CAMBRIDGE
International Examinations

Cambridge
IGCSE

SYLLABUS

Cambridge IGCSE®
Co-ordinated Sciences (Double Award)

0654

For examination in June and November 2019, 2020 and 2021.

Cambridge Secondary 2

Version 1

What has changed in Cambridge IGCSE Co-ordinated Sciences (Double Award) 0654 for 2019, 2020 and 2021?

The syllabus has been revised for first examination in 2019. Some changes are significant.

You are strongly advised to read the whole syllabus before planning your teaching programme.

Changes to the syllabus

Section 5. Syllabus content

The syllabus content has been completely revised, updated and reorganised to align with the single Science syllabuses (Cambridge IGCSE Biology 0610, Cambridge IGCSE Chemistry 0620 and Cambridge IGCSE Physics 0625).

Section 7. Appendix

The appendix has been revised, updated and reorganised to align with the single Science syllabuses (Cambridge IGCSE Biology 0610, Cambridge IGCSE Chemistry 0620 and Cambridge IGCSE Physics 0625).

Significant changes to the appendix are indicated by black vertical lines either side of the text.

Changes to assessment

- **Paper 5, Practical Test**, 2 hours, 60 marks
  - The number of marks for Paper 5 Practical Test is now 60 marks.
  - The duration of Paper 5 Practical Test is unchanged.

Paper 5: Practical Test will now typically consist of six to seven exercises, one of which will not require the use of apparatus.

One question on Paper 5 will assess the skill of planning. This question will be based on any one of the sciences, which could be: Biology, Chemistry or Physics and may vary between each examination series.

- **Paper 6, Alternative to Practical**, 1 hour 30 minutes, 60 marks
  - The number of marks for Paper 6 Alternative to Practical is unchanged.
  - The duration of Paper 6 Alternative to Practical is now 1 hour 30 minutes.

One question on Paper 6 will assess the skill of planning. This question will be based on any one of the sciences, which could be: Biology, Chemistry or Physics and may vary between each examination series.

Significant changes to the assessment are indicated by black vertical lines either side of the text.

In addition to reading the syllabus, teachers should refer to the updated specimen papers.

Contents

1. Introduction

1.1 Why choose Cambridge?

Cambridge International Examinations prepares school students for life, helping them develop an informed curiosity and a lasting passion for learning. We are part of Cambridge Assessment, a department of the University of Cambridge.

Our international qualifications are recognised by the world's best universities and employers, giving students a wide range of options in their education and career. As a not-for-profit organisation, we devote our resources to delivering high-quality educational programmes that can unlock learners' potential.

Our programmes and qualifications set the global standard for international education. They are created by subject experts, rooted in academic rigour and reflect the latest educational research. They provide a strong platform for learners to progress from one stage to the next, and are well supported by teaching and learning resources.

Every year, nearly a million Cambridge learners from 10 000 schools in 160 countries prepare for their future with an international education from Cambridge.

Cambridge learners

Our mission is to provide educational benefit through provision of international programmes and qualifications for school education and to be the world leader in this field. Together with schools, we develop Cambridge learners who are:

- **confident** in working with information and ideas – their own and those of others
- **responsible** for themselves, responsive to and respectful of others
- **reflective** as learners, developing their ability to learn
- **innovative** and equipped for new and future challenges
- **engaged** intellectually and socially, ready to make a difference.

Recognition

Cambridge IGCSE® is recognised by leading universities and employers worldwide, and is an international passport to progression and success. It provides a solid foundation for moving on to higher level studies. Learn more at **www.cie.org.uk/recognition**

Support for teachers

A wide range of materials and resources is available to support teachers and learners in Cambridge schools. Resources suit a variety of teaching methods in different international contexts. Through subject discussion forums and training, teachers can access the expert advice they need for teaching our qualifications. More details can be found in Section 2 of this syllabus and at **www.cie.org.uk/teachers**

Support for exams officers

Exams officers can trust in reliable, efficient administration of exams entries and excellent personal support from our customer services. Learn more at **www.cie.org.uk/examsofficers**

Our systems for managing the provision of international qualifications and education programmes for learners aged 5 to 19 are certified as meeting the internationally recognised standard for quality management, ISO 9001:2008. Learn more at **www.cie.org.uk/ISO9001**

1.2 Why choose Cambridge IGCSE?

Cambridge IGCSEs are international in outlook, but retain a local relevance. The syllabuses provide opportunities for contextualised learning and the content has been created to suit a wide variety of schools, avoid cultural bias and develop essential lifelong skills, including creative thinking and problem-solving.

Our aim is to balance knowledge, understanding and skills in our programmes and qualifications to enable students to become effective learners and to provide a solid foundation for their continuing educational journey.

Through our professional development courses and our support materials for Cambridge IGCSEs, we provide the tools to enable teachers to prepare learners to the best of their ability and work with us in the pursuit of excellence in education.

Cambridge IGCSEs are considered to be an excellent preparation for Cambridge International AS & A Levels, the Cambridge AICE (Advanced International Certificate of Education) Diploma, Cambridge Pre-U, and other education programmes, such as the US Advanced Placement program and the International Baccalaureate Diploma programme. Learn more about Cambridge IGCSEs at **www.cie.org.uk/cambridgesecondary2**

Guided learning hours

Cambridge IGCSE syllabuses are designed on the assumption that learners have about 130 guided learning hours per subject over the duration of the course. As this is a double award, the guided learning hours are about 260 hours, but this is for guidance only. The number of hours required to gain the qualification may vary according to local curricular practice and the learners' prior experience of the subject.

1.3 Why choose Cambridge IGCSE Co-ordinated Sciences (Double Award)?

Cambridge IGCSE Co-ordinated Sciences gives learners the opportunity to study biology, chemistry and physics within a scientifically coherent syllabus and is accepted by universities and employers as proof of essential knowledge and ability.

As well as a subject focus, the Cambridge IGCSE Co-ordinated Sciences syllabus encourages learners to develop:

- a better understanding of the technological world, with an informed interest in scientific matters
- a recognition of the usefulness (and limitations) of scientific method, and how to apply this to other disciplines and in everyday life
- relevant attitudes, such as a concern for accuracy and precision, objectivity, integrity, enquiry, initiative and inventiveness
- an interest in, and care for, the environment
- a better understanding of the influence and limitations placed on scientific study by society, economy, technology, ethics, the community and the environment
- an understanding of the scientific skills essential for both further study and everyday life.

Prior learning

We recommend that learners who are beginning this course should previously have studied a science syllabus such as that of the Cambridge Lower Secondary Programme or equivalent national educational frameworks. Learners should also have adequate mathematical skills for the content contained in this syllabus (see the *Mathematical requirements* in section 7.7).

Progression

Cambridge IGCSEs are general qualifications that enable learners to progress either directly to employment, or to proceed to further qualifications.

Candidates who are awarded grades CC to A*A* in Cambridge IGCSE Co-ordinated Sciences are well prepared to follow courses leading to Level 3 AS and A Levels in sciences, Cambridge Pre-U sciences, IB certificates in sciences or the Cambridge International AS and A Level sciences, or the equivalent.

1.4 Cambridge ICE (International Certificate of Education)

Cambridge ICE is a group award for Cambridge IGCSE. It gives schools the opportunity to benefit from offering a broad and balanced curriculum by recognising the achievements of learners who pass examinations in a number of different subjects.

Learn more about Cambridge ICE at **www.cie.org.uk/cambridgesecondary2**

1.5 How can I find out more?

If you are already a Cambridge school

You can make entries for this qualification through your usual channels. If you have any questions, please contact us at **info@cie.org.uk**

If you are not yet a Cambridge school

Learn about the benefits of becoming a Cambridge school at **www.cie.org.uk/startcambridge**. Email us at **info@cie.org.uk** to find out how your organisation can register to become a Cambridge school.

2. Teacher support

2.1 Support materials

You can go to our public website at **www.cie.org.uk/igcse** to download current and future syllabuses together with specimen papers or past question papers, examiner reports and grade threshold tables from one series.

For teachers at registered Cambridge schools a range of additional support materials for specific syllabuses is available from Teacher Support, our secure online support for Cambridge teachers. Go to **https://teachers.cie.org.uk** (username and password required). If you do not have access, speak to the Teacher Support coordinator at your school.

2.2 Endorsed resources

We work with publishers providing a range of resources for our syllabuses including print and digital materials. Resources endorsed by Cambridge go through a detailed quality assurance process to make sure they provide a high level of support for teachers and learners.

We have resource lists which can be filtered to show all resources, or just those which are endorsed by Cambridge. The resource lists include further suggestions for resources to support teaching. See **www.cie.org.uk/i-want-to/resource-centre** for further information.

2.3 Training

We offer a range of support activities for teachers to ensure they have the relevant knowledge and skills to deliver our qualifications. See **www.cie.org.uk/events** for further information.

3. Syllabus overview

3.1 Content

The syllabus content that follows is divided into three sections: Biology (B1–B13), Chemistry (C1–C14) and Physics (P1–P8). **Candidates must study all three sections.**

Candidates can either follow the Core syllabus only, or they can follow the Extended syllabus which includes both the Core and the Supplement. Candidates aiming for grades A*A* to CC should follow the Extended syllabus.

It is important that, throughout this course, teachers should make candidates aware of the relevance of the concepts studied to everyday life, and to the natural and man-made worlds.

Biology

B1 Characteristics of living organisms
B2 Cells
B3 Biological molecules
B4 Enzymes
B5 Plant nutrition
B6 Animal nutrition
B7 Transport
B8 Gas exchange and respiration
B9 Coordination and response
B10 Reproduction
B11 Inheritance
B12 Organisms and their environment
B13 Human influences on ecosystems

Chemistry

C1 The particulate nature of matter
C2 Experimental techniques
C3 Atoms, elements and compounds
C4 Stoichiometry
C5 Electricity and chemistry
C6 Energy changes in chemical reactions
C7 Chemical reactions
C8 Acids, bases and salts
C9 The Periodic Table
C10 Metals
C11 Air and water
C12 Sulfur
C13 Carbonates
C14 Organic chemistry

Physics

P1 Motion
P2 Work, energy and power
P3 Thermal physics
P4 Properties of waves, including light and sound
P5 Electricity and magnetism
P6 Electric circuits
P7 Electromagnetic effects
P8 Atomic physics

3.2 Assessment

All candidates must enter for three papers.

Core candidates take:		Extended candidates take:
Paper 1 **45 minutes** A multiple-choice paper consisting of 40 items of the four-choice type. (This paper will test assessment objectives AO1 and AO2.) Questions will be based on the Core syllabus content. 40 marks This paper will be weighted at 30% of the final total mark. Externally assessed.		**Paper 2** **45 minutes** A multiple-choice paper consisting of 40 items of the four-choice type. (This paper will test assessment objectives AO1 and AO2.) Questions will be based on the Extended syllabus content (Core and Supplement). 40 marks This paper will be weighted at 30% of the final total mark. Externally assessed.
and:		**and:**
Paper 3 **2 hours** A written paper consisting of short-answer and structured questions. (This paper will test assessment objectives AO1 and AO2.) Questions will be based on the Core syllabus content. 120 marks This paper will be weighted at 50% of the final total mark. Externally assessed.		**Paper 4** **2 hours** A written paper consisting of short-answer and structured questions. (This paper will test assessment objectives AO1 and AO2.) Questions will be based on the Extended syllabus content (Core and Supplement). 120 marks This paper will be weighted at 50% of the final total mark. Externally assessed.

All candidates take:		
either:		**or:**
Paper 5 **2 hours** Practical Test This paper will test assessment objective AO3. Questions will be based on the experimental skills in Section 6. The paper is structured to assess grade ranges A*A*–GG. 60 marks This paper will be weighted at 20% of the final total mark. Externally assessed.		**Paper 6** **1 hour 30 minutes** Alternative to Practical This paper will test assessment objective AO3. Questions will be based on the experimental skills in Section 6. The paper is structured to assess grade ranges A*A*–GG. 60 marks This paper will be weighted at 20% of the final total mark. Externally assessed.

Candidates who have studied the Core syllabus content, or who are expected to achieve a grade DD or below, should be entered for Paper 1, Paper 3 and either Paper 5 or Paper 6. These candidates will be eligible for grades CC to GG.

Candidates who have studied the Extended syllabus content (Core and Supplement), and who are expected to achieve a grade CC or above, should be entered for Paper 2, Paper 4 and either Paper 5 or Paper 6. These candidates will be eligible for grades A*A* to GG.

Availability

This syllabus is examined in the June and November examination series.

This syllabus is available to private candidates.

Detailed timetables are available from **www.cie.org.uk/timetables**

Combining this with other syllabuses

Candidates can combine this syllabus in an examination series with any other Cambridge syllabus, except:

- 0610 Cambridge IGCSE Biology
- 0620 Cambridge IGCSE Chemistry
- 0625 Cambridge IGCSE Physics
- 0652 Cambridge IGCSE Physical Science
- 0653 Cambridge IGCSE Combined Science
- 5054 Cambridge O Level Physics
- 5070 Cambridge O Level Chemistry
- 5090 Cambridge O Level Biology
- 5129 Cambridge O Level Combined Science
- syllabuses with the same title at the same level.

Please note that Cambridge IGCSE, Cambridge IGCSE (9–1) (Level 1/Level 2 Certificate) and Cambridge O Level syllabuses are at the same level.

4. Syllabus aims and assessment objectives

4.1 Syllabus aims

The syllabus aims listed below describe the educational purposes of a course based on this syllabus. These aims are not intended as assessment criteria but outline the educational context in which the syllabus content should be viewed. These aims are the same for all learners and are not listed in order of priority. Some of these aims may be delivered by the use of suitable local, international or historical examples and applications, or through collaborative experimental work.

The aims are to:

- provide an enjoyable and worthwhile educational experience for all learners, whether or not they go on to study science beyond this level
- enable learners to acquire sufficient knowledge and understanding to:
  - become confident citizens in a technological world and develop an informed interest in scientific matters
  - be suitably prepared for studies beyond Cambridge IGCSE
- allow learners to recognise that science is evidence-based and understand the usefulness, and the limitations, of scientific method
- develop skills that:
  - are relevant to the study and practice of science
  - are useful in everyday life
  - encourage a systematic approach to problem-solving
  - encourage efficient and safe practice
  - encourage effective communication through the language of science
- develop attitudes relevant to science such as:
  - concern for accuracy and precision
  - objectivity
  - integrity
  - enquiry
  - initiative
  - inventiveness
- enable learners to appreciate that:
  - science is subject to social, economic, technological, ethical and cultural influences and limitations
  - the applications of science may be both beneficial and detrimental to the individual, the community and the environment.

4.2 Assessment objectives

AO1: **Knowledge with understanding**

Candidates should be able to demonstrate knowledge and understanding of:

- scientific phenomena, facts, laws, definitions, concepts and theories
- scientific vocabulary, terminology and conventions (including symbols, quantities and units)
- scientific instruments and apparatus, including techniques of operation and aspects of safety
- scientific and technological applications with their social, economic and environmental implications.

Syllabus content defines the factual material that candidates may be required to recall and explain. Candidates will also be asked questions which require them to apply this material to unfamiliar contexts and to apply knowledge from one area of the syllabus to another.

Questions testing this assessment objective will often begin with one of the following words: *define*, *state*, *describe*, *explain* (*using your knowledge and understanding*) or *outline* (see the *Glossary of terms used in science papers* in section 7.6).

AO2: **Handling information and problem solving**

Candidates should be able, in words or using other written forms of presentation (i.e. symbolic, graphical and numerical), to:

- locate, select, organise and present information from a variety of sources
- translate information from one form to another
- manipulate numerical and other data
- use information to identify patterns, report trends and draw inferences
- present reasoned explanations for phenomena, patterns and relationships
- make predictions and hypotheses
- solve problems, including some of a quantitative nature.

Questions testing these skills may be based on information that is unfamiliar to candidates, requiring them to apply the principles and concepts from the syllabus to a new situation, in a logical, deductive way.

Questions testing these skills will often begin with one of the following words: *predict*, *suggest*, *calculate* or *determine* (see the *Glossary of terms used in science papers* in section 7.6).

AO3: **Experimental skills and investigations**

Candidates should be able to:

- demonstrate knowledge of how to safely use techniques, apparatus and materials (including following a sequence of instructions where appropriate)
- plan experiments and investigations
- make and record observations, measurements and estimates
- interpret and evaluate experimental observations and data
- evaluate methods and suggest possible improvements.

4.3 Relationship between assessment objectives and components

The approximate weightings allocated to each of the assessment objectives are summarised in the table below.

Assessment objective	Papers 1 and 2	Papers 3 and 4	Papers 5 and 6	Weighting of AO in overall qualification
AO1: Knowledge with understanding	63%	63%	–	50%
AO2: Handling information and problem solving	37%	37%	–	30%
AO3: Experimental skills and investigations	–	–	100%	20%
Weighting of paper in overall qualification	30%	50%	20%	

4.4 Grade descriptions

The scheme of assessment is intended to encourage positive achievement by all candidates.

A **Grade AA** candidate will be able to:

- recall and communicate precise knowledge and display comprehensive understanding of scientific phenomena, facts, laws, definitions, concepts and theories
- apply scientific concepts and theories to present reasoned explanations of familiar and unfamiliar phenomena, to solve complex problems involving several stages, and to make reasoned predictions and hypotheses
- communicate and present complex scientific ideas, observations and data clearly and logically, independently using scientific terminology and conventions consistently and correctly
- independently select, process and synthesise information presented in a variety of ways, and use it to draw valid conclusions and discuss the scientific, technological, social, economic and environmental implications
- devise strategies to solve problems in complex situations which may involve many variables or complex manipulation of data or ideas through multiple steps
- analyse data to identify any patterns or trends, taking account of limitations in the quality of the data and justifying the conclusions reached
- select, describe, justify and evaluate techniques for a large range of scientific operations and laboratory procedures.

A **Grade CC** candidate will be able to:

- recall and communicate secure knowledge and understanding of scientific phenomena, facts, laws, definitions, concepts and theories
- apply scientific concepts and theories to present simple explanations of familiar and some unfamiliar phenomena, to solve straightforward problems involving several stages, and to make detailed predictions and simple hypotheses
- communicate and present scientific ideas, observations and data using a wide range of scientific terminology and conventions
- select and process information from a given source, and use it to draw simple conclusions and state the scientific, technological, social, economic or environmental implications
- solve problems involving more than one step, but with a limited range of variables or using familiar methods
- analyse data to identify a pattern or trend, and select appropriate data to justify a conclusion
- select, describe and evaluate techniques for a range of scientific operations and laboratory procedures.

A **Grade FF** candidate will be able to:

- recall and communicate limited knowledge and understanding of scientific phenomena, facts, laws, definitions, concepts and theories
- apply a limited range of scientific facts and concepts to give basic explanations of familiar phenomena, to solve straightforward problems and to make simple predictions
- communicate and present simple scientific ideas, observations and data using a limited range of scientific terminology and conventions
- select a single piece of information from a given source, and use it to support a given conclusion, and to make links between scientific information and its scientific, technological, social, economic or environmental implications
- solve problems involving more than one step if structured help is given
- analyse data to identify a pattern or trend
- select, describe and evaluate techniques for a limited range of scientific operations and laboratory procedures.

4.5 Conventions (e.g. signs, symbols, terminology and nomenclature)

Syllabuses and question papers conform with generally accepted international practice. In particular, the following document, produced by the Association for Science Education (ASE) should be used as a guideline.

- *Signs, Symbols and Systematics: The ASE Companion to 16–19 Science* (2000)

Litre/dm^3

To avoid any confusion concerning the symbol for litre, **dm^3** will be used in place of l or litre.

Decimal markers

In accordance with current ASE convention, decimal markers in examination papers will be a single dot on the line. Candidates are expected to follow this convention in their answers.

Numbers

Numbers from 1000 to 9999 will be printed without commas or spaces. Numbers greater than or equal to 10000 will be printed without commas. A space will be left between each group of three whole numbers, e.g. 4256789.

5. Syllabus content

The syllabus content that follows is divided into three sections: Biology (B1–B13), Chemistry (C1–C14) and Physics (P1–P8). **Candidates must study all three sections.**

All candidates should be taught the Core syllabus content. Candidates who are only taught the Core syllabus content can achieve a maximum of grade CC. Candidates aiming for grades A*A* to CC should be taught the Extended syllabus content. The Extended syllabus content includes both the Core and the Supplement. Candidates should be made familiar with the information found in sections 7.1, 7.2, 7.3 and 7.4.

In delivering the course, teachers should aim to show the relevance of concepts to the learners' everyday lives and to the world around them. The syllabus content has been designed so as to allow teachers to develop flexible programmes which meet all of the general aims of the syllabus while drawing on appropriate local and international contexts.

Scientific subjects are, by their nature, experimental. Wherever possible, learners should pursue a fully integrated course which allows them to develop their practical skills by carrying out practical work and investigations within all of the topics listed.

0654 Biology	
B1 Characteristics of living organisms	
Core	**Supplement**
1 Describe the characteristics of living organisms by defining the terms:	2 Define the terms:
– *movement* as an action by an organism causing a change of position or place	– *movement* as an action by an organism or part of an organism causing a change of position or place
– *respiration* as the chemical reactions in cells that break down nutrient molecules and release energy	– *respiration* as the chemical reactions in cells that break down nutrient molecules and release energy for metabolism
– *sensitivity* as the ability to detect and respond to changes in the environment	– *sensitivity* as the ability to detect or sense stimuli in the internal or external environment and to make appropriate responses
– *growth* as a permanent increase in size	– *growth* as a permanent increase in size and dry mass by an increase in cell number or cell size or both
– *reproduction* as the processes that make more of the same kind of organism	
– *excretion* as removal from organisms of toxic materials and substances in excess of requirements	– *excretion* as removal from organisms of the waste products of metabolism (chemical reactions in cells including respiration), toxic materials, and substances in excess of requirements
– *nutrition* as taking in of materials for energy, growth and development	– *nutrition* as taking in of materials for energy, growth and development; plants require light, carbon dioxide, water and ions; animals need organic compounds and ions and usually need water

0654 Biology	
B2 Cells	
B2.1 Cell structure **Core** 1 State that living organisms are made of cells 2 Describe and compare the structure of a plant cell with an animal cell, as seen under a light microscope, limited to cell wall, nucleus, cytoplasm, chloroplasts, vacuoles and location of the cell membrane 3 State the functions of the structures seen under the light microscope in the plant cell and in the animal cell 5 Calculate magnification and size of biological specimens using millimetres as units	**Supplement** 4 Relate the structure of the following to their functions: – ciliated cells – movement of mucus in the trachea and bronchi – root hair cells – absorption – palisade mesophyll cells – photosynthesis – red blood cells – transport of oxygen – sperm and egg cells – reproduction
B2.2 Movement in and out of cells **Core** 1 Define *diffusion* as the net movement of particles from a region of their higher concentration to a region of their lower concentration down a concentration gradient, as a result of their random movement 3 State that substances move into and out of cells by diffusion through the cell membrane 4 State that water diffuses through partially permeable membranes by osmosis 5 State that water moves in and out of cells by osmosis through the cell membrane 7 Investigate and describe the effects on plant tissues of immersing them in solutions of different concentrations	**Supplement** 2 Investigate the factors that influence diffusion, limited to surface area, temperature, concentration gradients and diffusion distance 6 Define *osmosis* as the net movement of water molecules from a region of higher water potential (dilute solution) to a region of lower water potential (concentrated solution), through a partially permeable membrane 8 Explain the effects on plant tissues of immersing them in solutions of different concentrations by using the terms turgid, turgor pressure, plasmolysis and flaccid 9 Explain the importance of water potential and osmosis in the uptake of water by plants 10 Explain the importance of water potential and osmosis on animal cells and tissues

0654 Biology	
B3 Biological molecules	
Core 1 List the chemical elements that make up: – carbohydrates – fats – proteins 2 State that large molecules are made from smaller molecules, limited to: – starch and glycogen from glucose – proteins from amino acids – fats and oils from fatty acids and glycerol 3 Describe the use of: – iodine solution to test for starch – Benedict's solution to test for reducing sugars – biuret test for proteins – ethanol emulsion test for fats and oils 4 State that water is important as a solvent	
B4 Enzymes	
Core 1 Define *enzymes* as proteins that function as biological catalysts 3 Investigate and describe the effect of changes in temperature and pH on enzyme activity	**Supplement** 2 Explain enzyme action with reference to the complementary shape of the active site of an enzyme and its substrate and the formation of a product 4 Explain the effect of changes in temperature on enzyme activity, in terms of kinetic energy, shape and fit, frequency of effective collisions and denaturation 5 Explain the effect of changes in pH on enzyme activity in terms of shape and fit and denaturation

0654 Biology	
B5 Plant nutrition	
Core	**Supplement**
1 Define *photosynthesis* as the process by which plants manufacture carbohydrates from raw materials using energy from light	
2 State the word equation for photosynthesis: carbon dioxide + water → glucose + oxygen, in the presence of light and chlorophyll	3 State the balanced equation for photosynthesis $6CO_2 + 6H_2O \xrightarrow[\text{chlorophyll}]{\text{light}} C_6H_{12}O_6 + 6O_2$ 4 Explain that chlorophyll transfers light energy into chemical energy in molecules, for the synthesis of carbohydrates 5 Outline the subsequent use and storage of the carbohydrates made in photosynthesis
6 Investigate the necessity for chlorophyll, light and carbon dioxide for photosynthesis, using appropriate controls	7 Investigate and describe the effect of varying light intensity and temperature on the rate of photosynthesis (e.g. in submerged aquatic plants)
8 Identify chloroplasts, cuticle, guard cells and stomata, upper and lower epidermis, palisade mesophyll, spongy mesophyll, vascular bundles, xylem and phloem in leaves of a dicotyledonous plant	9 Describe the significance of the features of a leaf in terms of functions, to include: – palisade mesophyll and distribution of chloroplasts – photosynthesis – stomata, spongy mesophyll cells and guard cells – gas exchange – xylem for transport and support – phloem for transport
10 Describe the importance of: – nitrate ions for making amino acids – magnesium ions for making chlorophyll	11 Explain the effects of nitrate ion and magnesium ion deficiency on plant growth

0654 Biology	
B6 Animal nutrition	
B6.1 Diet **Core** 1 State what is meant by the term *balanced diet* for humans 2 List the principal sources of, and describe the dietary importance of: – carbohydrates – fats – proteins – vitamins, limited to C and D – mineral salts, limited to calcium and iron – fibre (roughage) – water	**Supplement** 3 Explain how age, gender and activity affect the dietary needs of humans including during pregnancy and whilst breast-feeding 4 Describe the effects of malnutrition in relation to starvation, constipation, coronary heart disease, obesity and scurvy 5 Explain the causes and effects of vitamin D and iron deficiencies 6 Explain the causes and effects of protein-energy malnutrition, e.g. kwashiorkor and marasmus

0654 Biology	
B6.2 Alimentary canal **Core**	**Supplement**
1 Define *ingestion* as the taking of substances, e.g. food and drink, into the body through the mouth	
2 Define *digestion* as the breakdown of large, insoluble food molecules into small, water-soluble molecules using mechanical and chemical processes	3 Define *mechanical digestion* as the breakdown of food into smaller pieces without chemical change to the food molecules 4 Define *chemical digestion* as the breakdown of large, insoluble molecules into small, soluble molecules
5 Define *absorption* as movement of digested food molecules through the wall of the intestine into the blood	
6 Define *assimilation* as the movement of digested food molecules into the cells of the body where they are used, becoming part of the cells	
7 Define *egestion* as passing out of food that has not been digested, as faeces, through the anus	
8 Identify the main regions of the alimentary canal and associated organs, including mouth, salivary glands, oesophagus, stomach, small intestine, pancreas, liver, gall bladder, large intestine and anus	
9 Describe the functions of the regions of the alimentary canal listed above, in relation to ingestion, digestion, absorption, assimilation and egestion of food	

0654 Biology	
B6.3 Digestion **Core**	**Supplement**
1 Identify the types of human teeth (incisors, canines, premolars and molars)	
2 Describe the structure of human teeth, limited to enamel, dentine, pulp, nerves and cement, as well as the gums	
3 Describe the functions of the types of human teeth in mechanical digestion of food	
4 Describe the proper care of teeth in terms of diet and regular brushing	5 State the causes of dental decay in terms of a coating of bacteria and food on teeth, the bacteria respiring sugars in the food, producing acid which dissolves the enamel and dentine
6 State the significance of chemical digestion in the alimentary canal in producing small, soluble molecules that can be absorbed	7 State the functions of enzymes as follows: – amylase breaks down starch to simpler sugars – protease breaks down protein to amino acids – lipase breaks down fats to fatty acids and glycerol 8 State where, in the alimentary canal, amylase, protease and lipase are secreted 9 State the functions of the hydrochloric acid in gastric juice, limited to killing bacteria in food and giving an acid pH for enzymes 10 Explain the functions of the hydrochloric acid in gastric juice, limited to the low pH: – denaturing enzymes in harmful microorganisms in food – giving the optimum pH for protease activity 11 Outline the role of bile in neutralising the acidic mixture of food and gastric juices entering the duodenum from the stomach, to provide a suitable pH for enzyme action 12 Outline the role of bile in emulsifying fats to increase the surface area for the chemical digestion of fat to fatty acids and glycerol by lipase 13 Explain the significance of villi in increasing the internal surface area of the small intestine 14 Describe the structure of a villus 15 Describe the roles of capillaries and lacteals in villi

0654 Biology	
B7 Transport	
B7.1 Transport in plants **Core**	**Supplement**
1 State the functions of xylem and phloem	
2 Identify the position of xylem as seen in sections of roots, stems and leaves, limited to non-woody dicotyledonous plants	
3 Identify root hair cells, as seen under the light microscope, and state their functions	4 Explain that the large surface area of root hairs increases the rate of the absorption of water and ions
5 State the pathway taken by water through root, stem and leaf as root hair, root cortex cells, xylem and mesophyll cells	
6 Investigate, using a suitable stain, the pathway of water through the above-ground parts of a plant	
7 State that water is transported from the roots to leaves through the xylem vessels	
8 Define *transpiration* as loss of water vapour from plant leaves by evaporation of water at the surfaces of the mesophyll cells followed by diffusion of water vapour through the stomata	9 Explain the mechanism by which water moves upwards in the xylem in terms of a transpiration pull, helping to create a water potential gradient that draws up a column of water molecules, held together by cohesion
10 Investigate and describe the effects of variation of temperature and humidity on transpiration rate	11 Explain the effects of variation of temperature and humidity on transpiration rate
	12 Define *translocation* in terms of the movement of sucrose and amino acids in phloem: – from regions of production (source) – to regions of storage OR to regions where they are used in respiration or growth (sink)

0654 Biology	
B7.2 Transport in mammals **Core**	**Supplement**
1 Describe the circulatory system as a system of blood vessels with a pump and valves to ensure one-way flow of blood	2 Describe the double circulation in terms of circulation to the lungs and circulation to the body tissues in mammals 3 Explain the advantages of a double circulation
4 Name and identify the structures of the mammalian heart, limited to the muscular wall, the septum, the left and right ventricles and atria, one-way valves and coronary arteries	
5 State that blood is pumped away from the heart into arteries and returns to the heart in veins	6 Describe the functioning of the heart in terms of the contraction of muscles of the atria and ventricles and the action of the valves
7 Name the main blood vessels to and from the: – heart, limited to vena cava, aorta, pulmonary artery and pulmonary vein – lungs, limited to the pulmonary artery and pulmonary vein – kidney, limited to the renal artery and renal vein	8 Describe coronary heart disease in terms of the blockage of coronary arteries and state the possible risk factors as diet, stress, smoking, genetic predisposition, age and gender
9 Investigate and state the effect of physical activity on pulse rate	10 Explain the effect of physical activity on the heart rate
11 Describe the structure and functions of arteries, veins and capillaries	12 Explain how the structures of arteries, veins and capillaries are adapted for their function
13 List the components of blood as red blood cells, white blood cells, platelets and plasma	
14 Identify red and white blood cells, as seen under the light microscope, on prepared slides and in diagrams and photomicrographs	
15 State the functions of the following components of blood: – red blood cells in transporting oxygen, including the role of haemoglobin – white blood cells in phagocytosis and antibody production – platelets in clotting (details are not required) – plasma in the transport of blood cells, ions, soluble nutrients, hormones and carbon dioxide	

0654 Biology	
B8 Gas exchange and respiration	
B8.1 Gas exchange **Core**	**Supplement**
1 Name and identify the lungs, diaphragm, ribs, intercostal muscles, larynx, trachea, bronchi, bronchioles, alveoli and associated capillaries	2 List the features of gas exchange surfaces in humans, limited to large surface area, thin surface, good blood supply and good ventilation with air
3 State the differences in composition between inspired and expired air limited to oxygen, carbon dioxide and water vapour	4 Explain the differences in composition between inspired and expired air
5 Use limewater as a test for carbon dioxide to investigate the differences in composition between inspired and expired air	
6 Investigate and describe the effects of physical activity on rate and depth of breathing	7 Explain the effects of physical activity on rate and depth of breathing in terms of the increased carbon dioxide concentration in the blood, causing an increased rate of breathing
	8 Explain the role of goblet cells, mucus and ciliated cells in protecting the gas exchange system from pathogens and particles
	9 State that tobacco smoking can cause chronic obstructive pulmonary disease (COPD), lung cancer and coronary heart disease
	10 Describe the effects on the gas exchange system of tobacco smoke and its major toxic components, limited to carbon monoxide, nicotine and tar

0654 Biology	
B8.2 Respiration **Core** 1 State the uses of energy in the body of humans limited to: muscle contraction, protein synthesis, cell division, growth and the maintenance of a constant body temperature 3 State the word equation for aerobic respiration as glucose + oxygen → carbon dioxide + water	**Supplement** 2 Define *aerobic respiration* as the chemical reactions in cells that use oxygen to break down nutrient molecules to release energy 4 State the balanced chemical equation for aerobic respiration as $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ 5 Define *anaerobic respiration* as the chemical reactions in cells that break down nutrient molecules to release energy without using oxygen 6 State the word equation for anaerobic respiration in muscles during vigorous exercise (glucose → lactic acid) 7 State that lactic acid builds up in muscles and blood during vigorous exercise causing an oxygen debt 8 State the word equation for anaerobic respiration in microorganism yeast (glucose → alcohol + carbon dioxide) 9 Describe the role of anaerobic respiration in yeast during bread-making 10 State that anaerobic respiration releases much less energy per glucose molecule than aerobic respiration

0654 Biology	
B9 Coordination and response	
B9.1 Nervous control in humans **Core** 1 Describe a nerve impulse as an electrical signal that passes along nerve cells called neurones 2 Describe the human nervous system in terms of: – the central nervous system consisting of brain and spinal cord – the peripheral nervous system – coordination and regulation of body functions 4 Identify motor (effector), relay (connector) and sensory neurones from diagrams 5 Describe a simple reflex arc in terms of receptor, sensory neurone, relay neurone, motor neurones and effector 6 Describe a reflex action as a means of automatically and rapidly integrating and coordinating stimuli with the responses of effectors (muscles and glands)	**Supplement** 3 Distinguish between voluntary and involuntary actions
B9.2 Sense organs	**Supplement** 1 Identify the structures of the eye, limited to cornea, iris, pupil, lens, retina, optic nerve, ciliary muscles, suspensory ligaments and blind spot 2 Describe the function of each part of the eye, limited to: – cornea – refracts light – iris – controls how much light enters pupil – lens – focuses light onto retina – retina – contains light receptors, some sensitive to light of different colours – optic nerve – carries impulses to the brain 3 Explain the pupil reflex in terms of light intensity and antagonistic action of circular and radial muscles in the iris 4 Explain accommodation to view near and distant objects in terms of the contraction and relaxation of the ciliary muscles, tension in the suspensory ligaments, shape of the lens and refraction of light

0654 Biology	
B9.3 Hormones **Core** 1 Define a *hormone* as a chemical substance, produced by a gland, carried by the blood, which alters the activity of one or more specific target organs 2 Describe adrenaline as the hormone secreted in 'fight or flight' situations and its effects, limited to increased breathing and pulse rate and widened pupils 3 Give examples of situations in which adrenaline secretion increases	**Supplement** 4 Discuss the role of the hormone adrenaline in the chemical control of metabolic activity, including increasing the blood glucose concentration and pulse rate 5 Compare nervous and hormonal control system in terms of speed and longevity of action
B9.4 Homeostasis **Core** 1 Define *homeostasis* as the maintenance of a constant internal environment 5 Name and identify on a diagram of the skin: hairs, hair erector muscles, sweat glands, receptors, sensory neurones, blood vessels and fatty tissue 6 Describe the maintenance of a constant internal body temperature in humans in terms of insulation, sweating, shivering and the role of the brain (limited to blood temperature receptors and coordination)	**Supplement** 2 Explain that homeostasis is the control of internal conditions within set limits 3 Explain the concept of control by negative feedback 4 Describe the control of the glucose content of the blood by the liver and the roles of insulin and glucagon from the pancreas 7 Describe the maintenance of a constant internal body temperature in humans in terms of vasodilation and vasoconstriction of arterioles supplying skin surface capillaries

0654 Biology	
B9.5 Tropic responses **Core** 1 Define *gravitropism* as a response in which parts of a plant grow towards or away from gravity 2 Define *phototropism* as a response in which parts of a plant grow towards or away from the direction from which light is coming 4 Investigate gravitropism and phototropism in shoots and roots	**Supplement** 3 Explain phototropism and gravitropism of a shoot as examples of the chemical control of plant growth 5 Explain the role of auxin in controlling shoot growth, limited to: – auxin made in shoot tip (only) – auxin spreads through the plant from the shoot tip – auxin is unequally distributed in response to light and gravity – auxin stimulates cell elongation
B10 Reproduction	
B10.1 Asexual and sexual reproduction **Core** 1 Define *asexual reproduction* as a process resulting in the production of genetically identical offspring from one parent 3 Identify examples of asexual reproduction from information provided 4 Define *sexual reproduction* as a process involving the fusion of the nuclei of two gametes (sex cells) to form a zygote and the production of offspring that are genetically different from each other	**Supplement** 2 Discuss the advantages and disadvantages of asexual reproduction to a population of a species in the wild 5 State that the nuclei of gametes are haploid and that the nucleus of a zygote is diploid 6 Discuss the advantages and disadvantages of sexual reproduction to a population of a species in the wild
B10.2 Sexual reproduction in plants **Core** 1 Identify and draw, using a hand lens if necessary, the sepals, petals, stamens, filaments and anthers, carpels, style, stigma, ovary and ovules, of an insect-pollinated flower 3 State the functions of the sepals, petals, anthers, stigmas and ovaries 5 Define *pollination* as the transfer of pollen grains from the anther to the stigma 6 Name the agents of pollination 7 State that fertilisation occurs when a pollen nucleus fuses with a nucleus in an ovule 9 Investigate and state the environmental conditions that affect germination of seeds, limited to the requirement for water, oxygen and a suitable temperature	**Supplement** 2 Use a hand lens to identify and describe the anthers and stigmas of a wind-pollinated flower 4 Distinguish between the pollen grains of insect-pollinated and wind-pollinated flowers 8 Describe the structural adaptations of insect-pollinated and wind-pollinated flowers

0654 Biology	
B10.3 Sexual reproduction in humans **Core**	**Supplement**
1 Identify and name on diagrams of the male reproductive system: the testes, scrotum, sperm ducts, prostate gland, urethra and penis 2 State the function of the parts of the male reproductive system limited to: – testes – production of male gametes (sperm) – scrotum – sac that holds the testes outside the body – sperm ducts – transfer sperm to the urethra – prostate gland – secrete fluids for sperm to swim in forming semen – urethra – carries urine and semen out of the body – penis – transfers semen to vagina during sexual intercourse 3 Identify and name on diagrams of the female reproductive system: the ovaries, oviducts, uterus, cervix and vagina 4 State the function of the parts of the female reproductive system limited to: – ovaries – release of female gametes (eggs) – oviducts – transfers egg to uterus and the site of fertilisation – uterus – where the fetus develops – cervix – ring of muscle at the opening of the uterus – vagina – receives penis during sexual intercourse 5 Describe fertilisation as the fusion of the nuclei from a male gamete (sperm) and a female gamete (egg cell/ovum)	6 Compare male and female gametes in terms of size, structure, numbers and mobility 7 State the adaptive features of sperm, limited to flagellum and the presence of enzymes 8 State the adaptive features of egg cells, limited to energy stores and a jelly coating that changes after fertilisation
9 Describe the menstrual cycle in terms of changes in the uterus and ovaries (knowledge of sex hormones are **not** required)	

continued

0654 Biology	
B10.3 Sexual reproduction in humans continued **Core**	**Supplement**
10 State that in early development, the zygote forms an embryo which is a ball of cells that implants into the wall of the uterus	11 State the functions of the umbilical cord, placenta, amniotic sac and amniotic fluid 12 Describe the function of the placenta and umbilical cord in relation to exchange of dissolved nutrients, gases and excretory products and providing a barrier to toxins (structural details are **not** required)
13 State that human immunodeficiency virus (HIV) infection may lead to acquired immune deficiency syndrome (AIDS) 14 Describe the methods of transmission of HIV 15 Explain how the spread of sexually transmitted infections (STIs) is controlled	
B11 Inheritance	
B11.1 Chromosomes and genes **Core**	**Supplement**
1 Define *inheritance* as the transmission of genetic information from generation to generation 2 Define *chromosome* as a thread-like structure of DNA, carrying genetic information in the form of genes 3 Define *gene* as a length of DNA that codes for a protein 4 Define *allele* as a version of a gene 5 Describe the inheritance of sex in humans with reference to XX and XY chromosomes	6 Define a *haploid nucleus* as a nucleus containing a single set of unpaired chromosomes, e.g. in gametes 7 Define a *diploid nucleus* as a nucleus containing two sets of chromosomes, e.g. in body cells 8 State that in a diploid cell, chromosomes are arranged in pairs and in a human diploid cell there are 23 pairs

0654 Biology	
B11.2 Cell division	**Supplement** 1 Define *mitosis* as nuclear division giving rise to genetically identical cells (details of stages are **not** required) 2 State that the exact duplication of chromosomes occurs before mitosis 3 State the role of mitosis in growth, repair of damaged tissues, replacement of cells and asexual reproduction 4 Define *meiosis* as reduction division in which the chromosome number is halved from diploid to haploid resulting in genetically different cells (details of stages are **not** required) 5 State that meiosis is involved in the production of gametes
B11.3 Monohybrid inheritance **Core** 1 Define *genotype* as the genetic make-up of an organism in terms of the alleles present 2 Define *phenotype* as the observable features of an organism 3 Define *homozygous* as having two identical alleles of a particular gene 4 State that two identical homozygous individuals that breed together will be pure-breeding 5 Define *heterozygous* as having two different alleles of a particular gene 6 State that a heterozygous individual will not be pure-breeding 7 Define *dominant* as an allele that is expressed if it is present 8 Define *recessive* as an allele that is only expressed when there is no dominant allele of the gene present 9 Use genetic diagrams to predict the results of monohybrid crosses and calculate phenotypic ratios, limited to 1:1 and 3:1 ratios 10 Use Punnett squares in crosses which result in more than one genotype to work out and show the possible different genotypes	**Supplement** 11 Interpret pedigree diagrams for the inheritance of a given characteristic

0654 Biology	
B11.4 Variation and selection **Core**	**Supplement**
1 Define *variation* as differences between individuals of the same species	
2 Distinguish between phenotypic variation and genetic variation	3 State that phenotypic variation is caused by both genetic and environmental factors
4 State that continuous variation results in a range of phenotypes between two extremes, e.g. height in humans	5 State that discontinuous variation is mostly caused by genes alone, e.g. A, B, AB and O blood groups in humans
6 State that discontinuous variation results in a limited number of phenotypes with no intermediates, e.g. tongue rolling	
7 Record and present the results of investigations into continuous and discontinuous variation	8 Define *mutation* as a change in a gene or chromosome 9 State that ionising radiation and some chemicals increase the rate of mutation
10 Describe natural selection with reference to: – variation within populations – production of many offspring – competition for resources – struggle for survival – reproduction by individuals that are better adapted to the environment than others – passing on of their alleles to the next generation	11 Describe evolution as the change in adaptive features of a population over time as the result of natural selection 12 Define the process of *adaptation* as the process, resulting from natural selection, by which populations become more suited to their environment over many generations 13 Describe the development of strains of antibiotic resistant bacteria as an example of evolution by natural selection
14 Describe selective breeding with reference to: – selection by humans of individuals with desirable features – crossing these individuals to produce the next generation – selection of offspring showing the desirable features	15 State the differences between natural and artificial selection 16 Outline how selective breeding by artificial selection is carried out over many generations to improve crop plants and domesticated animals

0654 Biology	
B12 Organisms and their environment	
Core	**Supplement**
1 State that the Sun is the principal source of energy input to biological systems	
2 Define the terms: – *food chain* as showing the transfer of energy from one organism to the next, beginning with a producer – *food web* as a network of interconnected food chains – *producer* as an organism that makes its own organic nutrients, usually using energy from sunlight, through photosynthesis – *consumer* as an organism that gets its energy by feeding on other organisms – *herbivore* as an animal that gets its energy by eating plants – *carnivore* as an animal that gets its energy by eating other animals – *decomposer* as an organism that gets its energy from dead or waste organic matter	3 Define the terms: – *ecosystem* as a unit containing all of the organisms and their environment, interacting together, in a given area, e.g. a lake – *trophic level* as the position of an organism in a food chain or food web
	4 Describe how energy is transferred between trophic levels
	5 Explain why food chains usually have fewer than five trophic levels
6 Construct simple food chains	
7 Interpret food chains and food webs in terms of identifying producers and consumers	
8 State that consumers may be classed as primary, secondary and tertiary according to their position in a food chain	9 Identify producers, primary consumers, secondary consumers, tertiary consumers and quaternary consumers as the trophic levels in food webs and food chains

0654 Biology	
B13 Human influences on ecosystems	
Core	**Supplement**
1 Describe the carbon cycle, limited to photosynthesis, respiration, feeding, decomposition, fossilisation and combustion	2 Discuss the effects of the combustion of fossil fuels and the cutting down of forests on the oxygen and carbon dioxide concentrations in the atmosphere
3 List the undesirable effects of deforestation as an example of habitat destruction, to include extinction, loss of soil, flooding and increase of carbon dioxide in the atmosphere	4 Explain the undesirable effects of deforestation on the environment
5 State the sources and effects of pollution of water (rivers, lakes and the sea) by chemical waste, discarded rubbish, untreated sewage and fertilisers	6 Explain the process of eutrophication of water in terms of: – increased availability of nitrate and other ions – increased growth of producers – increased decomposition after death of producers – increased aerobic respiration by decomposers – reduction in dissolved oxygen – death of organisms requiring dissolved oxygen in water

0654 Chemistry	
C1 The particulate nature of matter	
Core 1 State the distinguishing properties of solids, liquids and gases 2 Describe the structure of solids, liquids and gases in terms of particle separation, arrangement and types of motion 3 Describe the changes of state in terms of melting, boiling, evaporation, freezing and condensation 4 Demonstrate understanding of the terms *atom*, *molecule* and *ion* 6 Describe and explain diffusion in terms of the movement of particles (atoms, molecules or ions)	**Supplement** 5 Explain changes of state in terms of particle theory and the energy changes involved 7 Describe and explain dependence of rate of diffusion on molecular mass
C2 Experimental techniques	
C2.1 Measurement **Core** 1 Name and suggest appropriate apparatus for the measurement of time, temperature, mass and volume, including burettes, pipettes and measuring cylinders	
C2.2 Criteria of purity **Core** 1 Demonstrate knowledge and understanding of paper chromatography 2 Interpret simple chromatograms 4 Understand the importance of purity in substances for use in everyday life, e.g. in the manufacture of compounds to use in drugs and food additives 5 Recognise that mixtures melt and boil over a range of temperatures	**Supplement** 3 Interpret simple chromatograms, including the use of R_f values 6 Identify substances and assess their purity from melting point and boiling point information
C2.3 Methods of purification **Core** 1 Describe and explain methods of separation and purification by the use of a suitable solvent, filtration, crystallisation, distillation, fractional distillation and paper chromatography 2 Suggest suitable separation and purification techniques, given information about the substances involved	

0654 Chemistry	
C3 Atoms, elements and compounds	
C3.1 Physical and chemical changes **Core** 1 Identify physical and chemical changes, and understand the differences between them	**Supplement** 2 Understand that some chemical reactions can be reversed by changing the reaction conditions (Limited to the effects of heat and water on hydrated and anhydrous copper(II) sulfate and cobalt(II) chloride.) (Concept of equilibrium is **not** required.)
C3.2 Elements, compounds and mixtures **Core** 1 Describe the differences between elements, mixtures and compounds, and between metals and non-metals 2 Define the terms *solvent*, *solute*, *solution* and *concentration*	
C3.3 Atomic structure and the Periodic Table **Core** 1 Describe the structure of an atom in terms of a central nucleus, containing protons and neutrons, and 'shells' of electrons 2 Describe the build-up of electrons in 'shells' and understand the significance of the noble gas electronic structures and of the outer shell electrons (The ideas of the distribution of electrons in s and p orbitals and in d block elements are **not** required.) 3 State the charges and approximate relative masses of protons, neutrons and electrons 4 Define and use *proton number* (atomic number) as the number of protons in the nucleus of an atom 5 Define and use *nucleon number* (mass number) as the total number of protons and neutrons in the nucleus of an atom 6 Use proton number and the simple structure of atoms to explain the basis of the Periodic Table, with special reference to the elements of proton numbers 1 to 20 7 Define *isotopes* as atoms of the same element which have the same proton number but a different nucleon number Note: a copy of the Periodic Table, as shown in the Appendix, will be provided in Papers 1, 2, 3 and 4.	**Supplement** 8 Understand that isotopes have the same properties because they have the same number of electrons in their outer shell

0654 Chemistry	
C3.4 Ions and ionic bonds **Core** 1 Describe the formation of ions by electron loss or gain 2 Use dot-and-cross diagrams to describe the formation of ionic bonds between Group I and Group VII	**Supplement** 3 Describe the formation of ionic bonds between metallic and non-metallic elements to include the strong attraction between ions because of their opposite electrical charges 4 Describe the lattice structure of ionic compounds as a regular arrangement of alternating positive and negative ions, exemplified by the sodium chloride structure
C3.5 Molecules and covalent bonds **Core** 1 State that non-metallic elements form simple molecules with covalent bonds between atoms 2 Describe the formation of single covalent bonds in H_2, Cl_2, H_2O, CH_4, NH_3 and HCl as the sharing of pairs of electrons leading to the noble gas configuration including the use of dot-and-cross diagrams 4 Describe the differences in volatility, solubility and electrical conductivity between ionic and covalent compounds	**Supplement** 3 Use and draw dot-and-cross diagrams to represent the bonding in the more complex covalent molecules such as N_2, C_2H_4, CH_3OH, and CO_2 5 Explain the differences in melting point and boiling point of ionic and covalent compounds in terms of attractive forces
C3.6 Macromolecules **Core** 1 State that there are several different forms of carbon, including diamond and graphite 2 Describe the giant covalent structures of graphite and diamond	**Supplement** 3 Relate the structures of diamond and graphite to their uses, e.g. graphite as a lubricant and a conductor and diamond in cutting tools 4 Describe the macromolecular structure of silicon(IV) oxide (silicon dioxide, SiO_2)

0654 Chemistry	
C4 Stoichiometry	
C4.1 Stoichiometry **Core** 1 Use the symbols of the elements and write the formulae of simple compounds 3 Deduce the formula of a simple compound from the relative numbers of atoms present 4 Deduce the formula of a simple compound from a model or a diagrammatic representation 5 Construct and use word equations 6 Interpret and balance simple symbol equations	**Supplement** 2 Determine the formula of an ionic compound from the charges on the ions present 7 Construct and use symbol equations, with state symbols, including ionic equations 8 Deduce the balanced equation for a chemical reaction, given relevant information 9 Define *relative atomic mass*, A_r, as the average mass of naturally occurring atoms of an element on a scale where the ^{12}C atom has a mass of exactly 12 units 10 Define *relative molecular mass*, M_r, as the sum of the relative atomic masses (*relative formula mass* or M_r will be used for ionic compounds)
C4.2 The mole	**Supplement** 1 Define the *mole* in terms of a specific number of particles called Avogadro's constant 2 Use the molar gas volume, taken as 24 dm^3 at room temperature and pressure 3 Calculate stoichiometric reacting masses, volumes of gases and solutions, and concentrations of solutions expressed in g/dm^3 and mol/dm^3. (Calculations involving the idea of limiting reactants may be set.)

0654 Chemistry	
C5 Electricity and chemistry	
Core	**Supplement**
1 Define *electrolysis* as the breakdown of an ionic compound when molten or in aqueous solution by the passage of electricity	
2 Use the terms *inert electrode*, *electrolyte*, *anode* and *cathode*	3 Describe electrolysis in terms of the ions present and the reactions at the electrodes, in terms of gain of electrons by cations and loss of electrons by anions to form atoms
4 Describe the electrode products and the observations made, using inert electrodes (platinum or carbon), in the electrolysis of: – molten lead(II) bromide – concentrated aqueous sodium chloride – dilute sulfuric acid	5 State the general principle that metals or hydrogen are formed at the negative electrode (cathode), and that non-metals (other than hydrogen) are formed at the positive electrode (anode) 6 Relate the products of electrolysis to the electrolyte and electrodes used, exemplified by the specific examples in the Core together with aqueous copper(II) sulfate using carbon electrodes and using copper electrodes (as used in the refining of copper) 7 Construct simple ionic half-equations for the formation of elements at the cathode
8 Describe electroplating with copper	9 Predict the products of the electrolysis of a specified molten binary compound 10 Describe, in outline, the chemistry of the manufacture of: – aluminium from pure aluminium oxide in molten cryolite – chlorine, hydrogen and sodium hydroxide from concentrated aqueous sodium chloride (Starting materials and essential conditions should be given but not technical details or diagrams.)

0654 Chemistry	
C6 Energy changes in chemical reactions	
Core 1 Describe the meaning of *exothermic* and *endothermic* reactions	**Supplement** 2 Describe bond breaking as an endothermic process and bond forming as an exothermic process 3 Draw and label energy level diagrams for exothermic and endothermic reactions using data provided 4 Interpret energy level diagrams showing exothermic and endothermic reactions and the activation energy of a reaction
C7 Chemical reactions	
C7.1 Rate (speed) of reaction **Core** 1 Describe practical methods for investigating the rate of a reaction which produces a gas 2 Interpret data obtained from experiments concerned with rate of reaction 4 Describe the effect of concentration, particle size, catalysts and temperature on the rate of reactions 7 Describe how concentration, temperature and surface area create a danger of explosive combustion with fine powders (e.g. flour mills) and gases (e.g. methane in mines) Note: Candidates should be encouraged to use the term *rate* rather than *speed*.	**Supplement** 3 Suggest suitable apparatus, given information, for experiments, including collection of gases and measurement of rates of reaction 5 Describe and explain the effect of changing concentration in terms of frequency of collisions between reacting particles 6 Describe and explain the effect of changing temperature in terms of the frequency of collisions between reacting particles and more colliding particles possessing the minimum energy (activation energy) to react
C7.2 Redox **Core** 1 Describe oxidation and reduction in chemical reactions in terms of oxygen loss/gain (Oxidation state limited to its use to name ions, e.g. iron(II), iron(III), copper(II).)	**Supplement** 2 Define *redox* in terms of electron transfer, and identify such reactions from given information, which could include simple equations 3 Define and identify an *oxidising agent* as a substance which oxidises another substance during a redox reaction and a *reducing agent* as a substance which reduces another substance during a redox reaction

0654 Chemistry	
C8 Acids, bases and salts	
C8.1 The characteristic properties of acids and bases **Core** 1 Describe neutrality and relative acidity and alkalinity in terms of pH (whole numbers only) measured using Universal Indicator 2 Describe the characteristic properties of acids (exemplified by dilute hydrochloric acid and dilute sulfuric acid) including their effect on litmus paper and their reactions with metals, bases and carbonates 3 Describe the characteristic properties of bases including their effect on litmus paper and their reactions with acids and ammonium salts 4 Describe and explain the importance of controlling acidity in soil	**Supplement** 5 Define *acids* and *bases* in terms of proton (H^+) transfer, limited to aqueous solutions
C8.2 Types of oxides **Core** 1 Classify oxides as either acidic or basic, related to metallic and non-metallic character	**Supplement** 2 Further classify other oxides as neutral or amphoteric
C8.3 Preparation of salts **Core** 1 Describe the preparation, separation and purification of salts using techniques specified in Section C2 and the reactions specified in Section C8.1	**Supplement** 2 Suggest a method of making a given salt from suitable starting material, given appropriate information, including precipitation

0654 Chemistry	
C8.4 Identification of ions and gases **Core** 1 Describe and use the following tests to identify: *aqueous cations:* ammonium, calcium, copper(II), iron(II), iron(III) and zinc, using aqueous sodium hydroxide and aqueous ammonia as appropriate (formulae of complex ions are **not** required) *cations*: flame tests to identify lithium, sodium, potassium and copper(II) *anions*: carbonate (by reaction with dilute acid and then limewater), chloride and bromide (by reaction under acidic conditions with aqueous silver nitrate), nitrate (by reduction with aluminium) and sulfate (by reaction under acidic conditions with aqueous barium ions) *gases*: ammonia (using damp red litmus paper), carbon dioxide (using limewater), chlorine (using damp litmus paper), hydrogen (using a lighted splint), oxygen (using a glowing splint)	
C9 The Periodic Table	
C9.1 The Periodic Table **Core** 1 Describe the Periodic Table as a method of classifying elements and its use to predict properties of elements	
C9.2 Periodic trends **Core** 1 Describe the change from metallic to non-metallic character across a period	**Supplement** 2 Describe the relationship between Group number, number of outer shell electrons and metallic/non-metallic character

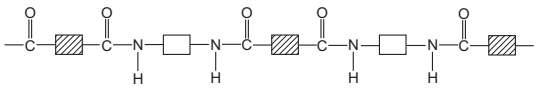
0654 Chemistry	
C9.3 Group properties **Core** 1 Describe lithium, sodium and potassium in Group I as a collection of relatively soft metals showing a trend in melting point, density and reaction with water 3 Describe the halogens, chlorine, bromine and iodine in Group VII, as a collection of diatomic non-metals showing a trend in colour and physical state	**Supplement** 2 Predict the properties of other elements in Group I, given data, where appropriate 4 State the reaction of chlorine, bromine and iodine with other halide ions 5 Predict the properties of other elements in Group VII, given data where appropriate 6 Identify trends in other groups, given data about the elements concerned
C9.4 Transition elements **Core** 1 Describe the transition elements as a collection of metals having high densities, high melting points and forming coloured compounds, and which, as elements and compounds, often act as catalysts	
C9.5 Noble gases **Core** 1 Describe the noble gases, in Group VIII or 0, as being unreactive, monoatomic gases and explain this in terms of electronic structure 2 State the uses of the noble gases in providing an inert atmosphere, i.e. argon in lamps, helium for filling balloons	
C10 Metals	
C10.1 Properties of metals **Core** 1 Describe the general physical properties of metals as solids with high melting and boiling points, malleable and good conductors of heat and electricity 3 Describe alloys, such as brass, as mixtures of a metal with other elements 4 Explain in terms of their properties why alloys are used instead of pure metals	**Supplement** 2 Describe metallic bonding as a lattice of positive ions in a 'sea of electrons' and use this to describe the electrical conductivity and malleability of metals 5 Describe how the properties of iron are changed by the controlled use of additives to form steel alloys, such as mild steel and stainless steel 6 Identify representations of alloys from diagrams of structure

0654 Chemistry	
C10.2 Reactivity series **Core** 1 Place in order of reactivity: potassium, sodium, calcium, magnesium, aluminium, (carbon), zinc, iron, (hydrogen) and copper, by reference to the reactions, if any, of the elements with: – water or steam – dilute hydrochloric acid – reduction of their oxides with carbon 3 Deduce an order of reactivity from a given set of experimental results	**Supplement** 2 Describe the reactivity series in terms of the tendency of a metal to form its positive ion, illustrated by its reaction, if any, with: – aqueous ions of other listed metals – the oxides of other listed metals
C10.3 Extraction of metals from their ores **Core** 1 Describe the use of carbon in the extraction of some metals from their ores 3 Know that aluminium is extracted from the ore bauxite by electrolysis 5 Describe metal ores as a finite resource and hence the need to recycle metals	**Supplement** 2 Describe and explain the essential reactions in the extraction of iron from hematite in the blast furnace, including the removal of acidic impurities as slag $C + O_2 \rightarrow CO_2$ $C + CO_2 \rightarrow 2CO$ $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$ $CaCO_3 \rightarrow CaO + CO_2$ $CaO + SiO_2 \rightarrow CaSiO_3$ 4 Relate the method of extraction of a metal from its ore to its position in the reactivity series for the metals listed in section C10.2 and for other metals, given information
C10.4 Uses of metals **Core** 1 Describe the uses of aluminium: – in aircraft parts because of its strength and low density – in food containers because of its resistance to corrosion 3 State the uses of mild steel (car bodies and machinery) and stainless steel (chemical plant and cutlery)	**Supplement** 2 Describe and explain the apparent unreactivity of aluminium in terms of the oxide layer which adheres to the metal 4 Explain the uses of zinc for galvanising steel and for making brass

0654 Chemistry	
C11 Air and water	
C11.1 Water **Core** 1 Describe a chemical test for water using copper(II) sulfate and cobalt(II) chloride 2 Describe, in outline, the treatment of the water supply in terms of filtration and chlorination	
C11.2 Air **Core** 1 State the composition of clean air as being a mixture of 78% nitrogen, 21% oxygen and small quantities of noble gases, water vapour and carbon dioxide 2 Name the common pollutants in air as being carbon monoxide, sulfur dioxide and oxides of nitrogen 3 State the adverse effect of these common air pollutants on buildings and on health 4 State the source of each of these pollutants: – carbon monoxide from the incomplete combustion of carbon-containing substances – sulfur dioxide from the combustion of fossil fuels which contain sulfur compounds (leading to acid rain) – oxides of nitrogen from car engines 7 State the conditions required for the rusting of iron (presence of oxygen and water) 8 Describe and explain barrier methods of rust prevention, including paint and other coatings	**Supplement** 5 Describe some approaches to reducing emissions of sulfur dioxide, including the use of low sulfur petrol and flue gas desulfurisation by calcium oxide 6 Describe, in outline, how a catalytic converter removes nitrogen monoxide and carbon monoxide from exhaust emissions by reaction over a hot catalyst $2CO + O_2 \rightarrow 2CO_2$ $2NO + 2CO \rightarrow N_2 + 2CO_2$ $2NO \rightarrow N_2 + O_2$ 9 Describe and explain sacrificial protection in terms of the reactivity series of metals and galvanising as a method of rust prevention

0654 Chemistry	
C11.3 Carbon dioxide and methane **Core** 1 State the formation of carbon dioxide: – as a product of complete combustion of carbon-containing substances – as a product of respiration – as a product of the reaction between an acid and a carbonate – as a product of thermal decomposition of calcium carbonate 2 State that carbon dioxide and methane are greenhouse gases	**Supplement** 3 State that increased concentrations of greenhouse gases cause an enhanced greenhouse effect, which may contribute to climate change
C11.4 Nitrogen and fertilisers **Core** 1 Describe the need for nitrogen-, phosphorus- and potassium-containing fertilisers 2 Describe the displacement of ammonia from its salts	**Supplement** 3 Describe and explain the essential conditions for the manufacture of ammonia by the Haber process including the sources of the hydrogen (reaction of methane/natural gas with steam) and nitrogen (from the air)
C12 Sulfur	
Core 1 Name the use of sulfur in the manufacture of sulfuric acid	**Supplement** 2 Describe the manufacture of sulfuric acid by the Contact process, including essential conditions and reactions $S + O_2 \rightarrow SO_2$ $2SO_2 + O_2 \rightleftharpoons 2SO_3$ $H_2SO_4 + SO_3 \rightarrow H_2S_2O_7$ $H_2S_2O_7 + H_2O \rightarrow 2H_2SO_4$
C13 Carbonates	
Core 1 Describe the manufacture of lime (calcium oxide) from limestone (calcium carbonate) in terms of the chemical reactions involved, and the use of limestone in treating acidic soil and neutralising acidic industrial waste products 2 Describe the thermal decomposition of calcium carbonate (limestone)	

0654 Chemistry	
C14 Organic chemistry	
C14.1 Names of compounds **Core** 1 Name and draw the structures of methane, ethane, ethene and ethanol 2 State the type of compound present, given a chemical name ending in *-ane*, *-ene* and *-ol*, or a molecular structure	**Supplement** 3 Name and draw the structures of the unbranched alkanes and alkenes (**not** *cis-trans*), containing up to four carbon atoms per molecule
C14.2 Fuels **Core** 1 State that coal, natural gas and petroleum are fossil fuels that produce carbon dioxide on combustion 2 Name methane as the main constituent of natural gas 3 Describe petroleum as a mixture of hydrocarbons and its separation into useful fractions by fractional distillation 5 Name the uses of the fractions as: – refinery gas for bottled gas for heating and cooking – gasoline fraction for fuel (petrol) in cars – naphtha fraction as a feedstock for making chemicals – diesel oil/gas oil for fuel in diesel engines – bitumen for road surfaces	**Supplement** 4 Describe the properties of molecules within a fraction
C14.3 Homologous series	**Supplement** 1 Describe the homologous series of alkanes and alkenes as families of compounds with the same general formula and similar chemical properties
C14.4 Alkanes **Core** 1 Describe alkanes as saturated hydrocarbons whose molecules contain only single covalent bonds 2 Describe the properties of alkanes (exemplified by methane) as being generally unreactive, except in terms of burning 3 Describe the complete combustion of hydrocarbons to give carbon dioxide and water	

0654 Chemistry	
C14.5 Alkenes **Core** 1 Describe alkenes as unsaturated hydrocarbons whose molecules contain one double covalent bond 2 State that cracking is a reaction that produces alkenes 4 Recognise saturated and unsaturated hydrocarbons: – from molecular structures – by their reaction with aqueous bromine	**Supplement** 3 Describe the formation of smaller alkanes, alkenes and hydrogen by the cracking of larger alkane molecules and state the conditions required for cracking 5 Describe the properties of alkenes in terms of addition reactions with bromine, hydrogen and steam, exemplified by ethene
C14.6 Alcohols **Core** 1 State that ethanol may be formed by fermentation and by reaction between ethene and steam 3 Describe the complete combustion of ethanol to give carbon dioxide and water 4 State the uses of ethanol as a solvent and as a fuel	**Supplement** 2 Describe the formation of ethanol by fermentation and the catalytic addition of steam to ethene
C14.7 Polymers **Core** 1 Define *polymers* as long chain molecules formed from small units (monomers)	**Supplement** 2 Understand that different polymers have different monomer units and/or different linkages
C14.8 Synthetic polymers **Core** 1 Describe the formation of poly(ethene) as an example of addition polymerisation of monomer units	**Supplement** 2 Deduce the structure of the polymer product from a given alkene and *vice versa* 3 Explain the differences between addition and condensation polymerisation 4 Describe the formation of a simple condensation polymer exemplified by nylon, the structure of nylon being represented as: 

0654 Physics	
P1 Motion	
P1.1 Length and time **Core** 1 Use and describe the use of rules and measuring cylinders to find a length or a volume 3 Use and describe the use of clocks and devices, both analogue and digital, for measuring an interval of time 4 Obtain an average value for a small distance and for a short interval of time by measuring multiples (including the period of a pendulum)	**Supplement** 2 Understand that a micrometer screw gauge is used to measure very small distances
P1.2 Motion **Core** 1 Define *speed* and calculate average speed from $\frac{\text{total distance}}{\text{total time}}$ 4 Plot and interpret a speed-time graph and a distance-time graph 6 Recognise from the shape of a speed-time graph when a body is: – at rest – moving with constant speed – moving with changing speed 8 Calculate the area under a speed-time graph to work out the distance travelled for motion with constant acceleration 10 Demonstrate an understanding that acceleration and deceleration are related to changing speed including qualitative analysis of the gradient of a speed-time graph 11 State that the acceleration of free fall *g* for a body near to the Earth is constant	**Supplement** 2 Distinguish between *speed* and *velocity* 3 Define and calculate *acceleration* using $\frac{\text{change of velocity}}{\text{time taken}}$ 5 Calculate acceleration from the gradient of a speed-time graph 7 Recognise linear motion for which the acceleration is constant and calculate the acceleration 9 Recognise motion for which the acceleration is not constant

0654 Physics	
P1.3 Mass and weight **Core** 1 Distinguish between *mass* and *weight* 2 Know that the Earth is the source of a gravitational field 4 Recognise that *g* is the gravitational force on unit mass and is measured in N/k*g* 5 Recall and use the equation $W = mg$ 6 Demonstrate understanding that weights (and hence masses) may be compared using a balance	**Supplement** 3 Describe, and use the concept of, weight as the effect of a gravitational field on a mass
P1.4 Density **Core** 1 Recall and use the equation $\rho = \frac{m}{V}$ 2 Describe an experiment to determine the density of a liquid and of a regularly shaped solid and make the necessary calculation	**Supplement** 3 Describe the determination of the density of an irregularly shaped solid by the method of displacement and make the necessary calculation
P1.5 Forces P1.5.1 Effects of forces **Core** 1 Describe how forces may change the size, shape and motion of a body 6 Understand friction as the force between two surfaces which impedes motion and results in heating 7 Recognise air resistance as a form of friction 8 Find the resultant of two or more forces acting along the same line 9 Recognise that if there is no resultant force on a body it either remains at rest or continues at constant speed in a straight line	**Supplement** 2 Plot and interpret extension-load graphs and describe the associated experimental procedure 3 State Hooke's Law and recall and use the expression $F = kx$, where k is the spring constant 4 Recognise the significance of the term *limit of proportionality* for an extension-load graph 5 Recall and use the relationship between resultant force, mass and acceleration, $F = ma$

0654 Physics	
P1.5.2 Turning effect **Core** 1 Describe the moment of a force as a measure of its turning effect, and give everyday examples 2 Calculate moment using the product force × perpendicular distance from the pivot 3 Recognise that, when there is no resultant force and no resultant turning effect, a system is in equilibrium	**Supplement** 4 Apply the principle of moments to the balancing of a weightless beam about a pivot 5 Apply the principle of moments to different situations
P1.5.3 Centre of mass **Core** 1 Perform and describe an experiment to determine the position of the centre of mass of a plane lamina 2 Describe qualitatively the effect of the position of the centre of mass on the stability of simple objects	
P1.5.4 Pressure **Core** 1 Relate qualitatively pressure to force and area, using appropriate examples	**Supplement** 2 Recall and use the equation $p = F/A$
P2 Work, energy and power	
P2.1 Work **Core** 1 Relate (without calculation) work done to the magnitude of a force and distance moved in the direction of the force	**Supplement** 2 Recall and use $W = Fd = \Delta E$

0654 Physics	
P2.2 Energy **Core** 1 Demonstrate an understanding that work done = energy transferred 2 Demonstrate understanding that an object may have energy due to its motion (kinetic energy, K.E.) or its position (potential energy, P.E.) and that energy may be transferred and stored 3 Give and identify examples of changes in kinetic, gravitational potential, chemical potential, elastic potential (strain), nuclear, thermal, light, sound and electrical energy that have occurred as a result of an event or process 5 Recognise that energy is transferred during events and processes, including examples of transfer by forces (mechanical working), by electric currents (electrical working), by heating and by waves 6 Apply the principle of conservation of energy to simple examples 7 Show a qualitative understanding of efficiency	**Supplement** 4 Recall and use the expressions K.E. = $\frac{1}{2}mv^2$ and gravitational potential energy (G.P.E) = mgh or change in G.P.E = $mg\Delta h$
P2.3 Power **Core** 1 Relate (without calculation) power to work done and time taken, using appropriate examples	**Supplement** 2 Recall and use the equation $P = \Delta E / t$ in simple systems, including electrical circuits

0654 Physics	
P2.4 Energy resources **Core**	**Supplement**
1 Distinguish between renewable and non-renewable sources of energy 2 Describe how electricity or other useful forms of energy may be obtained from: – chemical energy stored in fuel – water, including the energy stored in waves, in tides, and in water behind hydroelectric dams – geothermal resources – nuclear fission – heat and light from the Sun (solar cells and panels) – wind energy 3 Give advantages and disadvantages of each method in terms of renewability, cost, reliability, scale and environmental impact	4 Understand that the Sun is the source of energy for all our energy resources except geothermal, nuclear and tidal 5 Understand that the source of tidal energy is mainly the moon 6 Show an understanding that energy is released by nuclear fusion in the Sun 7 Recall and use the equations: $\text{efficiency} = \frac{\text{useful energy output}}{\text{energy input}} \times 100\%$ $\text{efficiency} = \frac{\text{useful power output}}{\text{power input}} \times 100\%$

0654 Physics	
P3 Thermal physics	
P3.1 Simple kinetic molecular model of matter **Core**	**Supplement**
1 State the distinguishing properties of solids, liquids and gases	2 Relate the properties of solids, liquids and gases to the forces and distances between the molecules and to the motion of the molcules
3 Describe qualitatively the molecular structure of solids, liquids and gases in terms of the arrangement, separation, and motion of the molecules	
4 Describe qualitatively the pressure of a gas and the temperature of a gas, liquid or solid in terms of the motion of its particles	5 Describe qualitatively the pressure of a gas in terms of the motion of its molecules and their colliding with the walls creating a force
6 Show an understanding of Brownian motion (the random motion of particles in a suspension) as evidence for the kinetic molecular model of matter	7 Show an appreciation that massive particles may be moved by light, fast-moving molecules
8 Use and describe the use of thermometers to measure temperature on the Celsius scale	
9 Describe *melting* and *boiling* in terms of energy input without a change in temperature	
10 State the meaning of *melting point* and *boiling point*, and recall the melting and boiling points for water	11 Distinguish between *boiling* and *evaporation*
12 Describe condensation and solidification	
13 Explain evaporation in terms of the escape of more-energetic molecules from the surface of a liquid	
14 Relate evaporation to the consequent cooling of the liquid	15 Demonstrate an understanding of how temperature, surface area and draught over a surface influence evaporation
P3.2 Pressure changes	**Supplement** 1 Describe qualitatively, in terms of molecules, the effect on the pressure of a gas of: – a change of temperature at constant volume – a change of volume at constant temperature

0654 Physics	
P3.3 Matter and thermal properties **Core** 1 Describe qualitatively the thermal expansion of solids, liquids and gases at constant pressure 3 Identify and explain some of the everyday applications and consequences of thermal expansion	**Supplement** 2 Explain in terms of the motion and arrangement of molecules, the relative order of the magnitude of the expansion of solids, liquids and gases
P3.4 Measurement of temperature **Core** 1 Describe how a physical property that varies with temperature may be used for the measurement of temperature, and state examples of such properties 4 Recognise the need for and identify fixed points 6 Describe and explain the structure and action of liquid-in-glass thermometers	**Supplement** 2 Demonstrate understanding of sensitivity, range and linearity 3 Describe the structure of a thermocouple and show understanding of its use as a thermometer for measuring high temperatures and those that vary rapidly 5 Describe and explain how the structure of a liquid-in-glass thermometer relates to its sensitivity, range and linearity
P3.5 Thermal processes P3.5.1 Conduction **Core** 1 Recognise and name typical good and bad thermal conductors 2 Describe experiments to demonstrate the properties of good and bad thermal conductors	**Supplement** 3 Explain conduction in solids in terms of molecular vibrations and transfer by electrons
P3.5.2 Convection **Core** 1 Recognise convection as the main method of energy transfer in fluids 3 Interpret and describe experiments designed to illustrate convection in liquids and gases (fluids)	**Supplement** 2 Relate convection in fluids to density changes

0654 Physics	
P3.5.3 Radiation **Core** 1 Recognise radiation as the method of energy transfer that does not require a medium to travel through 2 Identify infra-red radiation as the part of the electromagnetic spectrum often involved in energy transfer by radiation	**Supplement** 3 Describe the effect of surface colour (black or white) and texture (dull or shiny) on the emission, absorption and reflection of radiation 4 Interpret and describe experiments to investigate the properties of good and bad emitters and good and bad absorbers of infra-red radiation
P3.5.4 Consequences of energy transfer **Core** 1 Identify and explain some of the everyday applications and consequences of conduction, convection and radiation	
P4 Properties of waves, including light and sound	
P4.1 General wave properties **Core** 1 Demonstrate understanding that waves transfer energy without transferring matter 2 Describe what is meant by *wave motion* as illustrated by vibration in ropes and springs and by experiments using water waves 3 Use the term *wavefront* 4 State the meaning of *speed*, *frequency*, *wavelength* and *amplitude* 6 Describe how waves can undergo: – reflection at a plane surface – refraction due to a change of speed	**Supplement** 5 Distinguish between transverse and longitudinal waves and give suitable examples 7 Recall and use the equation $v = f\lambda$ 8 Understand that refraction is caused by a change in speed as a wave moves from one medium to another 9 Describe how waves can undergo diffraction through a narrow gap 10 Describe the use of water waves to demonstrate diffraction

0654 Physics	
P4.2 Light P4.2.1 Reflection of light **Core** 1 Describe the formation of an optical image by a plane mirror and give its characteristics 2 Recall and use the law: angle of incidence i = angle of reflection r recognising these angles are measured to the normal 3 Perform simple constructions, measurements and calculations for reflection by plane mirrors	
P4.2.2 Refraction of light **Core** 1 Interpret and describe an experimental demonstration of the refraction of light 3 Use the terminology for the angle of incidence i and angle of refraction r and describe the passage of light through parallel-sided transparent material	**Supplement** 2 Recall and use the definition of refractive index n in terms of speed 4 Recall and use the equation for refractive index $\frac{\sin i}{\sin r} = n$ 5 Describe internal and total internal reflection using ray diagrams 6 Give the meaning of *critical angle* 7 Describe and explain the action of optical fibres particularly in medicine and communications technology
P4.2.3 Thin converging lens **Core** 1 Describe the action of a thin converging lens on a beam of light 2 Use the terms *principal focus* and *focal length* 3 Draw ray diagrams for the formation of a real image by a single lens 4 Describe the nature of an image using the terms enlarged/same size/diminished and upright/inverted	**Supplement** 5 Describe the difference between a real image and a virtual image 6 Use and describe the use of a single lens as a magnifying glass

0654 Physics	
P4.3 Electromagnetic spectrum **Core** 1 Describe the main features of the electromagnetic spectrum in order of frequency, from radio waves to gamma radiation (γ) 2 State that all electromagnetic waves travel with the same high speed in a vacuum and approximately the same in air 4 Describe typical properties and uses of radiations in all the different regions of the electromagnetic spectrum including: – radio and television communications (radio waves) – satellite television and telephones (microwaves) – electrical appliances, remote controllers for televisions and intruder alarms (infra-red) – medicine and security (X-rays) 5 Demonstrate an understanding of safety issues regarding the use of microwaves and X-rays 6 State the dangers of ultraviolet radiation, from the Sun or from tanning lamps	**Supplement** 3 State that the speed of electromagnetic waves in a vacuum is 3.0×10^8 m/s
P4.4 Sound **Core** 1 Describe the production of sound by vibrating sources 4 State that the approximate range of audible frequencies for a healthy human ear is 20 Hz to 20 000 Hz 5 Show an understanding that a medium is needed to transmit sound waves 6 Describe and interpret an experiment to determine the speed of sound in air, including calculation 8 Relate the loudness and pitch of sound waves to amplitude and frequency 9 Describe how the reflection of sound may produce an echo	**Supplement** 2 Describe the longitudinal nature of sound waves 3 Describe the transmission of sound waves in air in terms of compressions and rarefactions 7 Recognise that sound travels faster in liquids than gases and faster in solids than in liquids

0654 Physics	
P5 Electricity and magnetism	
P5.1 Simple phenomena of magnetism **Core** 1 Describe the forces between magnets, and between magnets and magnetic materials 3 Draw and describe the pattern and direction of magnetic field lines around a bar magnet 4 Distinguish between the magnetic properties of soft iron and steel 5 Distinguish between the design and use of permanent magnets and electromagnets 6 Describe methods of magnetisation to include stroking with a magnet, use of direct current (d.c.) in a coil and hammering in a magnetic field	**Supplement** 2 Give an account of induced magnetism
P5.2 Electrical quantities P5.2.1 Electric charge **Core** 1 State that there are positive and negative charges 2 State that unlike charges attract and that like charges repel 3 Describe and interpret simple experiments to show the production and detection of electrostatic charges by friction 4 State that charging a body involves the addition or removal of electrons 6 Distinguish between electrical conductors and insulators and give typical examples	**Supplement** 5 Describe an electric field as a region in which an electric charge experiences a force
P5.2.2 Current, potential difference and electromotive force (e.m.f.) **Core** 1 Demonstrate understanding of *current*, *potential difference*, *e.m.f.* and *resistance* 2 State that current is related to the flow of charge 4 State that current in metals is due to a flow of electrons 5 State that the potential difference (p.d.) across a circuit component is measured in volts 6 Use and describe the use of an ammeter and a voltmeter, both analogue and digital 7 State that the electromotive force (e.m.f) of an electrical source of energy is measured in volts	**Supplement** 3 Show understanding that a current is a rate of flow of charge and recall and use the equation $I = Q/t$ 8 Show understanding that e.m.f. is defined in terms of energy supplied by a source in driving charge around a complete circuit

0654 Physics	
P5.2.3 Resistance **Core** 1 State that resistance = p.d./current and understand qualitatively how changes in p.d. or resistance affect current 3 Recall and use the equation $R = V/I$	**Supplement** 2 Sketch and explain the current-voltage characteristic of an ohmic resistor and a filament lamp 4 Recall and use quantitatively the proportionality between resistance and length, and the inverse proportionality between resistance and cross-sectional area of a wire
P6 Electric circuits	
P6.1 Circuit diagrams **Core** 1 Draw and interpret circuit diagrams containing sources, switches, resistors (fixed and variable), lamps, ammeters, voltmeters and fuses (Symbols for other common circuit components will be provided in questions.)	
P6.2 Series and parallel circuits **Core** 1 Understand that the current at every point in a series circuit is the same 2 Calculate the combined resistance of two or more resistors in series 4 State that, for a parallel circuit, the current from the source is larger than the current in each branch 6 State that the combined resistance of two resistors in parallel is less than that of either resistor by itself 8 State the advantages of connecting lamps in parallel in a circuit	**Supplement** 3 Recall and use the fact that the sum of the p.d.s across the components in a series circuit is equal to the total p.d. across the supply 5 Recall and use the fact that the current from the source is the sum of the currents in the separate branches of a parallel circuit 7 Calculate the combined resistance of two resistors in parallel 9 Draw and interpret circuit diagrams containing NTC thermistors and light-dependent resistors (LDRs) 10 Describe the action of NTC thermistors and LDRs and show understanding of their use as input transducers

0654 Physics	
P6.3 Electrical Energy	**Supplement** 1 Recall and use the equations $P = IV$ and $E = IVt$
P6.4 Dangers of electricity **Core** 1 Identify electrical hazards including: – damaged insulation – overheating of cables – damp conditions 2 State that a fuse protects a circuit 3 Explain the use of fuses and choose appropriate fuse ratings	
P7 Electromagnetic effects	
P7.1 Magnetic effect of an electric current **Core** 1 Describe the pattern of the magnetic field (including direction) due to currents in straight wires and in solenoids	**Supplement** 2 Describe the effect on the magnetic field of changing the magnitude and direction of the current
P7.2 Force on a current-carrying conductor **Core** 1 Describe an experiment to show that a force acts on a current-carrying conductor in a magnetic field, including the effect of reversing: – the current – the direction of the field	**Supplement** 2 State and use the relative directions of force, field and current
P7.3 d.c. motor **Core** 1 State that a current-carrying coil in a magnetic field experiences a turning effect and that the effect is increased by: – increasing the number of turns on the coil – increasing the current – increasing the strength of the magnetic field	**Supplement** 2 Relate this turning effect to the action of an electric motor including the action of a split-ring commutator

0654 Physics	
P7.4 Electromagnetic induction	**Supplement** 1 Show understanding that a conductor moving across a magnetic field or a changing magnetic field linking with a conductor can induce an e.m.f. in the conductor 2 State the factors affecting the magnitude of an induced e.m.f.
P7.5 a.c. generator	**Supplement** 1 Distinguish between direct current (d.c) and alternating current (a.c) 2 Describe and explain the operation of a rotating-coil generator and the use of slip rings 3 Sketch a graph of voltage output against time for a simple a.c. generator
P7.6 Transformer	**Supplement** 1 Describe the construction of a basic transformer with a soft-iron core, as used for voltage transformations 2 Describe the principle of operation of a transformer 3 Use the terms step-up and step-down 4 Recall and use the equation $(V_p / V_s) = (N_p / N_s)$ (for 100% efficiency) 5 Describe the use of the transformer in high-voltage transmission of electricity 6 Recall and use the equation $I_p V_p = I_s V_s$ (for 100% efficiency) 7 Explain why power losses in cables are lower when the voltage is high
P8 Atomic physics	
P8.1 The nuclear atom **Core** 1 Describe the composition of the nucleus in terms of protons and neutrons 2 Use the terms *proton number Z* and *nucleon number A* 3 Use and explain the term *isotope* 4 Use and interpret the term *nuclide* and use the nuclide notation ${}^{A}_{Z}X$	

0654 Physics	
P8.2 Radioactivity P8.2.1 Characteristics of the three kinds of emission **Core**	**Supplement**
1 Describe the random nature of radioactive emission 2 Identify alpha (α), beta (β) and gamma (γ)-emissions by recalling – their nature – their relative ionising effects – their relative penetrating abilities (β^+ are not included: β-particles will be taken to refer to β^-) 4 Recognise the general term *ionising radiation* can be used to describe radioactive emissions	3 Describe the deflection of α-particles, β-particles and γ-rays in electric fields and in magnetic fields 5 Describe and explain examples of practical applications of α, β and γ-emissions
P8.2.2 Detection of radioactivity **Core** 1 Demonstrate understanding of background radiation 2 Describe the detection of α-particles, β-particles and γ-rays	
P8.2.3 Radioactive decay **Core** 1 State the meaning of *radioactive decay* 2 Use word equations to represent changes in the composition of the nucleus when particles are emitted	**Supplement** 3 Use nuclide notation in equations to show α and β decay
P8.2.4 Half-life **Core** 1 Use the term *half-life* in simple calculations which may involve information in tables or decay curves	
P8.2.5 Safety precautions **Core** 1 Recall the effects of ionising radiations on living things 2 Describe how radioactive materials are handled, used and stored in a safe way	

6. Practical assessment

Scientific subjects are, by their nature, experimental. It is therefore important that an assessment of a candidate's knowledge and understanding of science should contain a practical component (see assessment objective AO3).

Schools' circumstances (e.g. the availability of resources) differ greatly, so two alternative ways of examining the practical component are provided. The alternatives are:

- Paper 5: Practical Test
- Paper 6: Alternative to Practical (written paper).

Whichever practical assessment route is chosen, the following points should be noted:

- the same assessment objectives apply
- the same practical skills are to be learned and developed
- the same sequence of practical activities is appropriate.

Candidates may **not** use textbooks in the practical component, nor any of their own records of laboratory work carried out during their course.

Calculators may be used in all parts of the assessment.

6.1 Teaching experimental skills

The best preparation for these papers is for learners to pursue a course in which practical work is fully integrated so that it is a normal and natural part of the teaching.

Teachers are expected to identify suitable opportunities to embed practical techniques and investigative work throughout the course, rather than as an isolated aspect of preparation for examination. This approach will not only provide opportunities for developing experimental skills but will increase the appeal of the course, and the enjoyment of the subject. Practical work helps learners to acquire a secure understanding of the syllabus topics and to appreciate how scientific theories are developed and tested. It also promotes important scientific attitudes such as objectivity, integrity, co-operation, enquiry and inventiveness.

Experimental work

Experimental work is an essential component of all science and should form a key part of teachers' delivery plans for this syllabus.

Experimental work within science education:

- gives candidates first-hand experience of phenomena
- enables candidates to acquire practical skills
- provides candidates with the opportunity to plan and carry out investigations into practical problems.

Note on taking readings

When approximate volumes are used, e.g. about 2 cm^3, it is expected that candidates will estimate this and not use measuring devices.

A measuring instrument should be used to its full precision. Thermometers may be marked in 1 °C intervals but it is often appropriate to interpolate between scale divisions and record a temperature to the nearest 0.0 °C or 0.5 °C. Measurements using a rule require suitable accuracy of recording, such as 15.0 cm rather than 15 cm; the use of millimetres when appropriate should be encouraged. Similarly, when measuring current, it is often more appropriate to use milliamperes rather than amperes.

Apparatus list

The list below details the apparatus expected to be generally available for both the teaching and the examination of Paper 5. The list is not exhaustive: in particular, some items that are commonly regarded as standard equipment in a science laboratory are not included.

The *Confidential Instructions*, provided to Centres prior to the examination of Paper 5, will give the detailed requirements for the examination.

- rulers capable of measuring to 1 mm
- metre rule
- mounted needles or seekers or long pins with large heads
- means of cutting biological materials, such as scalpels, solid edged razor blades or knives
- scissors
- forceps
- means of writing on glassware
- beakers, 100 cm^3, 250 cm^3
- polystyrene or other plastic beakers of approximate capacity 150 cm^3
- test-tubes (Pyrex or hard glass), approximately 125 mm × 16 mm
- boiling tubes, approximately 150 mm × 25 mm
- delivery tubes
- conical flasks, within the range 150 cm^3 to 250 cm^3
- means of measuring small volumes of liquids, such as syringes (with needles removed)
- measuring cylinders, 100 cm^3, 50 cm^3, 25 cm^3, 10 cm^3
- dropping pipettes
- white tiles
- spotting tiles
- water-bath
- large containers (e.g. plastic bowl) to hold cold water
- hand lens ×6 magnification
- thermometers, –10 °C to +110 °C with 1 °C graduations
- stopclocks (or wall clock or wrist-watch), to measure to an accuracy of 1 s
- Petri dishes
- glass rods
- spatulas
- wooden splints

- chemicals (e.g. for food tests, limewater test)
- indicators (e.g. litmus paper, Universal Indicator paper, full range Universal Indicator, hydrogencarbonate indicator)
- burettes, 50 cm^3
- pipettes, 25 cm^3
- pipette fillers
- filter funnels and filter paper
- wash bottle
- ammeter FSD 1 A, 1.5A
- voltmeter FSD 1 V, 5 V
- electrical cells (batteries) and holders to enable several cells to be joined
- connecting leads and crocodile clips
- d.c. power supply, variable to 12 V
- low-voltage filament lamps in holders
- various resistors and resistance wire
- switches
- good supply of masses and holders
- 2 cm expendable springs
- clamps and stands
- pendulum bobs
- newton meters
- Plasticine or modelling clay
- wooden boards
- converging lens with $f = 15$ cm
- glass or Perspex block, rectangular and semi-circular
- glass or Perspex prism, triangular
- optics pins
- plane mirrors
- ray box

6.2 Description of Components, Paper 5: Practical Test and Paper 6: Alternative to Practical

These papers are based on testing experimental skills. One question on each paper assesses the skill of planning. This question will be based on any one of the sciences, which could be: Biology, Chemistry or Physics and may vary between each examination series. The questions do not assess specific syllabus content from Section 5: Syllabus content. Any information required to answer these questions is contained within the question paper or from the experimental context and skills listed below.

Questions are structured to assess across the grade range A*A*–GG.

Paper 5: Practical Test will typically consist of six to seven exercises, one of which will **not** require the use of apparatus.

Paper 6: Alternative to Practical will test the same experimental skills as Paper 5, and will contain many of the same question parts.

Experimental skills tested in Paper 5: Practical Test and Paper 6: Alternative to Practical

Questions may be set requiring candidates to:

- carefully follow a sequence of instructions
- describe, explain or comment on experimental arrangements and techniques
- select the most appropriate apparatus or method for a task and justify the choice made
- draw, complete or label diagrams of apparatus
- perform simple arithmetical calculations
- take readings from an appropriate measuring device or from an image of the device (e.g. thermometer, rule, protractor, measuring cylinder, ammeter, stopwatch), including:
  - reading analogue and digital scales with accuracy and appropriate precision
  - interpolating between scale divisions when appropriate
  - correcting for zero errors when appropriate
- plan to take a sufficient number and range of measurements, repeating where appropriate to obtain an average value
- describe or explain precautions taken in carrying out a procedure to ensure safety or the accuracy of observations and data, including the control of variables and repetition of measurements
- identify key variables and describe how, or explain why, certain variables should be controlled
- record observations systematically, for example in a table, using appropriate units and to a consistent and appropriate degree of precision
- process data, using a calculator where necessary
- present and analyse data graphically, including the use of best-fit lines where appropriate, interpolation and extrapolation, and the determination of a gradient, intercept or intersection
- interpret and evaluate observations and experimental data
- draw an appropriate conclusion, justifying it by reference to the data and using an appropriate explanation
- comment critically on a procedure or point of practical detail, and suggest an appropriate improvement
- evaluate the quality of data, identifying and dealing appropriately with any anomalous results
- identify possible causes of uncertainty, in data or in a conclusion

- make estimates or describe outcomes which demonstrate their familiarity with an experiment, procedure or technique
- plan an experiment or investigation, including making reasoned predictions of expected results and suggesting suitable apparatus and techniques.

Biology

Candidates may be asked questions on the following experimental contexts:

- the use of familiar, and unfamiliar, techniques to record observations and data, process them and make deductions from them
- recall of simple chemical tests, e.g. for food substances and the use of limewater, hydrogencarbonate indicator, litmus and Universal Indicator paper
- recognise, observe, record and measure images of familiar, and unfamiliar, biological specimens
- make a clear line drawing from an image of a specimen, calculating the magnification and adding labels as required.

Chemistry

Candidates may be asked questions on the following experimental contexts:

- simple quantitative experiments involving the measurement of volumes and/or masses
- rates (speeds) of reaction
- measurement of temperature based on a thermometer with 1 °C graduations and energetics
- problems of an investigatory nature, possibly including suitable organic compounds
- filtration
- electrolysis
- identification of ions and gases
- metals and the reactivity series
- acids, bases, oxides and the preparation of salts
- redox reactions and rusting.

Physics

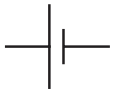
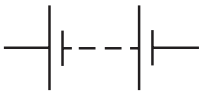
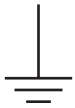
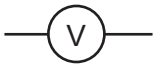
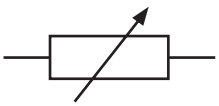
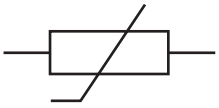
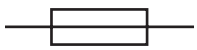
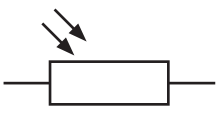
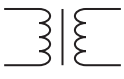
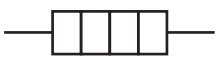
Candidates may be asked questions on the following experimental contexts:

- measurement of physical quantities such as length or volume or force or density
- cooling and heating
- springs and balances
- timing motion or oscillations
- electrical circuits, circuit diagrams and electrical symbols
- optics equipment such as mirrors, prisms and lenses
- procedures using simple apparatus, in situations where the method may not be familiar to the candidate
- use or describe the use of common techniques, apparatus and materials, for example ray-tracing equipment or the connection of electric circuits
- explain the manipulation of the apparatus to obtain observations or measurements, e.g.:
  - when determining a derived quantity, such as the extension per unit load for a spring
  - when testing/identifying the relationship between two variables, such as between the p.d. across a wire and its length
  - when comparing physical quantities, such as two masses, using a balancing method.

7. Appendix

7.1 Electrical symbols

Candidates are expected to be able to recall and use the standard electrical symbols listed below.

cell		switch	
battery of cells	 or 	earth or ground	
power supply		electric bell	
a.c. power supply		motor	
junction of conductors		generator	
lamp		ammeter	
fixed resistor		voltmeter	
variable resistor		oscilloscope	
thermistor		fuse	
light dependent resistor		transformer	
heater			

7.2 Symbols and units for physical quantities

Candidates should be able to give the symbols for the following physical quantities and, where indicated, state the units in which they are measured. The list for the Extended syllabus content includes both the Core and the Supplement.

Candidates should be familiar with the following multipliers: M mega, k kilo, c centi, m milli.

Core			Supplement		
Quantity	***Usual symbol***	***Usual unit***	***Quantity***	***Usual symbol***	***Usual unit***
length	*l, h …*	km, m, cm, mm			
area	*A*	m^2, cm^2			
volume	*V*	m^3, cm^3			
weight	*W*	N			
mass	*m, M*	kg, g	mass	*m, M*	mg
time	*t*	h, min, s	time	*t*	ms
density	*ρ*	g/cm^3, kg/m^3			
speed	*u, v*	km/h, m/s, cm/s			
acceleration	*a*		acceleration	*a*	m/s^2
acceleration of free fall	*g*		acceleration of free fall	*g*	m/s^2
force	*F*	N			
gravitational field strength	*g*	N/kg			
moment of a force		N m			
work done	*W, E*	J, kJ, MJ			
energy	*E*	J, kJ, MJ			
power	*P*	W, kW, MW			
pressure	*p*	N/m^2	pressure	*p*	Pa
temperature	*θ, T*	°C			
frequency	*f*	Hz, kHz			
wavelength	*λ*	m, cm			
focal length	*f*	cm			
angle of incidence	*i*	degree (°)			
angle of reflection, refraction	*r*	degree (°)			
critical angle	*c*	degree (°)			

Core			Supplement		
Quantity	***Usual symbol***	***Usual unit***	***Quantity***	***Usual symbol***	***Usual unit***
			refractive index	*n*	
potential difference/voltage	*V*	V, mV			
current	*I*	A, mA			
e.m.f.	*E*	V			
resistance	*R*	Ω			
			charge	*Q*	C

7.3 Notes for use in qualitative analysis

Tests for anions

anion	test	test result
carbonate (CO_3^{2-})	add dilute acid	effervescence, carbon dioxide produced
chloride (Cl^-) [in solution]	acidify with dilute nitric acid, then add aqueous silver nitrate	white ppt.
bromide (Br^-) [in solution]	acidify with dilute nitric acid, then add aqueous silver nitrate	cream ppt.
nitrate (NO_3^-) [in solution]	add aqueous sodium hydroxide, then aluminium foil; warm carefully	ammonia produced
sulfate (SO_4^{2-}) [in solution]	acidify, then add aqueous barium nitrate	white ppt.

Tests for aqueous cations

cation	effect of aqueous sodium hydroxide	effect of aqueous ammonia
ammonium (NH_4^+)	ammonia produced on warming	–
calcium (Ca^{2+})	white ppt., insoluble in excess	no ppt. or very slight white ppt.
copper (Cu^{2+})	light blue ppt., insoluble in excess	light blue ppt., soluble in excess, giving a dark blue solution
iron(II) (Fe^{2+})	green ppt., insoluble in excess	green ppt., insoluble in excess
iron(III) (Fe^{3+})	red-brown ppt., insoluble in excess	red-brown ppt., insoluble in excess
zinc (Zn^{2+})	white ppt., soluble in excess, giving a colourless solution	white ppt., soluble in excess, giving a colourless solution

Tests for gases

gas	test and test result
ammonia (NH_3)	turns damp, red litmus paper blue
carbon dioxide (CO_2)	turns limewater milky
chlorine (Cl_2)	bleaches damp litmus paper
hydrogen (H_2)	'pops' with a lighted splint
oxygen (O_2)	relights a glowing splint

Flame tests for metal ions

metal ion	flame colour
lithium (Li^+)	red
sodium (Na^+)	yellow
potassium (K^+)	lilac
copper(II) (Cu^{2+})	blue-green

7.4 The Periodic Table

Group																	
I	II											III	IV	V	VI	VII	VIII
							1 H hydrogen 1										2 He helium 4
3 Li lithium 7	4 Be beryllium 9											5 B boron 11	6 C carbon 12	7 N nitrogen 14	8 O oxygen 16	9 F fluorine 19	10 Ne neon 20
11 Na sodium 23	12 Mg magnesium 24											13 Al aluminium 27	14 Si silicon 28	15 P phosphorus 31	16 S sulfur 32	17 Cl chlorine 35.5	18 Ar argon 40
19 K potassium 39	20 Ca calcium 40	21 Sc scandium 45	22 Ti titanium 48	23 V vanadium 51	24 Cr chromium 52	25 Mn manganese 55	26 Fe iron 56	27 Co cobalt 59	28 Ni nickel 59	29 Cu copper 64	30 Zn zinc 65	31 Ga gallium 70	32 Ge germanium 73	33 As arsenic 75	34 Se selenium 79	35 Br bromine 80	36 Kr krypton 84
37 Rb rubidium 85	38 Sr strontium 88	39 Y yttrium 89	40 Zr zirconium 91	41 Nb niobium 93	42 Mo molybdenum 96	43 Tc technetium –	44 Ru ruthenium 101	45 Rh rhodium 103	46 Pd palladium 106	47 Ag silver 108	48 Cd cadmium 112	49 In indium 115	50 Sn tin 119	51 Sb antimony 122	52 Te tellurium 128	53 I iodine 127	54 Xe xenon 131
55 Cs caesium 133	56 Ba barium 137	57–71 lanthanoids	72 Hf hafnium 178	73 Ta tantalum 181	74 W tungsten 184	75 Re rhenium 186	76 Os osmium 190	77 Ir iridium 192	78 Pt platinum 195	79 Au gold 197	80 Hg mercury 201	81 Tl thallium 204	82 Pb lead 207	83 Bi bismuth 209	84 Po polonium –	85 At astatine –	86 Rn radon –
87 Fr francium –	88 Ra radium –	89–103 actinoids	104 Rf rutherfordium –	105 Db dubnium –	106 Sg seaborgium –	107 Bh bohrium –	108 Hs hassium –	109 Mt meitnerium –	110 Ds darmstadtium –	111 Rg roentgenium –	112 Cn copernicium –		114 Fl flerovium –		116 Lv livermorium –		

Key

atomic number
atomic symbol
name
relative atomic mass

lanthanoids	57 La lanthanum 139	58 Ce cerium 140	59 Pr praseodymium 141	60 Nd neodymium 144	61 Pm promethium –	62 Sm samarium 150	63 Eu europium 152	64 Gd gadolinium 157	65 Tb terbium 159	66 Dy dysprosium 163	67 Ho holmium 165	68 Er erbium 167	69 Tm thulium 169	70 Yb ytterbium 173	71 Lu lutetium 175
actinoids	89 Ac actinium –	90 Th thorium 232	91 Pa protactinium 231	92 U uranium 238	93 Np neptunium –	94 Pu plutonium –	95 Am americium –	96 Cm curium –	97 Bk berkelium –	98 Cf californium –	99 Es einsteinium –	100 Fm fermium –	101 Md mendelevium –	102 No nobelium –	103 Lr lawrencium –

The volume of one mole of any gas is 24 dm^3 at room temperature and pressure (r.t.p.)

7.5 Safety in the laboratory

Responsibility for safety matters rests with Centres. Further information can be found from the following UK association, publications and regulations.

Associations

CLEAPSS is an advisory service providing support in practical science and technology.
http://www.cleapss.org.uk

Publications

CLEAPSS Laboratory Handbook, updated 2009 (available to CLEAPSS members only)
CLEAPSS Hazcards, 2007 update of 1995 edition (available to CLEAPSS members only)

UK Regulations

Control of Substances Hazardous to Health Regulations (COSHH) 2002 and subsequent amendment in 2004
http://www.legislation.gov.uk/uksi/2002/2677/contents/made
http://www.legislation.gov.uk/uksi/2004/3386/contents/made

A brief guide may be found at **http://www.hse.gov.uk/pubns/indg136.pdf**

7.6 Glossary of terms used in science papers

This glossary (which is relevant only to science subjects) will prove helpful to candidates as a guide, but it is neither exhaustive nor definitive. The glossary has been deliberately kept brief, not only with respect to the number of terms included, but also to the descriptions of their meanings. Candidates should appreciate that the meaning of a term must depend, in part, on its context.

1 *Define* (the term(s) …) is intended literally, only a formal statement or equivalent paraphrase being required.

2 *What do you understand by*/*What is meant by* (the term(s) …) normally implies that a definition should be given, together with some relevant comment on the significance or context of the term(s) concerned, especially where two or more terms are included in the question. The amount of supplementary comment intended should be interpreted in the light of the indicated mark value.

3 *State* implies a concise answer with little or no supporting argument (e.g. a numerical answer that can readily be obtained 'by inspection').

4 *List* requires a number of points, generally each of one word, with no elaboration. Where a given number of points is specified this should not be exceeded.

5 (a) *Explain* may imply reasoning or some reference to theory, depending on the context. It is another way of asking candidates to give reasons. The candidate needs to leave the examiner in no doubt why something happens.

(b) *Give a reason*/*Give reasons* is another way of asking candidates to explain why something happens.

6 *Describe* requires the candidate to state in words (using diagrams where appropriate) the main points. *Describe* and *explain* may be coupled, as may *state* and *explain*.

7 *Discuss* requires the candidate to give a critical account of the points involved.

8 *Outline* implies brevity (i.e. restricting the answer to giving essentials).

9 *Predict* implies that the candidate is expected to make a prediction not by recall but by making a logical connection between other pieces of information.

10 *Deduce* implies that the candidate is not expected to produce the required answer by recall but by making a logical connection between other pieces of information.

11 *Suggest* is used in two main contexts, i.e. either to imply that there is no unique answer (e.g. in physics there are several examples of energy resources from which electricity, or other useful forms of energy, may be obtained), or to imply that candidates are expected to apply their general knowledge of the subject to a 'novel' situation, one that may be formally 'not in the syllabus' – many data response and problem solving questions are of this type.

12 *Find* is a general term that may variously be interpreted as calculate, measure, determine, etc.

13 *Calculate* is used when a numerical answer is required. In general, working should be shown, especially where two or more steps are involved.

14 *Measure* implies that the quantity concerned can be directly obtained from a suitable measuring instrument (e.g. length using a rule, or mass using a balance).

15 *Determine* often implies that the quantity concerned cannot be measured directly but is obtained from a graph or by calculation.

16 *Estimate* implies a reasoned order of magnitude statement or calculation of the quantity concerned, making such simplifying assumptions as may be necessary about points of principle and about the values of quantities not otherwise included in the question.

17 *Sketch*, when applied to graph work, implies that the shape and/or position of the curve need only be qualitatively correct, but candidates should be aware that, depending on the context, some quantitative aspects may be looked for (e.g. passing through the origin, having an intercept).

In diagrams, *sketch* implies that simple, freehand drawing is acceptable; nevertheless, care should be taken over proportions and the clear exposition of important details.

7.7 Mathematical requirements

Calculators may be used in all parts of the examination.

Candidates should be able to:

- add, subtract, multiply and divide
- use averages, decimals, fractions, percentages, ratios and reciprocals
- use standard notation, including both positive and negative indices
- understand significant figures and use them appropriately
- recognise and use direct and inverse proportion
- use positive, whole number indices in algebraic expressions
- draw charts and graphs from given data
- interpret charts and graphs
- determine the gradient and intercept of a graph
- select suitable scales and axes for graphs
- make approximate evaluations of numerical expressions
- recognise and use the relationship between length, surface area and volume and their units on metric scales
- recall and use equations for the areas of a rectangle, triangle and circle and the volumes of a rectangular block and a cylinder
- use mathematical instruments (ruler, compasses, protractor and set square)
- understand the meaning of angle, curve, circle, radius, diameter, circumference, square, parallelogram, rectangle and diagonal
- solve equations of the form $x = y + z$ and $x = yz$ for any one term when the other two are known
- recognise and use clockwise and anticlockwise directions
- recognise and use points of the compass (N, S, E, W)
- use sines and inverse sines (Extended candidates only).

7.8 Presentation of data

The solidus (/) is to be used for separating the quantity and the unit in tables, graphs and charts, e.g. time / s for time in seconds.

(a) Tables

- Each column of a table should be headed with the physical quantity and the appropriate unit, e.g. time / s.
- The column headings of the table can then be directly transferred to the axes of a constructed graph.

(b) Graphs

- Unless instructed otherwise, the independent variable should be plotted on the x-axis (horizontal axis) and the dependent variable plotted on the y-axis (vertical axis).
- Each axis should be labelled with the physical quantity and the appropriate unit, e.g. time / s.
- The scales for the axes should allow more than half of the graph grid to be used in both directions, and be based on sensible ratios, e.g. 2 cm on the graph grid representing 1, 2 or 5 units of the variable.
- The graph is the whole diagrammatic presentation, including the best-fit line when appropriate. It may have one or more sets of data plotted on it.
- Points on the graph should be clearly marked as crosses (x) or encircled dots (⊙).
- Large 'dots' are penalised. Each data point should be plotted to an accuracy of better than one half of each of the smallest squares on the grid.
- A best-fit line (trend line) should be a single, thin, smooth straight-line or curve. The line does not need to coincide exactly with any of the points; where there is scatter evident in the data, Examiners would expect a roughly even distribution of points either side of the line over its entire length. Points that are clearly anomalous should be ignored when drawing the best-fit line.
- The gradient of a straight line should be taken using a triangle whose hypotenuse extends over at least half of the length of the best-fit line, and this triangle should be marked on the graph.

(c) Numerical results

- Data should be recorded so as to reflect the precision of the measuring instrument.
- The number of significant figures given for calculated quantities should be appropriate to the least number of significant figures in the raw data used.

(d) Pie charts

- These should be drawn with the sectors in rank order, largest first, beginning at 'noon' and proceeding clockwise. Pie charts should preferably contain no more than six sectors.

(e) Bar charts

- These should be drawn when one of the variables is not numerical. They should be made up of narrow blocks of equal width that do **not** touch.

(f) Histograms

- These are drawn when plotting frequency graphs with continuous data. The blocks should be drawn in order of increasing or decreasing magnitude and they **should** touch.

7.9 ICT opportunities

In order to play a full part in modern society, candidates need to be confident and effective users of ICT. This syllabus provides candidates with a wide range of opportunities to use ICT in their study of biology, chemistry and physics.

Opportunities for ICT include:

- gathering information from the internet, DVDs and CD-ROMs
- gathering data using sensors linked to data-loggers or directly to computers
- using spreadsheets and other software to process data
- using animations and simulations to visualise scientific ideas
- using software to present ideas and information on paper and on screen.

8. Other information

Equality and inclusion

Cambridge International Examinations has taken great care in the preparation of this syllabus and assessment materials to avoid bias of any kind. To comply with the UK Equality Act (2010), Cambridge has designed this qualification with the aim of avoiding direct and indirect discrimination.

The standard assessment arrangements may present unnecessary barriers for candidates with disabilities or learning difficulties. Arrangements can be put in place for these candidates to enable them to access the assessments and receive recognition of their attainment. Access arrangements will not be agreed if they give candidates an unfair advantage over others or if they compromise the standards being assessed.

Candidates who are unable to access the assessment of any component may be eligible to receive an award based on the parts of the assessment they have taken.

Information on access arrangements is found in the *Cambridge Handbook* which can be downloaded from the website **www.cie.org.uk/examsofficers**

Language

This syllabus and the associated assessment materials are available in English only.

Grading and reporting

Cambridge IGCSE results are shown by one of the grades A*A*, AA, BB, CC, DD, EE, FF or GG indicating the standard achieved, A*A* being the highest and GG the lowest. 'Ungraded' indicates that the candidate's performance fell short of the standard required for grade GG. 'Ungraded' will be reported on the statement of results but not on the certificate. The letters Q (result pending), X (no result) and Y (to be issued) may also appear on the statement of results but not on the certificate.

Entry option codes

To maintain the security of our examinations, we produce question papers for different areas of the world, known as 'administrative zones'. Where the component entry option code has two digits, the first digit is the component number given in the syllabus. The second digit is the location code, specific to an administrative zone. Information about entry option codes can be found in the *Cambridge Guide to Making Entries*.

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