-type: none"> <li>estimate results to sense check that the calculated values are appropriate</li> </ul>
A.0.5	<b>Use calculators to find and use power, exponential and logarithmic functions</b>	<p><b>Candidates may be tested on their ability to:</b></p> <ul style="list-style-type: none"> <li><b>estimate the number of bacteria grown over a certain length of time</b></li> </ul>
<b>A.1- handling data</b>		
A.1.1	Use an appropriate number of significant figures	<p>Candidates may be tested on their ability to:</p> <ul style="list-style-type: none"> <li>report calculations to an appropriate number of significant figures given raw data quoted to varying numbers of significant figures</li> <li>understand that calculated results can only be reported to the limits of the least accurate measurement</li> </ul>
A.1.2	Find arithmetic means	<p>Candidates may be tested on their ability to:</p> <ul style="list-style-type: none"> <li>find the mean of a range of data, e.g. the mean number of stomata in the leaves of a plant</li> </ul>
A.1.3	Construct and interpret frequency tables and diagrams, bar charts and histograms	<p>Candidates may be tested on their ability to:</p> <ul style="list-style-type: none"> <li>represent a range of data in a table with clear headings, units and consistent decimal places</li> <li>interpret data from a variety of tables,</li> </ul>

		<p>e.g. data relating to organ function</p> <ul style="list-style-type: none"> <li>• plot a range of data in an appropriate format, e.g. enzyme activity over time represented on a graph</li> <li>• interpret data for a variety of graphs, e.g. explain electrocardiogram traces</li> </ul>
A.1.4	Understand simple probability	<p>Candidates may be tested on their ability to:</p> <ul style="list-style-type: none"> <li>• use the terms probability and chance appropriately</li> <li>• understand the probability associated with genetic inheritance</li> </ul>
A.1.5	Understand the principles of sampling as applied to scientific data	<p>Candidates may be tested on their ability to:</p> <ul style="list-style-type: none"> <li>• analyse random data collected by an appropriate means, e.g. use Simpson's index of diversity to calculate the biodiversity of a habitat</li> </ul>
A.1.6	Understand the terms mean, median and mode	<p>Candidates may be tested on their ability to:</p> <ul style="list-style-type: none"> <li>• calculate or compare the mean, median and mode of a set of data, e.g. height/mass/size of a group of organisms</li> </ul>
A.1.7	Use a scatter diagram to identify a correlation between two variables	<p>Candidates may be tested on their ability to:</p> <ul style="list-style-type: none"> <li>• interpret a scattergram, e.g. the effect of life style factors on health</li> </ul>
A.1.8	Make order of magnitude calculations	<p>Candidates may be tested on their ability to:</p> <ul style="list-style-type: none"> <li>• use and manipulate the magnification formula</li> </ul> $\text{magnification} = \frac{\text{size of image}}{\text{size of real object}}$
A.1.9	Select and use a statistical test	<p>Candidates may be tested on their ability to select and use:</p> <ul style="list-style-type: none"> <li>• the chi squared test to test the significance of the difference between observed and expected results</li> <li>• the Student's t-test</li> <li>• the correlation coefficient</li> </ul>

A.1.10	Understand measures of dispersion, including standard deviation and range	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>calculate the standard deviation</li> <li>understand why standard deviation might be a more useful measure of dispersion for a given set of data e.g. where there is an outlying result</li> </ul>
A.1.11	Identify uncertainties in measurements and use simple techniques to determine uncertainty when data are combined	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>calculate percentage error where there are uncertainties in measurement</li> </ul>
<b>A.2 – algebra</b>		
A.2.1	Understand and use the symbols: =, <, <<, >>, >, α, ~.	No exemplification required.
A.2.2	Change the subject of an equation	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>use and manipulate equations, e.g. magnification</li> </ul>
A.2.3	Substitute numerical values into algebraic equations using appropriate units for physical quantities	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>use a given equation e.g. Simpson's-index of diversity <math>[D = 1 - (\sum(n/N)^2)]</math></li> </ul>
A.2.4	Solve algebraic equations	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>solve equations in a biological context, e.g. cardiac output = stroke volume x heart rate</li> </ul>
A.2.5	<b>Use logarithms in relation to quantities that range over several orders of magnitude</b>	<b>Candidates may be tested on their ability to:</b> <ul style="list-style-type: none"> <li><b>use a logarithmic scale in the context of microbiology, e.g. growth rate of a microorganism such as yeast</b></li> </ul>
<b>A.3 - graphs</b>		
A.3.1	Translate information between graphical, numerical and algebraic forms	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>understand that data may be presented in a number of formats and be able to use these data, e.g. dissociation curves</li> </ul>
A.3.2	Plot two variables from experimental or other data	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>select an appropriate format for</li> </ul>

		presenting data, bar charts, histograms, graphs and scattergrams
A.3.3	Understand that $y = mx + c$ represents a linear relationship	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>• predict/sketch the shape of a graph with a linear relationship, e.g. the effect of substrate concentration on the rate of an enzyme-controlled reaction with excess enzyme</li> </ul>
A.3.4	<b>Determine the intercept of a graph</b>	<b>Candidates may be tested on their ability to:</b> <ul style="list-style-type: none"> <li>• <b>read off an intercept point from a graph, e.g. compensation point in plants</b></li> </ul>
A.3.5	Calculate rate of change from a graph showing a linear relationship	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>• calculate a rate from a graph, e.g. rate of transpiration</li> </ul>
A.3.6	Draw and use the slope of a tangent to a curve as a measure of rate of change	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>• use this method to measure the gradient of a point on a curve, e.g. amount of product formed plotted against time when the concentration of enzyme is fixed</li> </ul>
<b>A.4 - geometry and trigonometry</b>		
A.4.1	Calculate the circumferences, surface areas and volumes of regular shapes	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>• calculate the circumference and area of a circle</li> <li>• calculate the surface area and volume of rectangular prisms, of cylindrical prisms and of spheres</li> <li>• e.g. calculate the surface area or volume of a cell</li> </ul>

## 6b - chemistry

	Mathematical skills	Exemplification of mathematical skill in the context of A level chemistry (assessment is not limited to the examples given below)
<b>B.0 - arithmetic and numerical computation</b>		
B.0.0	Recognise and make use of appropriate units in calculation	<p>Candidates may be tested on their ability to:</p> <ul style="list-style-type: none"> <li>• convert between units e.g. <math>\text{cm}^3</math> to <math>\text{dm}^3</math> as part of volumetric calculations</li> <li>• <b>give units for an equilibrium constant or a rate constant</b></li> <li>• understand that different units are used in similar topic areas, so that conversions may be necessary e.g. entropy in <math>\text{J mol}^{-1} \text{K}^{-1}</math> and enthalpy changes in <math>\text{kJ mol}^{-1}</math></li> </ul>
B.0.1	Recognise and use expressions in decimal and ordinary form	<p>Candidates may be tested on their ability to:</p> <ul style="list-style-type: none"> <li>• use an appropriate number of decimal places in calculations, e.g. for pH</li> <li>• carry out calculations using numbers in standard and ordinary form, e.g. use of Avogadro's number</li> <li>• understand standard form when applied to areas such as (but not limited to) <math>K_w</math></li> <li>• convert between numbers in standard and ordinary form</li> <li>• understand that significant figures need retaining when making conversions between standard and ordinary form, e.g. <math>0.0050 \text{ mol dm}^{-3}</math> is equivalent to <math>5.0 \times 10^{-3} \text{ mol dm}^{-3}</math></li> </ul>
B.0.2	Use ratios, fractions and percentages	<p>Candidates may be tested on their ability to:</p> <ul style="list-style-type: none"> <li>• calculate percentage yields</li> <li>• calculate the atom economy of a reaction</li> <li>• construct and/or balance equations</li> </ul>

		using ratios
B.0.3	Estimate results	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>• <b>evaluate the effect of changing experimental parameters on measurable values, e.g. how the value of <math>K_c</math> would change with temperature given different specified conditions</b></li> </ul>
B.0.4	Use calculators to find and use power, <b>exponential and logarithmic functions</b>	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>• carry out calculations using the Avogadro constant</li> <li>• <b>carry out pH and <math>pK_a</math> calculations</b></li> <li>• <b>make appropriate mathematical approximations in buffer calculations</b></li> </ul>
<b>B.1- handling data</b>		
B.1.1	Use an appropriate number of significant figures	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>• report calculations to an appropriate number of significant figures given raw data quoted to varying numbers of significant figures</li> <li>• understand that calculated results can only be reported to the limits of the least accurate measurement</li> </ul>
B.1.2	Find arithmetic means	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>• calculate weighted means, e.g. calculation of an atomic mass based on supplied isotopic abundances</li> <li>• select appropriate titration data (i.e. identification of outliers) in order to calculate mean titres</li> </ul>
B.1.3	Identify uncertainties in measurements and use simple techniques to determine uncertainty when data are combined	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>• determine uncertainty when two burette readings are used to calculate a titre value</li> </ul>
<b>B.2 – algebra</b>		
B.2.1	Understand and use the	No exemplification required.

	symbols: =, <, <<, >>, >, $\alpha$ , $\sim$ , equilibrium sign	
B.2.2	Change the subject of an equation	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>• carry out structured and unstructured mole calculations <b>e.g. calculate a rate constant <math>k</math> from a rate equation</b></li> </ul>
B.2.3	Substitute numerical values into algebraic equations using appropriate units for physical quantities	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>• carry out structured and unstructured mole calculations</li> <li>• <b>carry out rate calculations</b></li> <li>• <b>calculate the value of an equilibrium constant <math>K_c</math></b></li> </ul>
B.2.4	Solve algebraic equations	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>• carry out Hess's law calculations</li> <li>• <b>calculate a rate constant <math>k</math> from a rate equation</b></li> </ul>
B.2.5	<b>Use logarithms in relation to quantities that range over several orders of magnitude</b>	<b>Candidates may be tested on their ability to:</b> <ul style="list-style-type: none"> <li>• <b>carry out pH and <math>pK_a</math> calculations</b></li> </ul>
<b>B.3 – graphs</b>		
B.3.1	Translate information between graphical, numerical and algebraic forms	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>• interpret and analyse spectra</li> <li>• <b>determine the order of a reaction from a graph</b></li> <li>• <b>derive rate expression from a graph</b></li> </ul>
B.3.2	Plot two variables from experimental or other data	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>• plot concentration–time graphs from collected or supplied data and draw an appropriate best-fit curve</li> </ul>
B.3.3	<b>Determine the slope and intercept of a linear graph</b>	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>• <b>calculate the rate constant of a zero-order reaction by determination of the gradient of a concentration–time graph</b></li> </ul>

B.3.4	<b>Calculate rate of change from a graph showing a linear relationship</b>	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>• <b>calculate the rate constant of a zero-order reaction by determination of the gradient of a concentration–time graph</b></li> </ul>
B.3.5	<b>Draw and use the slope of a tangent to a curve as a measure of rate of change</b>	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>• <b>determine the order of a reaction using the initial rates method</b></li> </ul>
<b>B.4 - geometry and trigonometry</b>		
B.4.1	Use angles and shapes in regular 2D and 3D structures	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>• predict/identify shapes of and bond angles in molecules with and without a lone pair(s), for example NH<sub>3</sub>, CH<sub>4</sub>, H<sub>2</sub>O etc.</li> </ul>
B.4.2	Visualise and represent 2D and 3D forms including two-dimensional representations of 3D objects	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>• draw different forms of isomers</li> <li>• <b>identify chiral centres from a 2D or 3D representation</b></li> </ul>
B.4.3	Understand the symmetry of 2D and 3D shapes	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>• describe the types of stereoisomerism shown by molecules/complexes</li> <li>• <b>identify chiral centres from a 2D or 3D representation</b></li> </ul>

## 6c - physics

	Mathematical skills	Exemplification of mathematical skill in the context of A level physics (assessment is not limited to the examples given below)
<b>C.0 - arithmetic and numerical computation</b>		
C.0.1	Recognise and make use of appropriate units in calculations	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>• identify the correct units for physical properties such as <math>\text{m s}^{-1}</math>, the unit for velocity</li> <li>• convert between units with different prefixes e.g. <math>\text{cm}^3</math> to <math>\text{m}^3</math></li> </ul>
C.0.2	Recognise and use expressions in decimal and standard form	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>• use physical constants expressed in standard form such as <math>c = 3.00 \times 10^8 \text{ m s}^{-1}</math></li> </ul>
C.0.3	Use ratios, fractions and percentages	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>• calculate efficiency of devices</li> <li>• calculate percentage uncertainties in measurements</li> </ul>
C.0.4	Estimate results	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>• estimate the effect of changing experimental parameters on measurable values</li> </ul>
C.0.5	Use calculators to find and use power, <b>exponential and logarithmic functions</b>	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>• <b>solve for unknowns in decay problems such as <math>N = N_0 e^{-\lambda t}</math></b></li> </ul>
C.0.6	Use calculators to handle $\sin x$ , $\cos x$ , $\tan x$ when $x$ is expressed in degrees or radians	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>• calculate the direction of resultant vectors</li> </ul>

<b>C.1 - handling data</b>		
C.1.1	Use an appropriate number of significant figures	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>report calculations to an appropriate number of significant figures given raw data quoted to varying numbers of significant figures</li> <li>understand that calculated results can only be reported to the limits of the least accurate measurement</li> </ul>
C.1.2	Find arithmetic means	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>calculate a mean value for repeated experimental readings</li> </ul>
C.1.3	Understand simple probability	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>understand probability in the context of radioactive decay</li> </ul>
C.1.4	Make order of magnitude calculations	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>evaluate equations with variables expressed in different orders of magnitude</li> </ul>
C.1.5	Identify uncertainties in measurements and use simple techniques to determine uncertainty when data are combined by addition, subtraction, multiplication, division and raising to powers	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>determine the uncertainty where two readings for length need to be added together</li> </ul>
<b>C.2 - algebra</b>		
C.2.1	Understand and use the symbols: =, <, <<, >>, >, $\propto$ , $\approx$ , $\Delta$	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>recognise the significance of the symbols in the expression <math>F \propto \Delta p / \Delta t</math></li> </ul>
C.2.2	Change the subject of an equation, including non-linear equations	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>rearrange <math>E = mc^2</math> to make <math>m</math> the subject</li> </ul>
C.2.3	Substitute numerical values into algebraic equations using appropriate units for physical quantities	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>calculate the momentum <math>p</math> of an object by substituting the values for mass <math>m</math> and velocity <math>v</math> into the equation <math>p = mv</math></li> </ul>

C.2.4	Solve algebraic equations, including quadratic equations	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>• solve kinematic equations for constant acceleration such as <math>v = u + at</math> and <math>s = ut + \frac{1}{2} at^2</math></li> </ul>
C.2.5	<b>Use logarithms in relation to quantities that range over several orders of magnitude</b>	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>• <b>recognise and interpret real world examples of logarithmic scales</b></li> </ul>
<b>C.3 - graphs</b>		
C.3.1	Translate information between graphical, numerical and algebraic forms	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>• calculate Young modulus for materials using stress-strain graphs</li> </ul>
C.3.2	Plot two variables from experimental or other data	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>• plot graphs of extension of a wire against force applied</li> </ul>
C.3.3	Understand that $y = mx + c$ represents a linear relationship	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>• rearrange and compare <math>v = u + at</math> with <math>y = mx + c</math> for velocity-time graph in constant acceleration problems</li> </ul>
C.3.4	Determine the slope and intercept of a linear graph	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>• read off and interpret intercept point from a graph e.g. the initial velocity in a velocity-time graph</li> </ul>
C.3.5	Calculate rate of change from a graph showing a linear relationship	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>• calculate acceleration from a linear velocity-time graph</li> </ul>
C.3.6	Draw and use the slope of a tangent to a curve as a measure of rate of change	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>• draw a tangent to the curve of a displacement–time graph and use the gradient to approximate the velocity at a specific time</li> </ul>
C.3.7	Distinguish between instantaneous rate of change and average rate of change	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>• understand that the gradient of the tangent of a displacement–time graph gives the velocity at a point in time which is a different measure to the average velocity</li> </ul>

C.3.8	Understand the possible physical significance of the area between a curve and the x axis and be able to calculate it or estimate it by graphical methods as appropriate	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>recognise that for a capacitor the area under a voltage-charge graph is equivalent to the energy stored</li> </ul>
C.3.9	Apply the concepts underlying calculus (but without requiring the explicit use of derivatives or integrals) by solving equations involving rates of change, e.g. $\Delta x / \Delta t = -\lambda x$ using a graphical method or spreadsheet modelling	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>determine <math>g</math> from distance-time plot, projectile motion</li> </ul>
C.3.10	<b>Interpret logarithmic plots</b>	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li><b>obtain time constant for capacitor discharge by interpreting plot of <math>\log V</math> against time</b></li> </ul>
C.3.11	<b>Use logarithmic plots to test exponential and power law variations</b>	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li><b>use logarithmic plots with decay law of radioactivity / charging and discharging of a capacitor</b></li> </ul>
C.3.12	Sketch relationships which are modelled by $y = k/x$ , $y = kx^2$ , $y = k/x^2$ , $y = kx$ , $y = \sin x$ , $y = \cos x$ , $y = e^{\pm x}$ , and $y = \sin^2 x$ , $y = \cos^2 x$ as applied to physical relationships	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li><b>sketch relationships between pressure and volume for an ideal gas</b></li> </ul>
<b>C.4- geometry and trigonometry</b>		
C.4.1	Use angles in regular 2D and 3D structures	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>interpret force diagrams to solve problems</li> </ul>
C.4.2	Visualise and represent 2D and 3D forms including two-dimensional representations of 3D objects	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>draw force diagrams to solve mechanics problems</li> </ul>

C.4.3	Calculate areas of triangles, circumferences and areas of circles, surface areas and volumes of rectangular blocks, cylinders and spheres	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>calculate the area of the cross section to work out the resistance of a conductor given its length and resistivity</li> </ul>
C.4.4	Use Pythagoras' theorem, and the angle sum of a triangle	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>calculate the magnitude of a resultant vector, resolving forces into components to solve problems</li> </ul>
C.4.5	Use sin, cos and tan in physical problems	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>resolve forces into components</li> </ul>
C.4.6	Use of small angle approximations including $\sin \theta \approx \theta$ , $\tan \theta \approx \theta$ , $\cos \theta \approx 1$ for small $\theta$ where appropriate	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>calculate fringe separations in interference patterns</li> </ul>
C.4.7	Understand the relationship between degrees and radians and translate from one to the other	Candidates may be tested on their ability to: <ul style="list-style-type: none"> <li>convert angle in degrees to angle in radians</li> </ul>

## 6d - psychology

	Mathematical skills	Exemplification of mathematical skill in the context of A level psychology (assessment is not limited to the examples given below)
<b>D.0 - arithmetic and numerical computation</b>		
D.0.1	Recognise and use expressions in decimal and standard form	For example, converting data in standard form from a results table into decimal form in order to construct a pie chart.
D.0.2	Use ratios, fractions and percentages	For example, calculating the percentages of cases that fall into different categories in an observation study.
D.0.3	Estimate results	For example, commenting on the spread of scores for a set of data, which would require estimating the range.
<b>D.1 - handling data</b>		
D.1.1	Use an appropriate number of significant figures	For example, expressing a correlation coefficient to two or three significant figures.
D.1.2	Find arithmetic means	For example, calculating the means for two conditions using raw data from a class experiment.
D.1.3	Construct and interpret frequency tables and diagrams, bar charts and histograms	For example, selecting and sketching an appropriate form of data display for a given set of data.
D.1.4	Understand simple probability	For example, explaining the difference between the 0.05 and 0.01 levels of significance.
D.1.5	Understand the principles of sampling as applied to scientific data	For example, explaining how a random or stratified sample could be obtained from a target population.
D.1.6	Understand the terms mean, median and mode	For example, explaining the differences between the mean, median and mode and selecting which measure of central tendency is most appropriate for a given set of data. Calculate standard deviation
D.1.7	Use a scatter diagram to identify a correlation between two variables	For example, plotting two variables from an investigation on a scatter diagram and identifying the pattern as a positive correlation, a negative correlation or no correlation.

D.1.8	Use a statistical test	For example, calculating a non-parametric test of differences using data from a given experiment.
D.1.9	Make order of magnitude calculations	For example, estimating the mean test score for a large number of participants on the basis of the total overall score.
<b>D.1.10</b>	<b>Distinguish between levels of measurement</b>	<b>For example, stating the level of measurement (nominal, ordinal or interval) that has been used in a study.</b>
D.1.11	Know the characteristics of normal and skewed distributions	For example, being presented with a set of scores from an experiment and being asked to indicate the position of the mean (or median, or mode).
<b>D.1.12</b>	<b>Select an appropriate statistical test</b>	<b>For example, selecting a suitable inferential test for a given practical investigation and explaining why the chosen test is appropriate.</b>
<b>D.1.13</b>	<b>Use statistical tables to determine significance</b>	<b>For example, using an extract from statistical tables to say whether or not a given observed value is significant at the 0.05 level of significance for a one-tailed test.</b>
D.1.14	Understand measures of dispersion, including standard deviation and range	For example, explaining why the standard deviation might be a more useful measure of dispersion for a given set of scores e.g. where there is an outlying score.
D.1.15	Understand the differences between qualitative and quantitative data	For example, explaining how a given qualitative measure (for example, an interview transcript) might be converted into quantitative data.
D.1.16	Understand the difference between primary and secondary data	For example, stating whether data collected by a researcher dealing directly with participants is primary or secondary data.
<b>D.2 - algebra</b>		
D.2.1	Understand and use the symbols: =, <, <<, >>, >, ∞, ~.	For example, expressing the outcome of an inferential test in the conventional form by stating the level of significance at the 0.05 level or 0.01 level by using symbols appropriately.

<b>D.2.2</b>	<b>Substitute numerical values into algebraic equations using appropriate units for physical quantities</b>	<b>For example, inserting the appropriate values from a given set of data into the formula for a statistical test e.g. inserting the N value (for the number of scores) into the Chi Square formula.</b>
<b>D.2.3</b>	<b>Solve simple algebraic equations</b>	<b>For example, calculating the degrees of freedom for a Chi Square test.</b>
<b>D.3 - graphs</b>		
D.3.1	Translate information between graphical, numerical and algebraic forms	For example, using a set of numerical data (a set of scores) from a record sheet to construct a bar graph.
D.3.2	Plot two variables from experimental or other data	For example, sketching a scatter diagram using two sets of data from a correlational investigation.



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