AQA Level 1/2 Certificate in Science: Double Award

Specification

For exams June 2013 onwards
For certification June 2013 onwards

Level 1/2
Specification

Certificate in Science: Double Award 8404

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Contents

1 Introduction

1a Why choose AQA?

We are the United Kingdom's favourite exam board and more students get their academic qualifications from us than from any other board. But why are we so popular?

We understand the different requirements of each subject by working with teachers. Our qualifications:

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We are an educational charity focused on the needs of the learner. All our income is spent on improving the quality of our specifications, examinations and support services. We don't aim to profit from education, we want you to.

If you are already a customer we thank you for your support. If you are thinking of joining us we look forward to welcoming you.

1b Why choose AQA Level 1/2 Certificate in Science: Double Award?

In developing this specification we have consulted widely with teachers, science advisers and learned societies to produce content and assessments that will both stimulate students' interest in and enthusiasm for science and provide an excellent grounding for further study.

The substantive content covers much of, but is not restricted by, the GCSE Programme of Study. This specification thus contains a broad range of scientific topics that are designed to engage and stimulate students' interest in science whilst providing the knowledge and understanding required for progression to Level 3 qualifications. The specification emphasises scientific knowledge, the application of science and the scientific process.

Science is an enquiry-based discipline involving practical and investigational skills as well as knowledge. Section 3b on the scientific process gives the fundamental ideas behind scientific enquiry that should be delivered through teaching of the content.

This specification has less focus on some of the aspects of How Science Works that are covered in the GCSE sciences (for example, there is little sociological, economic and geographical content). This gives time for more detailed study of scientific knowledge and for development of the skills of scientific enquiry essential to this subject. The skills that will be assessed in this specification are listed in Section 3d.

The terminal assessment model is designed to ensure the maximum amount of time for teaching science without frequent interruptions for examinations.

The content has a significant overlap with that in AQA GCSE Science A and Additional Science, thereby enabling co-teaching if required.

1c How do I start using this specification?

You need to register at **www.aqa.org.uk/askaqa.php** to ensure that you receive regular updates and have access to mark schemes, past question papers, a whole range of teacher support materials and receive details of teacher support meetings.

Once you have decided to enter candidates you need to tell us so we can make sure that you get all the material you need for the examinations. You can let us know by filling in the appropriate *Intention to Enter* and *Estimated Entry* forms.

- If your centre is registered on e-AQA you will receive an e-mail prompting you to submit entry information on-line.
- If you are not e-AQA registered we will send copies to your Examinations Officer. Both forms can be downloaded from our website (**www.aqa.org.uk/admin/p_entries.php**).

If your centre has not used AQA for any examinations in the past, please contact our centre approval team at **centreapproval@aqa.org.uk**

1d How can I find out more?

You can choose to find out more about this specification or the services that AQA offer in a number of ways.

Ask AQA

You have 24-hour access to useful information and answers to the most commonly asked questions at **www.aqa.org.uk/askaqa**

If the answer to your question is not available, you can submit a query through **Ask AQA** for our team. We will respond within 2 working days.

Speak to your subject team

You can talk directly to the GCSE Sciences subject team about this specification either by e-mailing **science-gcse@aqa.org.uk** or by calling 08442 090 415.

Teacher Support Meetings

Details of the full range of our Teacher Support meetings are available on our website at **www.aqa.org.uk/support/teachers.php**

There is also a link to our fast and convenient online booking system for our Teacher Support meetings at **events.aqa.org.uk/ebooking**

If you need to contact the Teacher Support team, you can call us on 01483 477 860 or e-mail us at **teachersupport@aqa.org.uk**

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You can find out more including the latest news, how to register for support and downloadable resources on our website at **aqa.org.uk**

2 Specification at a Glance

AQA Level 1/2 Certificate in Science: Double Award

The Scheme of Assessment is linear, with six question papers to be taken in the same examination series as detailed below. Assessments are available at Foundation or Higher Tier.

Biology Paper 1		Chemistry Paper 1		Physics Paper 1
Foundation or Higher Tier	+	**Foundation or Higher Tier**	+	**Foundation or Higher Tier**
Written paper – 1 hour		**Written paper– 1 hour**		**Written paper– 1 hour**
60 marks – 16.67%		60 marks – 16.67%		60 marks – 16.67%
Structured and open questions		Structured and open questions		Structured and open questions

PLUS

Biology Paper 2		Chemistry Paper 2		Physics Paper 2
Foundation or Higher Tier	+	**Foundation or Higher Tier**	+	**Foundation or Higher Tier**
Written paper– 1 hour		**Written paper– 1 hour**		**Written paper– 1 hour**
60 marks – 16.67%		60 marks – 16.67%		60 marks – 16.67%
Structured and open questions		Structured and open questions		Structured and open questions

Within each of the subject areas (Biology, Chemistry, Physics) candidates must take the same tier for both Papers 1 and 2 but need not take the same tier in each of the subject areas. For example, candidates could take both of the Foundation Tier question papers in Biology, both of the Higher Tier question papers in Chemistry and both of the Higher Tier question papers in Physics. Candidates are not allowed to take different tiers within Biology or within Chemistry or within Physics.

3 Subject Content

3a Introduction

The subject content is presented as a series of topic areas listing the statements of what students need to know and understand, and what they will be assessed on. Expansion of the content and clarification of what may be examined, where necessary, is given in *italics*.

Tiering of subject content

In this specification there is additional content for Higher Tier candidates. This is denoted in the subject content in **bold** type.

How the specification is assessed

The content is assessed through six 1-hour written papers, two covering each subject area (Biology, Physics, Chemistry). Each paper is worth 16.67% of the overall marks for the specification. Assessments will be available twice a year, in January and June.

All written papers are available at Foundation or Higher Tier.

In all written papers, questions will be set that examine application of the knowledge and understanding gained in discussing, evaluating and suggesting implications of data and evidence in both familiar and unfamiliar situations. All applications will use the knowledge and understanding developed through the substantive content.

Questions may be taken from any part of the substantive content.

Paper 1 is more weighted to assessment of knowledge, understanding and application than Paper 2. Paper 2 will include a higher proportion of questions aimed towards the skills listed in Section 3d than Paper 1.

The importance of scientific literacy

Scientists need to be able to communicate their knowledge and understanding to others in a clear, comprehensive and literate manner. Questions are included in the scheme of assessment to test students' ability to use good English, organise information clearly and use scientific terms correctly. Each paper will also include some questions that require students to write full descriptions, explanations and/or evaluations in which statements and ideas are coherently linked.

3b The scientific process

Science attempts to explain the world in which we live. It provides technologies that have had a great impact on our society and the environment. Scientists try to explain phenomena, for example, using hypotheses and models, and to solve problems using evidence.

A scientifically literate person should be equipped to question, and engage in debate on, the evidence used in decision making.

The repeatability and reproducibility of evidence refers to how much we trust the data. The validity of evidence depends on these, as well as on whether the research answers the question. If data is not repeatable or reproducible the research cannot be valid.

To ensure the repeatability, reproducibility, and validity of evidence, scientists consider a range of ideas that relate to:

- how we observe the world
- carrying out investigations so that patterns and relationships between variables may be identified
- making measurements by selecting and using instruments effectively
- presenting and representing data
- identifying patterns and relationships and making suitable conclusions.

These ideas inform decisions and are central to science education. They constitute the scientific process that is a necessary complement to the subject content of biology, chemistry and physics.

Fundamental ideas

Evidence must be approached with a critical eye. It is necessary to look closely at how measurements have been made and what links have been established. Scientific evidence provides a powerful means of forming opinions. These ideas pervade all of the scientific process.

Observation as a stimulus to investigation

Observation is the link between the real world and scientific ideas. When we observe objects, organisms or events we do so using existing knowledge. Observations may suggest hypotheses that can be tested.

Investigations

An investigation is an attempt to determine whether or not there is a relationship between variables. It is therefore necessary to identify and understand the variables in an investigation. The design of an investigation should be scrutinised when evaluating the validity of the evidence it has produced.

3

Measurements in investigations

When making measurements we must consider such issues as inherent variation due to variables that have not been controlled, human error and the characteristics of the instruments used. Evidence should be evaluated with the repeatability and validity of the measurements that have been made in mind.

Presentation of data

To explain the relationship between two or more variables, data may be presented in such a way as to make the patterns more evident. The choice of graphical representation depends upon the type of variable represented.

Using data to draw conclusions

The patterns and relationships observed in data represent the behaviour of the variables in an investigation. However, it is necessary to look at patterns and relationships between variables with the limitations of the data in mind in order to draw conclusions.

Evaluation

In evaluating a whole investigation the repeatability, reproducibility and validity of the data obtained must be considered.

Societal aspects of scientific evidence

A judgement or decision relating to social-scientific issues may be biased, or may not be based on evidence alone, as other societal factors may be relevant.

Limitations of scientific evidence

Science can help us in many ways but it cannot supply all the answers. There are some questions that science cannot answer directly. These tend to be questions where beliefs, opinions and ethics are important.

Investigative skills and practical work

During their study of this course, students should be encouraged to:

- use their knowledge and understanding to pose scientific questions and define scientific problems
- plan and carry out investigative activities, including appropriate risk management, in a range of contexts
- collect, select, process, analyse and interpret both primary and secondary data to provide evidence
- evaluate methodology, evidence and data.

The scientific terms used in this specification are clearly defined by the ASE in *The Language of Measurement: Terminology used in school science investigations* (Association for Science Education, 2010). Teachers should ensure that they, and their students, are familiar with these terms. Definitions of the terms will **not** be required in assessments, but students will be expected to use them correctly.

Further information on how experimental and investigative skills will be assessed in this specification is given in Section 3d.

3c Subject content

Ref	Content
B1	**Cell activity**
B1.1	**Cell structure**
a)	Most animal cells have the following parts: ▪ a nucleus, which controls the activities of the cell ▪ cytoplasm, in which most of the chemical reactions take place ▪ a cell membrane, which controls the passage of substances into and out of the cell ▪ mitochondria, which is where most energy is released in respiration ▪ ribosomes, which is where protein synthesis occurs. Most human cells are like most other animal cells.
b)	In addition to the above, plant cells often have: ▪ chloroplasts, which absorb light energy to make food ▪ a permanent vacuole filled with cell sap. Plant and algal cells also have a cell wall made of cellulose, which strengthens the cell.
c)	A bacterial cell consists of cytoplasm and a membrane surrounded by a cell wall; the genes are not in a distinct nucleus; some of the genes are located in circular structures called plasmids.
d)	Yeast is a single-celled organism. Yeast cells have a nucleus, cytoplasm and a membrane surrounded by a cell wall.
e)	Cells may be specialised to carry out a particular function. *Candidates should be able, when provided with appropriate information, to relate the structure of different types of cell to their function in a tissue, an organ, or the whole organism.*
B1.2	**The movement of substances into and out of cells**
a)	Diffusion is the spreading of the particles of any substance in solution, or particles of a gas, resulting in a net movement from a region where they are of a higher concentration to a region with a lower concentration. The greater the difference in concentration, the faster the rate of diffusion.
b)	Dissolved substances can move into and out of cells by diffusion.
c)	Oxygen required for respiration passes through cell membranes by diffusion.
d)	Osmosis is the diffusion of water from a dilute to a more concentrated solution through a partially permeable membrane that allows the passage of water molecules.
e)	Differences in the concentrations of the solutions inside and outside a cell cause water to move into or out of the cell by osmosis. *Candidates should be familiar with experiments related to diffusion and osmosis as well as the terms isotonic, hypotonic, hypertonic, turgor and plasmolysis.*
f)	Substances are sometimes absorbed against a concentration gradient. This requires the use of energy from respiration. The process is called active transport.
g)	Active transport enables plants to absorb ions from very dilute solutions, eg by root hair cells. Similarly, sugar may be absorbed from low concentrations in the intestine and from low concentrations in the kidney tubules.
h)	A single-celled organism has a relatively large surface area to volume ratio. All the necessary exchanges occur via its surface membrane. The size and complexity of an organism increases the difficulty of exchanging materials.

3

Ref	Content
i)	In multicellular organisms many organ systems are specialised for exchanging materials. The effectiveness of an exchange surface is increased by: ■ having a large surface area that is thin, to provide a short diffusion path ■ (in animals) having an efficient blood supply ■ (in animals, for gaseous exchange) being ventilated. *Candidates should be able to explain how the small intestine and lungs in mammals, and the roots and leaves in plants, are adapted for exchanging materials.*
j)	Gas and solute exchange surfaces in humans and other organisms are adapted to maximise effectiveness. *Candidates should be able, when provided with appropriate information, to explain how gas and solute exchange surfaces are adapted to maximise effectiveness.*
B1.3 Cell division	
a)	The nucleus of a cell contains chromosomes. Chromosomes carry genes that control the characteristics of the body. Each chromosome carries a large number of genes.
b)	Many genes have different forms called alleles, which may produce different characteristics.
c)	In body cells the chromosomes are normally found in pairs.
d)	Body cells divide by mitosis to produce additional cells during growth or to produce replacement cells.
e)	When a body cell divides by mitosis: ■ copies of the genetic material are made ■ the cell then divides once to form two genetically identical body cells.
f)	Cells in reproductive organs divide to form gametes.
g)	A cell divides to form gametes by meiosis.
h)	**When a cell divides to form gametes:** ■ **copies of the genetic information are made** ■ **the cell then divides twice to form four gametes, each with a single set of chromosomes.**
i)	Gametes join at fertilisation to form a single body cell with new pairs of chromosomes. This cell repeatedly divides by mitosis to form many cells. As an organism develops, these cells differentiate to form different kinds of cells.
j)	Most types of animal cell differentiate at an early stage whereas many plant cells retain the ability to differentiate throughout life. In mature animals, cell division is mainly restricted to repair and replacement.
k)	Cells from human embryos and adult bone marrow, called stem cells, can be made to differentiate into many different types of human cell, eg nerve cells.
l)	In therapeutic cloning an embryo is produced with the same genes as the patient. Stem cells from the embryo will not be rejected by the patient's body so they may be used for medical treatment.
m)	Treatment with stem cells may be able to help conditions such as paralysis. *Knowledge and understanding of stem cell techniques is **not** required.* *Candidates should be able, when provided with appropriate information, to make informed judgements about the social and ethical issues concerning the use of stem cells from embryos in medical research and treatments.*
	Throughout Section B1.3, candidates should develop an understanding of the relationship from the molecular level upwards between genes, chromosomes, nuclei and cells and to relate these to tissues, organs and systems.

Ref	Content
B2	**Tissues, organs and organ systems**
B2.1	**Organisation**
a)	Large multicellular organisms develop systems for exchanging materials. During the development of a multicellular organism, cells differentiate so that they can perform different functions.
b)	A tissue is a group of cells with similar structure and function.
c)	Organs are made of tissues. One organ may contain several tissues.
d)	Organ systems are groups of organs that perform a particular function. *Candidates should develop an understanding of size and scale in relation to cells, tissues, organs and systems.*
B2.2	**Animal tissues, organs and systems**
a)	Examples of animal tissues include: - muscular tissue, which can contract to bring about movement - glandular tissue, which can produce substances such as enzymes and hormones - epithelial tissue, which covers some parts of the body.
b)	An example of an animal organ is the stomach, which contains: - muscular tissue, to allow contents to move through the digestive system - glandular tissue, to produce digestive juices - epithelial tissue, to cover the outside and the inside of the stomach.
c)	An example of an animal organ system is the digestive system, a system in which humans and other mammals exchange substances with the environment. The digestive system includes: - glands, such as the pancreas and salivary glands, which produce digestive juices - the stomach and small intestine, where digestion occurs - the liver, which produces bile - the small intestine, where the absorption of soluble food occurs - the large intestine, where water is absorbed from the undigested food, producing faeces.
B2.3	**Plant tissues, organs and systems**
a)	Examples of plant tissues include: - epidermal tissues, which cover the plant - palisade mesophyll, which carries out photosynthesis - spongy mesophyll, which has air spaces to facilitate diffusion of gases - xylem and phloem, which transport substances around the plant.
b)	Plant organs include stems, roots and leaves. *Details of the internal structure of these organs are limited to the leaf and to the position of the xylem and phloem in a dicotyledonous primary root and primary stem.*

Ref Content

B3 Carbohydrates, lipids, proteins and enzymes

B3.1 Carbohydrates, lipids and proteins

Ref	Content
a)	All carbohydrates are made up of units of sugar. ■ Carbohydrates that contain only one sugar unit, eg glucose, or two sugar units, eg sucrose, are referred to as simple sugars. ■ Complex carbohydrates, eg starch and cellulose, are long chains of simple sugar units bonded together.
b)	Lipids are molecules consisting of three molecules of fatty acids joined to a molecule of glycerol.
c)	Protein molecules are made up of long chains of amino acids. These long chains are folded to produce a specific shape that enables other molecules to fit into the protein. Proteins act as: ■ structural components of tissues such as muscles ■ hormones ■ antibodies ■ enzymes.

B3.2 Enzymes

Ref	Content
a)	Enzymes are biological catalysts. Catalysts increase the rate of chemical reactions.
b)	The shape of an enzyme is vital for the enzyme's function. High temperatures change the shape.
c)	Different enzymes work best at different pH values.
d)	Some enzymes work outside the body cells. The digestive enzymes are produced by specialised cells in glands and in the lining of the gut. The enzymes then pass out of the cells into the gut, where they come into contact with food molecules. They catalyse the breakdown of large molecules into smaller molecules.
e)	Some microorganisms produce enzymes that pass out of the cells. These enzymes have many uses in the home and in industry.
f)	In the home: ■ biological detergents may contain protein-digesting and fat-digesting enzymes (proteases and lipases) ■ biological detergents are more effective at low temperatures than other types of detergents.
g)	In industry: ■ proteases are used to 'pre-digest' the protein in some baby foods ■ carbohydrases are used to convert starch into sugar syrup ■ isomerase is used to convert glucose syrup into fructose syrup, which is much sweeter than glucose and therefore can be used in smaller quantities in slimming foods.

Ref	Content
B4	**Human biology**
B4.1	**Breathing**
a)	The respiratory (breathing) system takes air into and out of the body so that oxygen from the air can diffuse into the bloodstream and carbon dioxide can diffuse out of the bloodstream into the air. The lungs are in the upper part of the body (thorax), protected by the ribcage and separated from the lower part of the body (abdomen) by the diaphragm. *Candidates should be able to recognise the following on a diagram of the respiratory system: ribs, intercostal muscles, diaphragm, lungs, trachea, bronchi, bronchioles, alveoli.*
b)	To inhale: - the intercostal muscles contract, pulling the ribcage upwards - at the same time the diaphragm muscles contract, causing the diaphragm to flatten - these two movements cause an increase in the volume of the thorax - the consequent decrease in pressure to below that of the air surrounding the body results in atmospheric air entering the lungs. To exhale: - the intercostal muscles relax, allowing the rib cage to move downwards - at the same time the diaphragm muscles relax, allowing the diaphragm to resume its domed shape - these two movements cause a reduction in the volume of the thorax - the consequent increase in pressure results in air leaving the lungs.
c)	The alveoli provide a very large surface area, richly supplied with blood capillaries, so that gases can readily diffuse into and out of the blood.
d)	A healthy person breathes automatically twenty four hours each day. However, spontaneous breathing may stop due to disease or injury. If this happens the patient can be helped to breathe by using a mechanical ventilator. There are two main types of mechanical ventilator: - negative pressure ventilators, which cause air to be 'drawn' into the lungs - positive pressure ventilators, which force air into the lungs.
B4.2	**Respiration**
a)	Respiration in cells can take place aerobically (using oxygen) or anaerobically (without oxygen), to release energy.
b)	During aerobic respiration chemical reactions occur that use glucose (a sugar) and oxygen and release energy.
c)	Aerobic respiration is summarised by the equations: glucose + oxygen $\longrightarrow$ carbon dioxide + water (+ energy) $C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O$ (+ energy)
d)	Aerobic respiration takes place continuously in both plants and animals.
e)	Most of the reactions in aerobic respiration take place inside mitochondria.
f)	The energy that is released during respiration may be used by the organism in a variety of ways: - to build larger molecules from smaller ones - in animals, to enable muscles to contract - in mammals and birds, to maintain a steady body temperature in colder surroundings - in plants, to build up sugars, nitrates and other nutrients into amino acids, which are then built up into proteins.

Ref	Content
g)	During exercise the human body needs to react to the increased demand for energy. A number of changes take place: - the heart rate increases, increasing blood flow to the muscles - the rate and depth of breathing increase - glycogen stored in the muscles is converted back to glucose.
h)	These changes increase the supply of glucose and oxygen to, and increase the rate of removal of carbon dioxide from, the muscles.
i)	If insufficient oxygen is reaching the muscles, energy is produced by anaerobic respiration. glucose $\longrightarrow$ lactic acid (+ energy) $C_6H_{12}O_6 \longrightarrow 2C_3H_6O_3$ (+ energy)
j)	Anaerobic respiration in muscles is the incomplete breakdown of glucose, which causes a build-up of lactic acid. **An oxygen debt needs to be repaid to oxidise the lactic acid to carbon dioxide and water.**
k)	**Because the breakdown of glucose is incomplete, much less energy is released in anaerobic respiration than during aerobic respiration.**
l)	During long periods of vigorous activity muscles become fatigued and stop contracting efficiently. One cause of muscle fatigue is the build-up of lactic acid in the muscles. Blood flowing through the muscles eventually removes the lactic acid. *Candidates will be expected to interpret data relating to the effects of exercise on the human body.*
m)	Anaerobic respiration in plant cells and in some microorganisms results in the production of ethanol and carbon dioxide.

B4.3 Digestion

a)	Starch (a carbohydrate), proteins and fats are insoluble. They are broken down into soluble substances so that they can be absorbed into the bloodstream in the wall of the small intestine. In the large intestine much of the water mixed with the food is absorbed into the bloodstream. The indigestible food which remains makes up the bulk of the faeces. Faeces leave the body via the anus. *Candidates should be able to recognise the following on a diagram of the digestive system: salivary glands, oesophagus, stomach, liver, gall bladder, pancreas, duodenum, small intestine, large intestine, anus.*
b)	The enzyme amylase is produced in the salivary glands, the pancreas and the small intestine. Amylase catalyses the breakdown of starch into sugars in the mouth and small intestine.
c)	Protease enzymes are produced by the stomach, the pancreas and the small intestine. These enzymes catalyse the breakdown of proteins into amino acids in the stomach and the small intestine.
d)	Lipase enzymes are produced by the pancreas and small intestine. These enzymes catalyse the breakdown of lipids into fatty acids and glycerol in the small intestine.
e)	The stomach also produces hydrochloric acid. The enzymes in the stomach work most effectively in acid conditions.
f)	The liver produces bile, which is stored in the gall bladder before being released into the small intestine. Bile neutralises the acid that was added to food in the stomach. This provides alkaline conditions in which enzymes in the small intestine work most effectively. Bile also emulsifies fats (breaks large drops of fats into smaller droplets). This increases the surface area of fats for lipase enzymes to act upon.

Ref	Content
B4.4 Homeostasis	
B4.4.1	**Principles of homeostasis**
a)	Automatic control systems in the body keep conditions inside the body relatively constant.
b)	Control systems include: - cells called receptors, which detect stimuli (changes in the environment) - coordination centres that receive and process information from receptors - effectors, which bring about responses.
c)	Receptors are found in many organs, including: - the eyes – sensitive to light - the ears – sensitive to sound, and to changes in position (which enables us to keep our balance) - the tongue and in the nose – sensitive to chemicals (enable us to taste and to smell) - the skin – sensitive to touch, pressure, pain and to temperature changes - the brain – sensitive to blood temperature and the concentration of water in the blood - the pancreas – sensitive to the concentration of glucose in the blood. *Knowledge and understanding of the structure and functions of sense organs such as the eye and the ear is **not** required.*
d)	Coordination centres include the brain and spinal cord and the pancreas. Many processes are coordinated by chemical substances called hormones. Hormones are secreted by glands and are usually transported to their target organs by the bloodstream.
e)	Reflex actions are automatic and rapid. They often involve sensory, relay and motor neurones.
f)	In a simple reflex action such as a pain-withdrawal reflex: - impulses from a receptor pass along a sensory neurone to the central nervous system - at a junction (synapse) between a sensory neurone and a relay neurone in the central nervous system, a chemical is released that causes an impulse to be sent along a relay neurone - a chemical is then released at the synapse between a relay neurone and motor neurone in the central nervous system, causing impulses to be sent along a motor neurone to the effector - the effector is either a muscle or a gland: a muscle responds by contracting and a gland responds by releasing (secreting) chemical substances.
g)	Effectors include muscles and glands. *Candidates should be able, when provided with appropriate information, to analyse a particular given example of behaviour in terms of:* *stimulus* ⟶ *receptor* ⟶ *co-ordinator* ⟶ *effector* ⟶ *response*
h)	Internal conditions that are controlled include: - temperature - the water content of the body - the ion content of the body - blood glucose levels.

Ref	Content
B4.4.2	**Temperature control**
a)	Body temperature is monitored and controlled by the thermoregulatory centre in the brain. This centre has receptors sensitive to the temperature of the blood flowing through the brain. *The name of the centre in the brain (hypothalamus) is **not** required.*
b)	Temperature receptors in the skin send impulses to the thermoregulatory centre, giving information about skin temperature.
c)	**If the core body temperature is too high:** - **blood vessels supplying the skin capillaries dilate so that more blood flows through the capillaries and more heat is lost** - **sweat glands release more sweat, which cools the body as it evaporates.** *Foundation Tier candidates are **not** expected to describe details of changes in the blood vessels when the core body temperature is too high, but should understand that the skin looks red when we are hot due to increased blood flow.*
d)	Sweating helps to cool the body. More water is lost when it is hot, and more fluid has to be taken through drink or food to balance this loss.
e)	**If the core body temperature is too low:** - **blood vessels supplying the skin capillaries constrict to reduce the flow of blood through the capillaries** - **muscles may 'shiver' – their contraction needs respiration, which releases some energy to warm the body.** *Foundation Tier candidates are **not** expected to describe details of changes in the blood vessels when the core body temperature is too low.*
B4.4.3	**Control of blood glucose**
a)	The blood glucose concentration is monitored and controlled by the pancreas. Much of the glucose is stored as glycogen in the liver and muscles.
b)	If blood glucose levels are too high, the pancreas produces the hormone insulin, which allows the glucose to move from the blood into the cells.
c)	**When blood glucose levels fall, the pancreas produces a second hormone, glucagon. This causes glycogen to be converted into glucose and released into the blood.**
d)	In Type 1 diabetes a person's blood glucose level may be too high because the pancreas does not produce enough of the hormone insulin. Type 1 diabetes may be controlled by careful diet, exercise, and by injecting insulin.
e)	Type 2 diabetes develops when the body does not respond to its own insulin. Obesity is a significant factor in the development of Type 2 diabetes. Type 2 diabetes can be controlled by careful diet, exercise and by drugs that help the cells to respond to insulin.

Ref	Content
B5	**Defending ourselves against infectious disease**
a)	Microorganisms that cause infectious disease are called pathogens.
b)	Bacteria and viruses may reproduce rapidly inside the body. Bacteria may produce poisons (toxins) that make us feel ill. Viruses live and reproduce inside cells, causing damage. *Knowledge of the structure of viruses is **not** required.*
c)	White blood cells help to defend against pathogens by: - ingesting pathogens - producing antibodies, which destroy particular bacteria or viruses - producing antitoxins, which counteract the toxins released by the pathogens.
d)	The immune system of the body produces specific antibodies to kill a particular pathogen. This leads to immunity from that pathogen. In some cases, dead or inactivated pathogens stimulate antibody production. If a large proportion of the population is immune to a pathogen, the spread of the pathogen is very much reduced.
e)	People can be immunised against a disease by introducing small quantities of dead or inactive forms of the pathogen into the body (vaccination). Vaccines stimulate the white blood cells to produce antibodies that destroy the pathogen. This makes the person immune to future infections by the microorganism, because the body can respond by rapidly making the correct antibody, in the same way as if the person had previously had the disease. The MMR vaccine is used to protect children against measles, mumps and rubella. *Details of vaccination schedules and side effects associated with specific vaccines are **not** required.* *Candidates should be able, when provided with appropriate information, to evaluate the advantages and disadvantages of being vaccinated against a particular disease.*
f)	Some medicines, including painkillers, help to relieve the symptoms of infectious disease, but do not kill the pathogens.
g)	Antibiotics, such as penicillin, are medicines that help to cure bacterial disease by killing infective bacteria inside the body. It is important that specific bacteria should be treated by specific antibiotics. The use of antibiotics has greatly reduced deaths from infectious bacterial diseases.
h)	Antibiotics cannot kill viral pathogens. *Candidates should be aware that it is difficult to develop drugs that kill viruses without also damaging the body's tissues.*
i)	Mutations of pathogens produce new strains. **Antibiotics kill individual pathogens of the non-resistant strain but individual resistant pathogens survive and reproduce, so the population of the resistant strain rises**. Antibiotics and vaccinations may no longer be effective against a new resistant strain of the pathogen. The new strain will then spread rapidly because people are not immune to it and there is no effective treatment. ***Knowledge of development of resistance in bacteria is limited to the fact that pathogens mutate, producing resistant strains.***
j)	Many strains of bacteria, including MRSA, have developed resistance to antibiotics. Overuse and inappropriate use of antibiotics has increased the rate of development of antibiotic-resistant strains of bacteria. **Antibiotics are not currently used to treat non-serious infections such as mild throat infections, in order to slow down the rate of development of resistant strains.**
k)	The development of antibiotic-resistant strains of bacteria necessitates the development of new antibiotics.

Ref	Content
l)	Uncontaminated cultures of microorganisms are required for investigating the action of disinfectants and antibiotics. For this: - Petri dishes and culture media must be sterilised before use to kill unwanted microorganisms - inoculating loops used to transfer microorganisms to the media must be sterilised by passing them through a flame - the lid of the Petri dish should be secured with adhesive tape to prevent microorganisms from the air contaminating the culture, and stored upside down to stop bacteria falling onto the agar surface.
m)	In school and college laboratories, cultures should be incubated at a maximum temperature of 25 °C, which greatly reduces the likelihood of the growth of pathogens that might be harmful to humans.
n)	In industrial conditions higher temperatures can produce more rapid growth.

3

B6 Plants as organisms

B6.1 Photosynthesis

a)	Photosynthesis is summarised by the equations: carbon dioxide + water $\xrightarrow{\text{light energy}}$ glucose + oxygen $6CO_2 + 6H_2O \xrightarrow{\text{light energy}} C_6H_{12}O_6 + 6O_2$
b)	During photosynthesis: - light energy is absorbed by a green substance called chlorophyll, which is found in chloroplasts in some plant cells and in algae - this energy is used to convert carbon dioxide (from the air) and water (from the soil) into sugar (glucose) - oxygen is released as a by-product.
c)	The rate of photosynthesis may be limited by: - low temperature - shortage of carbon dioxide - shortage of light. These factors interact and any one of them may be the factor that limits photosynthesis. *Candidates should be able to relate the principle of limiting factors to the economics of enhancing the following conditions in greenhouses:* - *temperature* - *carbon dioxide concentration* - *light intensity.*
d)	The glucose produced in photosynthesis may be: - used for respiration - converted into insoluble starch for storage - used to produce fat or oil for storage - used to produce cellulose, which strengthens the cell wall - used to produce proteins.
e)	To produce proteins, plants also use nitrate ions that are absorbed from the soil.
f)	Carnivorous plants such as the Venus Fly Trap are adapted to live in nutrient-poor soil as they obtain most of their nutrients from the animals, such as insects, that they catch.

Ref	Content
B6.2 Plant responses	
a)	Plants are sensitive to light (phototropism), moisture (hydrotropism) and gravity (gravitropism): - their shoots grow towards light and against the force of gravity - their roots grow towards moisture and in the direction of the force of gravity.
b)	Plants produce hormones to coordinate and control growth. The hormone auxin controls phototropism and gravitropism (geotropism).
c)	The responses of plant roots and shoots to light, gravity and moisture are the result of unequal distribution of auxin, causing unequal growth rates.
d)	Plant growth hormones are used in agriculture and horticulture as weed killers and as rooting hormones. *Names of specific weed killers and rooting hormones are **not** required.*

B7 Variation and inheritance

Ref	Content
B7.1 Genetic variation	
a)	Differences in the characteristics of individuals of the same kind may be due to differences in: - the genes they have inherited (genetic causes) - the conditions in which they have developed (environmental causes) - a combination of the above.
b)	The information that results in plants and animals having similar characteristics to their parents is carried by genes, which are passed on in the sex cells (gametes) from which the offspring develop.
c)	The nucleus of a cell contains chromosomes. Chromosomes carry genes that control the characteristics of the body. Chromosomes are normally found in pairs.
d)	In human body cells, one of the 23 pairs of chromosomes carries the genes that determine sex. In females the sex chromosomes are the same (XX); in males the sex chromosomes are different (XY).
e)	Different genes control the development of different characteristics of an organism. Some characteristics are controlled by a single gene. Each gene may have different forms called alleles. *Candidates should understand that genes operate at a molecular level to develop characteristics that can be seen.*
f)	If both chromosomes in a pair contain the same allele of a gene, the individual is homozygous for that gene. If the chromosomes in a pair contain different alleles of a gene, the individual is heterozygous for that gene.
g)	An allele that controls the development of a characteristic when it is present on only one of the chromosomes is called a dominant allele. An allele that controls the development of a characteristic only if the dominant allele is not present is called a recessive allele. *Candidates should be familiar with principles used by Mendel in investigating monohybrid inheritance in peas. They should understand that Mendel's work preceded the work by other scientists which linked Mendel's 'inherited factors' with chromosomes.* ***Higher Tier candidates should be able to construct genetic diagrams of monohybrid crosses and predict the outcomes of monohybrid crosses, and should be able to use the terms homozygous, heterozygous, phenotype and genotype.*** *Foundation Tier candidates should be able to interpret genetic diagrams of monohybrid inheritance and sex inheritance, but will **not** be expected to construct genetic diagrams or use the terms homozygous, heterozygous, phenotype or genotype.* *Candidates should understand that genetic diagrams are biological models which can be used to predict the outcomes of crosses.* *Candidates should be able to interpret genetic diagrams, including family trees.*

Ref	Content
h)	There are two forms of reproduction: ▪ sexual reproduction – the joining (fusion) of male and female gametes. The mixture of the genetic information from two parents leads to variety in the offspring ▪ asexual reproduction – no fusion of gametes and only one individual is needed as the parent. There is no mixing of genetic information and so no genetic variation in the offspring. These genetically identical individuals are known as clones.
i)	Chromosomes are made up of large molecules of DNA (deoxyribonucleic acid). DNA contains the coded information that determines inherited characteristics.
j)	A gene is a small section of DNA. **Each gene codes for a particular combination of amino acids, to make a specific protein.**
k)	DNA is made of very long strands, twisted to form a double helix, which contain four different compounds, called bases. *Candidates are **not** expected to know the names of the four bases or how complementary pairs of bases enable DNA replication to take place.*
l)	A sequence of three bases is the code for a particular amino acid. The order of bases controls the order in which amino acids are assembled to produce a particular protein.

B7.2 Genetic disorders

Ref	Content
	Attention is drawn to the potential sensitivity needed in teaching about inherited disorders.
a)	Some disorders are inherited.
b)	Polydactyly (having extra fingers or toes) is caused by a dominant allele and can therefore be passed on by only one parent who has the disorder.
c)	Cystic fibrosis (a disorder of cell membranes) is caused by a recessive allele and must therefore be inherited from both parents. It can be passed on by parents who may be carriers of the disorder without actually having the disorder themselves.
d)	Some inherited conditions are caused by inheritance of abnormal numbers of chromosomes, eg Down's Syndrome is caused by the presence of an extra chromosome.
e)	Concerns about embryo screening include: ▪ the risk of miscarriages ▪ the reliability of the information from the screening procedure ▪ decisions about terminating pregnancy. *Candidates should be able, when provided with appropriate information, to evaluate and make informed judgements about issues concerning embryo screening.*

B7.3 Genetic manipulation

Ref	Content
a)	Modern cloning techniques include: ▪ tissue culture – using small groups of cells from part of a plant ▪ embryo transplants – splitting apart cells from a developing animal embryo before they become specialised, then transplanting the identical embryos into host mothers ▪ adult cell cloning – the nucleus is removed from an unfertilised egg cell and the nucleus from an adult body cell, eg a skin cell, is inserted into the egg cell. An electric shock then acts as the catalyst for the egg cell to begin to divide to form embryo cells. These embryo cells contain the same genetic information as the adult skin cell. When the embryo has developed into a ball of cells, it is inserted into the womb of an adult female to continue its development.

Ref	Content
b)	In genetic engineering, genes from the chromosomes of humans and other organisms can be 'cut out' and transferred to cells of other organisms: ▪ enzymes are used to isolate the required gene ▪ this gene is inserted into a vector, usually a bacterial plasmid or a virus ▪ the vector is used to insert the gene into the required cells.
c)	Genes can also be transferred to the cells of animals, plants or microorganisms at an early stage in their development so that they develop with desired characteristics. Crops that have had their genes modified in this way are called genetically modified crops (GM crops). Genetically modified crops include ones that are resistant to insect attack or to herbicides. Genetically modified crops generally show increased yields.
d)	Concerns about GM crops include the effect on populations of wild flowers and insects, and uncertainty about the effects of eating GM crops on human health.
	Candidates should be able, when provided with appropriate information, to interpret information about cloning techniques and genetic engineering techniques and to make informed judgements about issues concerning cloning and genetic engineering, including GM crops.

B8 Adaptation and interdependence

B8.1 Adaptation

a)	To survive and reproduce, organisms require a supply of materials from their surroundings and from the other living organisms there.
b)	Plants often compete with each other for light and space, and for water and nutrients from the soil.
c)	Animals often compete with each other for food, mates and territory.
d)	Organisms, including microorganisms, have features (adaptations) that enable them to survive in the conditions in which they normally live.
e)	Some organisms live in environments that are very extreme, containing high levels of salt, high temperatures or high pressures. These organisms are called extremophiles.
f)	Adaptations include: ▪ structural adaptations, eg the ways in which organisms are shaped, or coloured ▪ behavioural adaptations, eg migration ▪ functional adaptations, related to processes such as reproduction and metabolism.
	Throughout Section B8.1, candidates should be able, when provided with appropriate information: ▪ *to suggest how organisms are adapted to the conditions in which they live* ▪ *to suggest the factors for which organisms are competing in a given habitat.*

B8.2 Environmental change and distribution of organisms

a)	Living organisms form communities and we need to understand the relationships within and between these communities.
b)	Changes in the environment affect the distribution of living organisms. *Examples might include the changing distribution of some bird species and the disappearance of pollinating insects, including bees.*

Ref	Content
c)	Environmental factors that may affect organisms include living or non-living factors such as: - change in competitor - temperature - availability of nutrients - amount of light - availability of water - availability of oxygen and carbon dioxide - availability of nesting sites, shelter and appropriate habitats.
d)	Living organisms can be used as indicators of environmental change: - lichens can be used as air pollution indicators, particularly of the concentration of sulfur dioxide in the atmosphere - invertebrate animals can be used as water pollution indicators and are used as indicators of the concentration of dissolved oxygen in water. *Knowledge and understanding of the process of eutrophication is **not** required.*
e)	Environmental changes can be measured using non-living indicators such as oxygen levels, temperature and rainfall. *Candidates should understand the advantages and disadvantages of using equipment to measure oxygen levels, temperature and rainfall.*
f)	Quantitative data on the distribution of organisms can be obtained by: - random sampling with quadrats - sampling along a transect. *Candidates should understand:* - *the terms mean, median and mode* - *that sample size is related to validity, reproducibility and repeatability.* *Candidates should be able, when provided with appropriate information:* - *to suggest reasons for the distribution of living organisms in a particular habitat* - *to evaluate methods used to collect environmental data, and consider the validity, reproducibility and repeatability as evidence for environmental change.*

B9 Evolution

B9.1 Natural selection

a)	Darwin's theory of evolution by natural selection states that all species of living things have evolved from simple life forms that first developed more than three billion years ago. *A study of creationism is **not** required.*
b)	The theory of evolution by natural selection was only gradually accepted because: - the theory challenged the idea that God made all the animals and plants that live on Earth - there was insufficient evidence at the time the theory was published to convince many scientists - the mechanism of inheritance and variation was not known until 50 years after the theory was published.
c)	Other theories, including that of Lamarck, are based mainly on the idea that changes that occur in an organism during its lifetime can be inherited. We now know that in the vast majority of cases this type of inheritance cannot occur.

Ref	Content
d)	Studying the similarities and differences between organisms allows us to classify living organisms into animals, plants and microorganisms, and helps us to understand evolutionary and ecological relationships. Models allow us to suggest relationships between organisms. *Candidates should understand how evolutionary trees (models) are used to represent the relationships between organisms.*
e)	Evolution occurs via natural selection. - Individual organisms within a particular species may show a wide range of variation because of differences in their genes. - Individuals with characteristics most suited to the environment are more likely to survive to breed successfully. - The genes that have enabled these individuals to survive are then passed on to the next generation. *Candidates should develop an understanding of the timescales involved in evolution.*
B9.2 Speciation	
a)	Evidence of early forms of life comes from fossils.
b)	Fossils are the 'remains' of organisms from hundreds of thousands of years ago, which are found in rocks. Fossils may be formed in various ways: - from parts of organisms that have not decayed because one or more of the conditions needed for decay are absent - when parts of the organism are replaced by other materials as they decay - as preserved traces of organisms, eg footprints, burrows and rootlet traces.
c)	Many early forms of life were soft-bodied, which means that they have left few traces behind. What traces there were have been mainly destroyed by geological activity. This is why scientists cannot be certain about how life began on Earth.
d)	We can learn from fossils how much or how little different organisms have changed as life developed on Earth.
e)	Extinction may be caused by: - changes to the environment over geological time - new predators - new diseases - new, more successful, competitors - a single catastrophic event, eg massive volcanic eruptions or collisions with asteroids.
f)	New species arise as a result of: - isolation: two populations of a species become separated, eg geographically - **genetic variation: each population has a wide range of alleles that control their characteristics** - **natural selection: in each population, the alleles that control the characteristics which help the organism to survive are selected** - **speciation: the populations become so different that successful interbreeding is no longer possible.** *For Foundation Tier, ideas are restricted to knowledge and understanding of isolation.*

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Ref	Content
B10	**Energy and biomass in food chains**
a)	Radiation from the Sun is the source of energy for most communities of living organisms. Green plants and algae absorb a small amount of the light that reaches them. The transfer from light energy to chemical energy occurs during photosynthesis. This energy is stored in the substances that make up the cells of the plants.
b)	The mass of living material (biomass) at each stage in a food chain is less than it was at the previous stage because: - some materials and energy are always lost in the organisms' waste materials - respiration supplies all the energy needs for living processes, including movement. Much of this energy is eventually transferred to the surroundings. *Construction of food webs and chains, and of pyramids of numbers, is **not** required. An understanding of pyramids of numbers is **not** required.*
c)	The biomass at each stage can be drawn to scale and shown as a pyramid of biomass. *Candidates should be able to interpret pyramids of biomass and construct them from appropriate information.*

Ref	Content
B11	**Decay and the carbon cycle**
a)	Living organisms remove materials from the environment for growth and other processes. These materials are returned to the environment either in waste materials or when living things die and decay.
b)	Materials decay because they are broken down (digested) by microorganisms. Microorganisms are more active and digest materials faster in warm, moist, aerobic conditions.
c)	The decay process releases substances that plants need to grow.
d)	In a stable community, the processes that remove materials are balanced by processes that return materials. The materials are part of a constant cycle.
e)	The constant cycling of carbon is called the carbon cycle. In the carbon cycle: - carbon dioxide is removed from the environment by green plants and algae during photosynthesis - the carbon from the carbon dioxide is used to make carbohydrates, fats and proteins, which make up the body of plants and algae - when green plants and algae respire, some of this carbon becomes carbon dioxide and is released into the atmosphere - when green plants and algae are eaten by animals and these animals are eaten by other animals, some of the carbon becomes part of the fats and proteins that make up their bodies - when animals respire, some of this carbon becomes carbon dioxide and is released into the atmosphere - when plants, algae and animals die, some animals and microorganisms feed on their bodies - carbon is released into the atmosphere as carbon dioxide when microorganisms respire - by the time the microorganisms and detritus feeders have broken down the waste products and dead bodies of organisms in ecosystems and cycled the materials as plant nutrients, all the energy originally absorbed by green plants and algae has been transferred - combustion of wood and fossil fuels releases carbon dioxide into the atmosphere.

Ref	Content
C1	**The fundamental ideas in chemistry**
C1.1	**Solids, liquids and gases**
a)	Matter can be classified in terms of the three states of matter. *Candidates should be familiar with the states of matter and be able to define and explain their inter-conversion in terms of how the particles are arranged and their movement. They should understand the energy changes that accompany changes of state.*
b)	Evidence for the existence of particles can be obtained from simple experiments. *Candidates should be familiar with simple diffusion experiments such as Br_2 / air, NH_3 / HCl, $KMnO_4$ / water.*
C1.2	**Atoms**
a)	All substances are made of atoms. A substance that is made of only one sort of atom is called an element. There are about 100 different elements. Elements are shown in the periodic table. The groups contain elements with similar properties. *Candidates should understand where metals and non-metals appear in the periodic table*
b)	Atoms of each element are represented by a chemical symbol, eg O represents an atom of oxygen, Na represents an atom of sodium. *Knowledge of the chemical symbols for elements other than those named in the specification is **not** required.*
c)	Atoms have a small central nucleus, which is made up of protons and neutrons, and around which there are electrons.
d)	The relative electrical charges are as shown:

Name of particle	Charge
Proton	+1
Neutron	0
Electron	–1

e)	In an atom, the number of electrons is equal to the number of protons in the nucleus. Atoms have no overall electrical charge.
f)	The number of protons in an atom of an element is its atomic number. The sum of the protons and neutrons in an atom is its mass number. *Candidates will be expected to calculate the numbers of each sub-atomic particle in an atom from its atomic number and mass number.*
g)	All atoms of a particular element have the same number of protons. Atoms of different elements have different numbers of protons.
h)	Atoms of the same element can have different numbers of neutrons; these atoms are called isotopes of that element.
i)	Atoms can be represented as shown in this example: (Mass number) 23 Na (Atomic number) 11

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Ref	Content
j)	Electrons occupy particular energy levels. Each electron in an atom is at a particular energy level (in a particular shell). The electrons in an atom occupy the lowest available energy levels (innermost available shells). *Candidates may answer questions in terms of either energy levels or shells.* *Candidates should be able to represent the electronic structure of the first twenty elements of the periodic table in the following forms:*  *sodium* *2,8,1*
k)	The relative masses of protons, neutrons and electrons are:
l)	**The relative atomic mass of an element (A_r) compares the mass of atoms of the element with the ^{12}C isotope. It is an average value for the isotopes of the element.** ***Candidates will not be expected to calculate relative atomic masses from isotopic abundances.***

Name of particle	Mass
Proton	1
Neutron	1
Electron	Very small

C1.3 Chemical reactions and related calculations

Ref	Content
a)	When elements react, their atoms join with other atoms to form compounds. This involves giving, taking or sharing electrons to form ions or molecules to attain the electron arrangement of the nearest noble gas.
b)	The relative formula mass (M_r) of a compound is the sum of the relative atomic masses of the atoms in the numbers shown in the formula. *Candidates are expected to use relative atomic masses in the calculations specified in the subject content. Candidates should be able to calculate the relative formula mass (M_r) of a compound from its formula.*
c)	The relative formula mass of a substance, in grams, is known as one mole of that substance. *Candidates are expected to use the relative formula mass of a substance to calculate the number of moles in a given mass of that substance and vice versa.*
d)	Chemical reactions can be represented by word equations or by symbol equations. *Candidates should be able to write word equations for reactions in the specification and balance given symbol equations.* ***Higher Tier candidates will also be expected to write and balance symbol equations for reactions in the specification.***
e)	Information about the states of reactants and products can be included in chemical equations. *Candidates should be able to use the state symbols (g), (l), (s) and (aq) in equations where appropriate.*
f)	No atoms are lost or made during a chemical reaction so the mass of the products equals the mass of the reactants.
g)	**The masses of reactants and products can be calculated from balanced symbol equations.** ***Candidates should be able to calculate the mass of a reactant or product from information about the masses of the other reactants and products in the reaction and the balanced symbol equation.***

Ref **Content**

h) In some chemical reactions, the products of the reaction can react to produce the original reactants. Such reactions are called reversible reactions and are represented:

$A + B \rightleftharpoons C + D$

For example:

ammonium chloride $\rightleftharpoons$ ammonia + hydrogen chloride

C1.4 The periodic table

a) The periodic table is arranged in order of atomic (proton) number and so that elements with similar properties are in columns, known as groups. The table is called a periodic table because similar properties occur at regular intervals.

b) Elements in the same group in the periodic table have the same number of electrons in their highest energy level (outer electrons) and this gives them similar chemical properties.

*Candidates are **not** required to know of trends within each group in the periodic table, but should be aware of similarities between the elements within a group. Knowledge is limited to the reactions of Group 1 elements with water and with non-metal elements.*

c) The elements in Group 0 of the periodic table are called the noble gases. They are unreactive because their atoms have stable arrangements of electrons.

Candidates should know that the noble gases have eight electrons in their outer energy level, except for helium, which has only two electrons.

C2 Bonding and structure

C2.1 Bonding

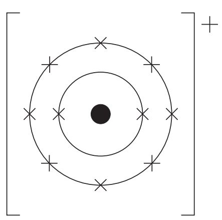
a) Compounds are substances in which atoms of two or more elements are chemically combined.

b) Chemical bonding involves either transferring or sharing electrons in the highest occupied energy levels (shells) of atoms in order to achieve the electron arrangement of a noble gas.

c) When atoms form chemical bonds by transferring electrons, they form ions. Atoms that lose electrons become positively charged ions. Atoms that gain electrons become negatively charged ions. Ions have the electronic structure of a noble gas (Group 0). Compounds formed from metals and non-metals consist of ions.

Candidates should know that metals form positive ions, whereas non-metals form negative ions.

Candidates should be able to represent the electronic structure of ions in the following form:



for sodium ion (Na^+)

Candidates should be able to relate the charge on simple ions to the group number of the element in the periodic table.

d) The elements in Group 1 of the periodic table, the alkali metals, all react with non-metal elements to form ionic compounds in which the metal ion has a single positive charge.

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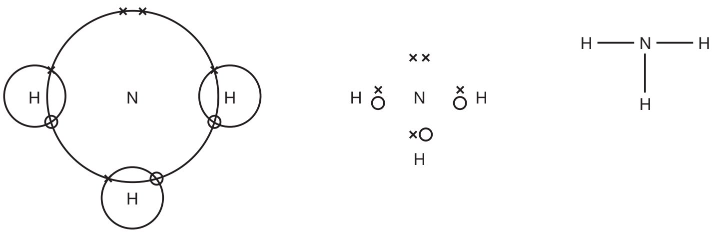
Ref	Content
e)	The elements in Group 7 of the periodic table, the halogens, all react with metals to form ionic compounds in which the halide ions have a single negative charge. *Knowledge of the chemical properties of the halogens is limited to reactions with metals and displacement of less reactive halogens.*
f)	An ionic compound is a giant structure of ions. Ionic compounds are held together by strong electrostatic forces of attraction between oppositely charged ions. These forces act in all directions in the lattice and this is called ionic bonding. *Candidates should be familiar with the structure of sodium chloride but do **not** need to know the structures of other ionic compounds.*
g)	When atoms share pairs of electrons, they form covalent bonds. These bonds between atoms are strong. Some covalently bonded substances, such as H_2, Cl_2, O_2, HCl, H_2O, NH_3 and CH_4, consist of simple molecules. Others, such as diamond and silicon dioxide, have giant covalent structures (macromolecules).
h)	Compounds formed from non-metals consist of molecules. In molecules, the atoms are held together by covalent bonds. *Candidates should be able to represent the covalent bonds in molecules such as water, ammonia, hydrogen, hydrogen chloride, methane and oxygen in the following forms:*

for ammonia (NH_3) and/or and/or



Candidates should be able to recognise other simple molecules and giant structures from diagrams that show their bonding.

C2.2 Structure and how it influences the properties and uses of substances

Ref	Content
a)	Ionic compounds have regular structures (giant ionic lattices) in which there are strong electrostatic forces of attraction in all directions between oppositely charged ions. These compounds have high melting points and high boiling points because of the large amounts of energy needed to break the many strong bonds.
b)	When melted or dissolved in water, ionic compounds conduct electricity because the ions are free to move and carry the current. *Knowledge of the structures of specific ionic compounds other than sodium chloride is **not** required.*
c)	Substances that consist of simple molecules are gases, liquids or solids that have relatively low melting points and boiling points.
d)	**Substances that consist of simple molecules have only weak forces between the molecules (intermolecular forces). It is these intermolecular forces that are overcome, not the covalent bonds, when the substance melts or boils.** ***Candidates need to understand that intermolecular forces are weak compared with covalent bonds.***
e)	Substances that consist of simple molecules do not conduct electricity because the molecules do not have an overall electric charge.
f)	Atoms that share electrons can also form giant structures or macromolecules. Diamond and graphite (forms of carbon) and silicon dioxide (silica) are examples of giant covalent structures (lattices) of atoms. All the atoms in these structures are linked to other atoms by strong covalent bonds and so they have very high melting points. *Candidates should be able to recognise other giant structures or macromolecules from diagrams showing their bonding.*

Ref	Content
g)	In diamond, each carbon atom forms four covalent bonds with other carbon atoms in a giant covalent structure, so diamond is very hard.
h)	In graphite, each carbon atom bonds to three others, forming layers. The layers are free to slide over each other because there are no covalent bonds between the layers and so graphite is soft and slippery. ***Higher Tier candidates should be able to explain the properties of graphite in terms of weak forces between the layers.***
i)	**In graphite, one electron from each carbon atom is delocalised. These delocalised electrons allow graphite to conduct heat and electricity.** ***Candidates should realise that graphite is similar to metals in that it has delocalised electrons.***
j)	**Carbon can also form fullerenes with different numbers of carbon atoms. Fullerenes can be used for drug delivery into the body, in lubricants, as catalysts, and in nanotubes for reinforcing materials, eg in tennis rackets.** ***Candidates are only required to know that the structure of fullerenes is based on hexagonal rings of carbon atoms.***

C3 Air and water

C3.1 Air and oxygen

a)	Air is a mixture of gases with different boiling points. *Candidates should recall the approximate composition of air in terms of percentages of oxygen and nitrogen.* *Candidates should know that there are relatively small amounts of water vapour, carbon dioxide, neon and argon but the percentages of these components is **not** required.*
b)	**Dry air, free from carbon dioxide, can be liquefied and then fractionally distilled to obtain oxygen and nitrogen.** ***Knowledge of the boiling points of the different gases is not required.***
c)	Elements can burn in air to form oxides, which can be classified as acidic, basic and amphoteric. *Candidates should be able to describe the burning of Na, Mg, Fe, C and S. They should know that water-soluble oxides of metals give alkaline solutions and those of non-metals give acidic solutions.*
d)	When substances burn in air they are reacting with the oxygen. *Candidates should be able to describe a test for oxygen.*
e)	Oxidation and reduction reactions involve the addition and removal of oxygen respectively.
f)	Air is often polluted by carbon monoxide, sulfur dioxide and oxides of nitrogen. *Candidates should know how each pollutant arises and be able to describe one effect of each pollutant.*

C3.2 Water

a)	Natural waters contain dissolved salts, which can be removed to obtain pure water. *Candidates should be aware that pure water can be made by distillation and that desalination is an important method of obtaining water for domestic use in some countries.* *Candidates should know the boiling point of pure water and a simple chemical test to show the presence of water.*
b)	Drinking water should have sufficiently low levels of dissolved salts and microbes. *Candidates should be aware that water of the correct quality is produced by passing water from a suitable source through filter beds to remove solids, and then sterilising with chlorine.*

Ref	Content
c)	Water filters containing carbon, silver and ion exchange resins can remove some dissolved substances from tap water to improve the taste and quality. *Detailed knowledge of specific water filters is **not** required.* *Examination questions may give information about water filters so that comparisons can be made.* *Candidates should understand the principles of how ion exchange resins work, but do **not** need detailed knowledge of the structure or chemical nature of specific resins.*
d)	Chlorine may be added to drinking water to reduce microbes and fluoride may be added to improve dental health. *Candidates should be aware of the arguments for and against the addition of fluoride to drinking water.*

C3.3 Rusting

a)	Both air and water are necessary for iron to rust. *Candidates should know that rusting refers to the corrosion of iron. They should be able to describe and interpret experiments to show that both air and water are necessary for rusting.*
b)	There are a number of ways in which rusting can be prevented, most of which are based on the exclusion of air and water. *Candidates should be able to recall and explain some methods of rust prevention, eg greasing, painting and sacrificial protection.*

C4 Acids, bases and salts

C4.1 Acids, bases and salts

a)	Metal oxides and hydroxides are bases. Soluble hydroxides are called alkalis.
b)	The particular salt produced in any reaction between an acid and a base or alkali depends on: - the acid used (hydrochloric acid produces chlorides, nitric acid produces nitrates, sulfuric acid produces sulfates) - the metal in the base or alkali.
c)	Ammonia dissolves in water to produce an alkaline solution. It is used to produce ammonium salts. Ammonium salts are important as fertilisers.
d)	A solution of calcium hydroxide in water (limewater) reacts with carbon dioxide to produce calcium carbonate. Limewater is used as a test for carbon dioxide. Carbon dioxide turns limewater cloudy. *Candidates should be familiar with using limewater to test for carbon dioxide gas.*
e)	Hydrogen ions, H^+ (aq), make solutions acidic and hydroxide ions, OH^- (aq), make solutions alkaline. The pH scale is a measure of the acidity or alkalinity of a solution. *Candidates should be familiar with the pH scale from 0 to 14, and know that pH 7 is a neutral solution.*
f)	In neutralisation reactions, hydrogen ions react with hydroxide ions to produce water. This reaction can be represented by the equation: $H^+ (aq) + OH^- (aq) \longrightarrow H_2O (l)$

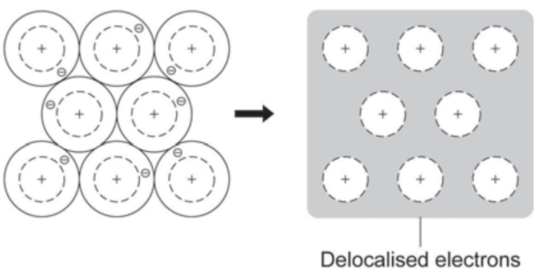
Ref	Content
C4.2 Making salts	
a)	Soluble salts can be made from acids by reacting them with: - metals – not all metals are suitable; some are too reactive and others are not reactive enough - insoluble bases – the base is added to the acid until no more will react and the excess solid is filtered off - alkalis – an indicator can be used to show when the acid and alkali have completely reacted to produce a salt solution. *Candidates should be able to suggest methods to make a named soluble salt.*
b)	Salt solutions can be crystallised to produce solid salts.
c)	Insoluble salts can be made by mixing appropriate solutions of ions so that a precipitate is formed. Precipitation can be used to remove unwanted ions from solutions: for example, in treating water for drinking or in treating effluent. *Candidates should be able to name the substances needed to make a named insoluble salt.*
C4.3 Metal carbonates	
a)	The carbonates of magnesium, copper, zinc, calcium and lithium decompose on heating (thermal decomposition) in a similar way. *Candidates should be aware that not all carbonates of metals in Group 1 of the periodic table decompose at the temperatures reached by a Bunsen burner.*
b)	Metal carbonates react with acids to produce carbon dioxide, a salt and water.
c)	Limestone, containing the compound calcium carbonate ($CaCO_3$), is quarried and can be used as a building material, or powdered and used to control acidity in the soil. It can be used in the manufacture of cement, glass and iron and to produce calcium oxide (lime).

C5 Metals

C5.1 The reactivity series	
a)	Metals can be arranged in an order of their reactivity from their reactions with water and dilute acids. *Candidates should be able to recall and describe the reactions, if any, of potassium, sodium, lithium, calcium, magnesium, zinc, iron and copper with water and/or dilute acids to place them in order of reactivity.*
b)	Displacement reactions involving metals and their compounds in aqueous solution establish positions within the reactivity series. *Candidates should be able to describe displacement reactions in terms of oxidation and reduction, and to write the ionic equations.* *Candidates should be aware that copper can be obtained from solutions of copper salts by displacement using scrap iron.*
c)	The non-metals hydrogen and carbon are often included in the reactivity series based on the reactions of metals with dilute acid, and of metal oxides with carbon. *Candidates should know that a lighted spill can be used to test for hydrogen.*

3

Ref	Content
C5.2 Extracting metals	
a)	Unreactive metals such as gold are found in the Earth as the metal itself but most metals are found as compounds that require chemical reactions to extract the metal.
b)	Metals that are less reactive than carbon can be extracted from their oxides by reduction with carbon: for example, iron oxide is reduced in the blast furnace to make iron. *Knowledge and understanding are limited to the reduction of oxides using carbon.* *Knowledge of reduction is limited to the removal of oxygen.* *Details of the blast furnace are **not** required, but candidates should know the raw materials used and explain the simple chemistry involved, including the use of equations.* *Knowledge of the details of the extraction of other metals is **not** required. Examination questions may provide information about specific processes for candidates to interpret or evaluate.*
c)	Metals that are more reactive than carbon, such as aluminium, are extracted by electrolysis of molten compounds. The use of large amounts of energy in the extraction of these metals makes them expensive. *Knowledge of the details of industrial methods of electrolysis is **not** required, other than the detail required for aluminium (see Section C10(i)).*
d)	New ways of extracting copper from low-grade ores are being researched to limit the environmental impact of traditional mining. Copper can be extracted by phytomining, or by bioleaching. *Candidates should know and understand that:* - *phytomining uses plants to absorb metal compounds and that the plants are burned to produce ash that contains the metal compounds* - *bioleaching uses bacteria to produce leachate solutions that contain metal compounds.* *Further specific details of these processes are **not** required.*
e)	Copper can be obtained from solutions of copper salts by electrolysis. *Candidates should know the electrode material and be able to write the ionic half equations for the reactions occurring at both electrodes.*
f)	Copper can be obtained from solutions of copper salts by displacement using scrap iron. *Candidates should be able to describe this in terms of oxidation and reduction, and to write the ionic equation.*
g)	We should recycle metals because extracting them uses limited resources, and is expensive in terms of energy and in terms of effects on the environment. *Candidates are **not** required to know details of specific examples of recycling, but should understand the benefits of recycling in the general terms specified here.*
C5.3 Structure and bonding in metals and alloys	
a)	Metals consist of giant structures of atoms arranged in a regular pattern.
b)	**The electrons in the highest occupied energy levels (outer shell) of metal atoms are delocalised and so free to move through the whole structure. This corresponds to a structure of positive ions with electrons between the ions holding them together by strong electrostatic attractions. The bonding in metals is represented in the following form:**



Ref	Content
c)	**Metals conduct heat and electricity because of the delocalised electrons in their structures.** ***Candidates should know that conduction depends on the ability of electrons to move throughout the metal.***
d)	The layers of atoms in metals are able to slide over each other. This means metals can be bent and shaped.
e)	Alloys are usually made from two or more different metals. The different sizes of atoms in the metals distort the layers in the structure, making it more difficult for them to slide over each other. This makes alloys harder than pure metals.
f)	Most metals in everyday use are alloys. Pure copper, gold, iron and aluminium are too soft for many uses and so are mixed with small amounts of similar metals to make them harder for everyday use. *Candidates should be familiar with these specified examples but examination questions may contain information about alloys other than those named in the subject content to enable candidates to make comparisons.*
g)	Shape memory alloys can return to their original shape after being deformed. An example is Nitinol, which is used in dental braces.

3

C5.4 Properties and uses of metals

a)	The elements in the central block of the periodic table are known as transition metals. Like other metals, they are good conductors of heat and electricity and can be bent or hammered into shape. They are useful as structural materials and for making things that must allow heat or electricity to pass through them easily. *Knowledge of the properties of specific transition metals other than those named in this unit is **not** required.*
b)	Iron from the blast furnace contains about 96% iron. The impurities make it brittle and so it has limited uses. *Knowledge of uses of iron from the blast furnace is limited to its use as cast iron because of its strength in compression.*
c)	Most iron is converted into steels. Steels are alloys since they are mixtures of iron with carbon. Some steels contain other metals. Steels can be designed to have properties for specific uses. Low-carbon steels are easily shaped, high-carbon steels are hard, and stainless steels are resistant to corrosion. *Knowledge and understanding of the types of steel and their properties are limited to those specified in the subject content. Information about the composition of specific types of steel may be given in examination questions so that candidates can evaluate their uses.*
d)	Copper has properties that make it useful for electrical wiring and plumbing. *Candidates should know and understand that copper:* - *is a good conductor of electricity and heat* - *can be bent but is hard enough to be used to make pipes or tanks* - *does not react with water.*

3

Ref	Content

C6 Rates of reaction

a)	The rate of a chemical reaction can be found by measuring the amount of a reactant used or the amount of product formed over time: $$\text{Rate of reaction} = \frac{\text{amount of reactant used}}{\text{time}}$$ $$\text{Rate of reaction} = \frac{\text{amount of product formed}}{\text{time}}$$ *Candidates need to be able to interpret graphs showing the amount of product formed (or reactant used up) with time, in terms of the rate of the reaction.* *Knowledge of specific reactions other than those in the subject content is **not** required, but candidates will be expected to have studied examples of chemical reactions and processes in developing their skills during their study of this section.*
b)	Chemical reactions can occur only when reacting particles collide with each other and with sufficient energy. The minimum amount of energy that particles must have to react is called the activation energy.
c)	Increasing the temperature increases the speed of the reacting particles so that they collide more frequently and more energetically. This increases the rate of reaction.
d)	Increasing the pressure of reacting gases increases the frequency of collisions and so increases the rate of reaction.
e)	Increasing the concentration of reactants in solutions increases the frequency of collisions and so increases the rate of reaction.
f)	Increasing the surface area of solid reactants increases the frequency of collisions and so increases the rate of reaction.
g)	Catalysts change the rate of chemical reactions but are not used up during the reaction. Different reactions need different catalysts. *Knowledge of named catalysts other than those specified in the subject content is **not** required, but candidates should be aware of some examples of chemical reactions and processes that use catalysts.*
h)	Catalysts are important in increasing the rates of chemical reactions used in industrial processes to reduce costs.

C7 Crude oil and fuels

C7.1 Crude oil

a)	Crude oil is a mixture of a very large number of compounds.
b)	Most of the compounds in crude oil are hydrocarbons, which are molecules made up of hydrogen and carbon atoms only.
c)	The many hydrocarbons in crude oil may be separated into fractions, each of which contains molecules with a similar number of carbon atoms, by evaporating the oil and allowing it to condense at a number of different temperatures. This process is called fractional distillation. *Candidates should know and understand the main processes in continuous fractional distillation in a fractionating column.* *Knowledge of the names of specific fractions or fuels is **not** required.*

Ref Content

C7.2 Hydrocarbons

a) Most of the hydrocarbons in crude oil are saturated hydrocarbons called alkanes. The general formula for the homologous series of alkanes is C_nH_{2n+2}

Candidates should know that in saturated hydrocarbons all the carbon–carbon bonds are single covalent bonds.

b) Alkane molecules can be represented in the following forms:

C_2H_6 or

$$\begin{array}{ccccccc} & & H & & H & & \\ & & | & & | & & \\ H & — & C & — & C & — & H \\ & & | & & | & & \\ & & H & & H & & \end{array}$$

Candidates should know that in displayed structures a — represents a covalent bond.

Candidates should be able to recognise alkanes from their formulae in any of the forms, but do ***not*** *need to know the names of specific alkanes other than methane, ethane and propane.*

c) Some properties of hydrocarbons depend on the size of their molecules. These properties influence how hydrocarbons are used as fuels.

Knowledge of trends in properties of hydrocarbons is limited to:

- *boiling points*
- *viscosity*
- *flammability.*

C7.3 Fuels

a) Most fuels, including coal, contain carbon and/or hydrogen and may also contain some sulfur. The gases released into the atmosphere when a fuel burns may include carbon dioxide, water (vapour), carbon monoxide, sulfur dioxide and oxides of nitrogen. Solid particles (particulates) may also be released.

Candidates should be able to relate products of combustion to the elements present in compounds in the fuel and to the extent of combustion (whether complete or partial).

No details of how the oxides of nitrogen are formed are required, other than the fact that they are formed at high temperatures.

Solid particles may contain soot (carbon) and unburnt fuels.

b) The combustion of hydrocarbon fuels releases energy. During combustion, the carbon and hydrogen in the fuels are oxidised.

c) Sulfur dioxide and oxides of nitrogen cause acid rain, carbon dioxide causes climate change, and solid particles cause global dimming.

Candidates are ***not*** *required to know details of any other causes of acid rain or climate change.*

d) Sulfur can be removed from fuels before they are burned, eg in vehicles. Sulfur dioxide can be removed from the waste gases after combustion, eg in power stations.

Knowledge of the methods of removing sulfur is ***not*** *required.*

e) Biofuels, including biodiesel and ethanol, are produced from plant material, and are possible alternatives to hydrocarbon fuels.

Candidates should know and understand the benefits and disadvantages of biofuels in terms of:

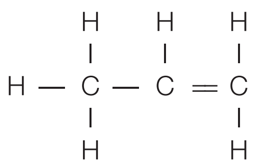
- *use of renewable resources*
- *their impacts on land use*
- *their carbon footprint.*

Candidates should know that ethanol for use as a biofuel is produced from a dilute solution of ethanol obtained by the fermentation of plant materials at a temperature between 20°C and 35°C. Detailed knowledge of the methods used to produce other biofuels is ***not*** *required.*

Ref	Content
f)	Hydrogen can be burned as a fuel in combustion engines or can be used in fuel cells that produce electricity to power vehicles. *Candidates should be able to compare the advantages and disadvantages of the combustion of hydrogen with the use of hydrogen fuel cells from information that is provided.* *Candidates should know and understand the benefits and disadvantages of hydrogen fuel in terms of:* - *storage and use* - *products of combustion.* *Knowledge of the details of the reactions in fuel cells is **not** required.*

C8 Other useful substances from crude oil

C8.1 Obtaining useful substances from crude oil

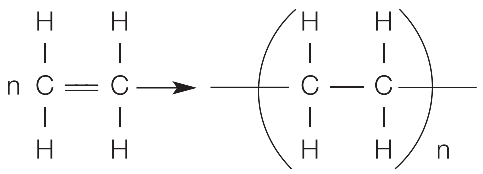
Ref	Content
a)	Hydrocarbons can be broken down (cracked) to produce smaller, more useful molecules. This process involves heating the hydrocarbons to vaporise them. The vapours are either passed over a hot catalyst or mixed with steam and heated to a very high temperature so that thermal decomposition reactions then occur.
b)	The products of cracking include alkanes and unsaturated hydrocarbons called alkenes. The general formula for the homologous series of alkenes is C_nH_{2n} *Candidates should know that in unsaturated hydrocarbons some of the carbon–carbon bonds are double covalent bonds.*
c)	Unsaturated hydrocarbon molecules can be represented in the following forms: C_3H_6 or  *Candidates should know that in displayed structures an $=$ represents a double bond.* *Candidates should be able to recognise alkenes from their names or formulae, but do **not** need to know the names of individual alkenes other than ethene and propene.*
d)	Alkenes react with bromine water, turning it from orange to colourless.
e)	Some of the products of cracking are useful as fuels.

Ref Content

C8.2 Polymers

a) Alkenes can be used to make polymers such as poly(ethene) and poly(propene). In polymerisation reactions, many small molecules (monomers) join together to form very large molecules (polymers).

For example:



ethene poly(ethene)

Candidates should be able to recognise the molecules involved in these reactions in the forms shown in the subject content. They should be able to represent the formation of a polymer from a given alkene monomer.

*Further details of polymerisation are **not** required.*

*Although candidates will probably know the names of some common polymers, these are **not** required knowledge, unless they are included in the subject content for this section.*

b) The properties of polymers depend on what they are made from and the conditions under which they are made. For example, low-density (LD) and high-density (HD) poly(ethene) are produced using different catalysts and reaction conditions.

c) Thermosoftening polymers consist of individual, tangled polymer chains. Thermosetting polymers consist of polymer chains with cross-links between them so that they do not melt when they are heated.

Higher Tier candidates should be able to explain thermosoftening polymers in terms of intermolecular forces.

d) Polymers have many useful applications and new uses are being developed. Examples include: new packaging materials, waterproof coatings for fabrics, dental polymers, wound dressings, hydrogels, and smart materials (including shape memory polymers).

Candidates should consider the ways in which new materials are being developed and used, but will not need to recall the names of specific examples.

e) Many polymers are not biodegradable, ie they are not broken down by microbes. This can lead to problems with waste disposal.

*Knowledge of specific named examples is **not** required, but candidates should be aware of the problems that are caused in landfill sites and in litter.*

f) Plastic bags are being made from polymers and cornstarch so that they break down more easily. Biodegradable plastics made from cornstarch have been developed.

Ref	Content
C9	**Energy changes in chemical reactions**
a)	When chemical reactions occur, energy is transferred to or from the surroundings. *Knowledge of delta H (ΔH) conventions and enthalpy changes, including the use of positive values for endothermic reactions and negative values for exothermic reactions, is required.*
b)	An exothermic reaction is one that transfers energy to the surroundings. Examples of exothermic reactions include combustion, many oxidation reactions and neutralisation. Everyday uses of exothermic reactions include self-heating cans (eg for coffee) and hand warmers.
c)	An endothermic reaction is one that takes in energy from the surroundings. Endothermic reactions include thermal decompositions. Some sports injury packs are based upon endothermic reactions.
d)	If a reversible reaction is exothermic in one direction, it is endothermic in the opposite direction. The same amount of energy is transferred in each case. For example: hydrated copper sulfate (blue) $\underset{\text{exothermic}}{\overset{\text{endothermic}}{\rightleftharpoons}}$ anhydrous copper sulfate (white) + water
C10	**Electrolysis**
a)	When an ionic substance is melted or dissolved in water, the ions are free to move about within the liquid or solution.
b)	Passing an electric current through ionic substances that are molten, eg lead bromide, or in solution breaks them down into elements. This process is called electrolysis and the substance broken down is called the electrolyte.
c)	During electrolysis, positively charged ions move to the negative electrode (the cathode), and negatively charged ions move to the positive electrode (the anode).
d)	Oxidation and reduction can be defined as the loss and gain of electrons respectively.
e)	At the negative electrode, positively charged ions gain electrons; at the positive electrode, negatively charged ions lose electrons.
f)	Reactions at electrodes can be represented by half equations, for example: $2Cl^- \rightarrow Cl_2 + 2e^-$ or $2Cl^- - 2e^- \rightarrow Cl_2$ *Candidates should be able to complete and balance supplied half equations for the reactions occurring at the electrodes during electrolysis.*
g)	If there is a mixture of ions: - at the cathode, the products formed depend on the reactivity of the elements involved - at the anode, the products formed also depend on the relative concentrations of the ions present.
h)	**Electrolysis is used to electroplate objects. This may be for reasons such as appearance, durability and prevention of corrosion. It includes copper plating and silver plating.**
i)	Aluminium is manufactured by the electrolysis of a molten mixture of aluminium oxide and cryolite. Aluminium forms at the negative electrode and oxygen at the positive electrode. The positive electrode is made of carbon, which reacts with the oxygen to produce carbon dioxide. *Candidates should understand why cryolite is used in this process.* *Candidates should be aware that large amounts of energy are needed in the extraction process.*
j)	The electrolysis of sodium chloride solution produces hydrogen and chlorine. Sodium hydroxide solution is also produced. These are important reagents for the chemical industry, eg sodium hydroxide for the production of soap and chlorine for the production of bleach and plastics.

Ref	Content
C11 Analysis	
C11.1 Analysing substances	
a)	Flame tests can be used to identify metal ions. Lithium, sodium, potassium, calcium and barium compounds produce distinctive colours in flame tests: - lithium compounds result in a crimson flame - sodium compounds result in a yellow flame - potassium compounds result in a lilac flame - calcium compounds result in a red flame - barium compounds result in a green flame. *Flame colours of other metal ions are **not** required knowledge.*
b)	Aluminium, calcium and magnesium ions form white precipitates with sodium hydroxide solution but only the aluminium hydroxide precipitate dissolves in excess sodium hydroxide solution.
c)	Copper(II), iron(II) and iron(III) ions form coloured precipitates with sodium hydroxide solution. Copper(II) forms a blue precipitate, iron(II) a green precipitate and iron(III) a brown precipitate.
d)	Carbonates react with dilute acids to form carbon dioxide. Carbon dioxide produces a white precipitate with limewater, which turns limewater cloudy.
e)	Halide ions in solution produce precipitates with silver nitrate solution in the presence of dilute nitric acid. Silver chloride is white, silver bromide is cream and silver iodide is yellow.
f)	Sulfate ions in solution produce a white precipitate with barium chloride solution in the presence of dilute hydrochloric acid.
g)	A mixture consists of two or more elements or compounds not chemically combined together. The chemical properties of each substance in the mixture are unchanged. It is possible to separate the substances in a mixture by physical methods, including distillation, filtration and crystallisation.
h)	Paper chromatography can be used to analyse substances present in a solution, eg food colourings and inks/dyes. *Candidates should be able to describe how to carry out paper chromatography separations and **Higher Tier candidates should be able to decribe how the components of a mixture can be identified using R_f values.** Candidates have to be aware that solvents other than water can be used and that the separation depends on the relative solubilities of the components.*

Ref	Content
P1	**Forces and their effects**
P1.1	**Motion**
a)	Scalars are quantities that have magnitude only. Vectors are quantities that have magnitude and an associated direction. *Candidates should be aware that distance, speed and time are examples of scalars and displacement, velocity, acceleration, force and momentum are examples of vectors.*
b)	If an object moves in a straight line, how far it is from a certain point can be represented by a distance–time graph.
c)	The speed of an object can be determined from the gradient of a distance–time graph. **If an object is accelerating its speed at any particular time can be determined by finding the gradient of the tangent of the distance–time graph at that time.**
d)	The velocity of an object is its speed in a given direction.
e)	The velocity v of an object is given by the equation: $v = \frac{s}{t}$ where s is the displacement and t is the time taken.
f)	The acceleration a of an object is given by the equation: $a = \frac{v - u}{t}$ where u is the initial velocity, v is the final velocity and t is the time taken.
g)	The acceleration of an object can be determined from the gradient of a velocity–time graph. ***Higher Tier candidates will be expected to calculate acceleration from a velocity–time graph.***
h)	The distance travelled by an object can be determined from the area under a velocity–time graph. ***Higher Tier candidates will be expected to calculate the distance travelled from a velocity–time graph.***
P1.2	**Resultant forces**
a)	Whenever two objects interact, the forces they exert on each other are equal and opposite.
b)	A number of forces acting at a point may be replaced by a single force that has the same effect on the motion as the original forces all acting together. This single force is called the resultant force. *Candidates should be able to determine the resultant of opposite or parallel forces acting in a straight line and determine the resultant of two coplanar forces by scale drawing.*
c)	A resultant force acting on an object may cause a change in its state of rest or motion.
d)	If the resultant force acting on a stationary object is: - zero, the object will remain stationary - not zero, the object will accelerate in the direction of the resultant force.
e)	If the resultant force acting on a moving object is: - zero, the object will continue to move at the same speed and in the same direction - not zero, the object will accelerate in the direction of the resultant force.
f)	The relationship between force F, mass m and acceleration a is: $F = m \times a$

Ref	Content
P1.3 Momentum	
a)	The relationship between momentum p, mass m and velocity v is: $p = m \times v$
b)	In a closed system the total momentum before an event is equal to the total momentum after the event. This is called conservation of momentum. *Candidates may be required to complete calculations involving two objects. Examples of events are collisions and explosions.*
c)	The relationship between force F, change in momentum Δp and time t is: $F = \frac{\Delta p}{t}$ *Candidates should be able to use this relationship to explain safety features such as air bags, seat belts, gymnasium crash mats, cushioned surfaces for playgrounds and cycle helmets.*
P1.4 Forces and braking	
a)	When a vehicle travels at a steady speed the resistive forces balance the driving force. *Candidates should realise that most of the resistive forces are caused by air resistance.*
b)	The greater the speed of a vehicle the greater the braking force needed to stop it in a certain distance. *Candidates should understand that for a given braking force, the greater the speed, the greater the stopping distance.*
c)	The stopping distance of a vehicle is the sum of the distance the vehicle travels during the driver's reaction time (thinking distance) and the distance it travels under the braking force (braking distance).
d)	A driver's reaction time can be affected by tiredness, drugs and alcohol. *Candidates should appreciate that distractions may affect a driver's ability to react.*
e)	When the brakes of a vehicle are applied, work done by the friction force between the brakes and the wheel reduces the kinetic energy of the vehicle and the temperature of the brakes increases.
f)	A vehicle's braking distance can be affected by adverse road and weather conditions and poor condition of the vehicle. *Candidates should understand that 'adverse road conditions' includes wet or icy conditions. Poor condition of the car is limited to the car's brakes or tyres.*
P1.5 Forces and terminal velocity	
a)	The faster an object moves through a fluid the greater the frictional force which acts on it.
b)	An object falling through a fluid will initially accelerate due to the force of gravity. Eventually the resultant force will be zero and the object will move at its terminal velocity (steady speed). *Candidates should understand why the use of a parachute reduces the parachutist's terminal velocity.* *Candidates should be able to draw and interpret velocity–time graphs for objects that reach terminal velocity, including a consideration of the forces acting on the object.*
c)	The relationship between weight W, mass m and gravitational field strength (acceleration of free fall) g is: $W = m \times g$ *Candidates will **not** be expected to know the value of g.*

Ref	Content
P1.6 Forces and elasticity	
a)	A force acting on an object may cause a change in the shape of the object.
b)	An object behaves elastically if it returns to its original shape when the force is removed.
c)	A force applied to an elastic object such as a spring will result in the object stretching and storing elastic potential energy.
d)	For an object behaving elastically, the extension is directly proportional to the force applied, provided that the limit of proportionality is not exceeded. The relationship between the force F and the extension e is: $F = k \times e$ where k is a constant.
P1.7 Forces and energy	
a)	Work is done when a force causes an object to move through a distance.
b)	The relationship between work done W, force F and distance d moved in the direction of the force is: $W = F \times d$
c)	Energy is transferred when work is done.
d)	Work done against frictional forces causes energy transfer by heating. *Candidates should be able to discuss the transfer of kinetic energy in particular situations, for example shuttle re-entry into the atmosphere or meteorites burning up in the atmosphere and braking systems on vehicles.*
e)	The relationship between power P, work done or energy transferred W and time t is: $P = \frac{W}{t}$
f)	The relationship between gravitational potential energy E_p, mass m, gravitational field strength (acceleration of free fall) g and height h is: $E_p = m \times g \times h$ *Candidates should understand that when an object is raised vertically work is done against the gravitational force and the object gains gravitational potential energy.*
g)	The relationship between kinetic energy E_k, mass m and speed v is: $E_k = 1/2 \times m \times v^2$ *Candidates should understand that an object of double the mass of another object travelling with the same speed will have double the kinetic energy.* *Candidates should understand that an object travelling at double the speed of another object with the same mass will have four times the kinetic energy. They should be able to apply this idea in the context of road safety.*

Ref	Content
P2	**Waves**
P2.1	**General properties of waves**
a)	Waves transfer energy and information without transferring matter.
b)	In a transverse wave the oscillations are perpendicular to the direction of energy transfer.
c)	In a longitudinal wave the oscillations are parallel to the direction of energy transfer. Longitudinal waves show areas of compression and rarefaction.
d)	Electromagnetic waves are transverse, sound waves are longitudinal and mechanical waves may be either transverse or longitudinal.
e)	Waves can be reflected, refracted and diffracted. *Candidates should appreciate that for appreciable diffraction to take place the wavelength of the wave must be of the same order of magnitude as the size of the obstacle or gap.*
f)	When identical sets of waves overlap they interfere with each other.
g)	Waves may be described in terms of their frequency, wavelength, time period and amplitude. *Candidates should be able to explain the meaning of these terms.*
h)	The relationship between wave speed v, frequency f and wavelength λ is: $v = f \times \lambda$
P2.2	**The electromagnetic spectrum**
a)	Electromagnetic waves form a continuous spectrum and all types of electromagnetic wave travel at the same speed through a vacuum (space). *Candidates should know the order of electromagnetic waves within the spectrum, in terms of energy, frequency and wavelength.* *Candidates should appreciate that the wavelengths of the electromagnetic spectrum range from 10^{-15} m to 10^{4} m and beyond.*
b)	Radio waves, microwaves, infrared and visible light can be used for communication.
c)	Electromagnetic waves have many uses. For example: - radio waves – television and radio (including Bluetooth) - microwaves – mobile phones and satellite television - infrared – remote controls - visible light – photography - ultraviolet – security marking - X-rays – medical imaging - gamma rays – sterilising surgical instruments and killing harmful bacteria in food.
d)	Exposure to electromagnetic waves can be hazardous. For example: - microwaves – heating of body tissue - infrared – skin burns - ultraviolet – skin cancer and blindness - X-rays – high doses kill cells - gamma rays – genetic mutations.
e)	X-rays are part of the electromagnetic spectrum. They have a very short wavelength, high energy and cause ionisation.

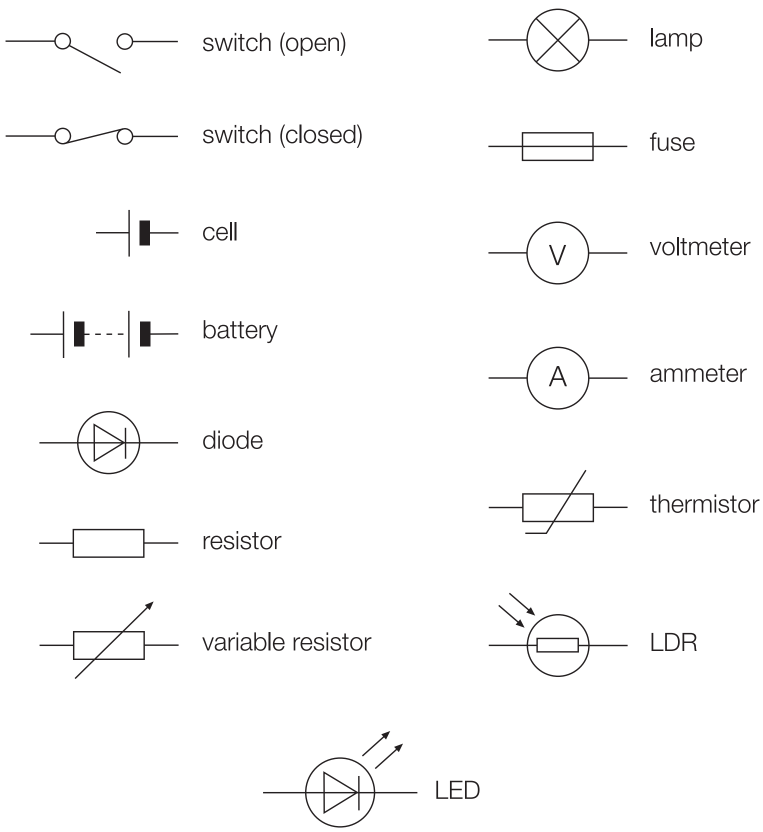
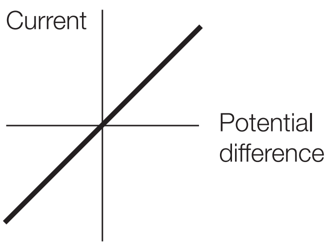
Ref	Content
f)	Properties of X-rays include: ■ they affect a photographic film in the same way as light ■ they are absorbed by metal and bone ■ they are transmitted by soft tissue.
g)	X-rays can be used to diagnose some medical conditions, for example in computed tomography (CT) scanning, bone fractures and dental problems. X-rays are also used to treat some conditions, for example in killing cancer cells.
h)	The use of high energy ionising radiation can be dangerous, and precautions need to be taken to monitor and minimise the levels of radiation that people who work with it are exposed to.
P2.3 Sound	
a)	Sound waves are longitudinal waves and cause vibrations in a medium, which are detected as sound.
b)	The range of human hearing is about 20 Hz to 20 000 Hz. ***No** details of the structure of the ear are required.*
c)	The pitch of a sound is determined by its frequency and loudness by its amplitude.
d)	Sound waves can be reflected (echoes) and diffracted.
P2.4 Reflection	
a)	When waves are reflected the angle of incidence is equal to the angle of reflection.
b)	The normal is a construction line perpendicular to the reflecting surface at the point of incidence.
c)	The image produced in a plane mirror is virtual. *Candidates will be expected to be able to construct ray diagrams.*
P2.5 Red-shift	
a)	If a wave source is moving relative to an observer there will be a change in the observed wavelength and frequency. This is known as the Doppler effect. *Candidates should understand that:* ■ *the wave source could be light, sound or microwaves* ■ *when the source moves away from the observer, the observed wavelength increases and the frequency decreases* ■ *when the source moves towards the observer, the observed wavelength decreases and the frequency increases.*
b)	There is an observed increase in the wavelength of light from most distant galaxies. The further away the galaxies, the faster they are moving and the bigger the observed increase in wavelength. This effect is called red-shift.
c)	The observed red-shift provides evidence that the Universe is expanding and supports the Big Bang theory (that the Universe began from a very small initial point). *Candidates should be able to explain how red-shift provides evidence for the Big Bang.*
d)	Cosmic microwave background radiation (CMBR) is a form of electromagnetic radiation filling the universe. It comes from radiation that was present shortly after the beginning of the Universe.
e)	The Big Bang theory is currently the only theory that can explain the existence of CMBR.

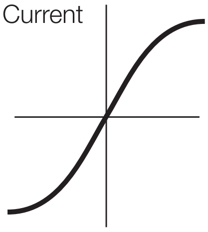
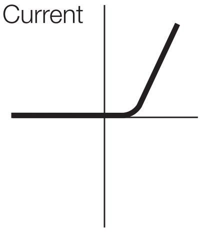
Ref	Content
P3	**Heating processes**
P3.1	**Kinetic theory**
a)	Kinetic theory can be used to explain the different states of matter. *Candidates should be able to recognise simple diagrams to model the difference between solids, liquids and gases.*
b)	The particles of solids, liquids and gases have different amounts of energy.
c)	The specific heat capacity of a substance is the amount of energy required to change the temperature of one kilogram of the substance by one degree Celsius.
d)	The relationship between energy E, mass m, specific heat capacity c and temperature change θ is: $E = m \times c \times \theta$
e)	The specific latent heat of vaporisation of a substance is the amount of energy required to change the state of one kilogram of the substance from a liquid to a vapour with no change in temperature.
f)	**The relationship between energy E, mass m and specific latent heat of vaporisation L_V is:** $\boldsymbol{E = m \times L_V}$
g)	The specific latent heat of fusion of a substance is the amount of energy required to change the state of one kilogram of the substance from a solid to a liquid with no change in temperature.
h)	**The relationship between energy E, mass m and specific latent heat of fusion L_F is:** $\boldsymbol{E = m \times L_F}$
i)	The melting point of a solid and the boiling point of a liquid are affected by impurities.
	Throughout Section P3.1, candidates should be able to explain the shape of the temperature–time graph for a substance that is either cooled or heated through changes in state.
P3.2	**Energy transfer by heating**
a)	Energy may be transferred by conduction and convection. *Candidates should be able to explain, in terms of particles, how these energy transfers take place.* *Candidates should understand in simple terms how the arrangement and movement of particles determine whether a material is a conductor or an insulator and understand the role of free electrons in conduction through a metal.* *Candidates should be able to use the idea of particles moving apart to make a fluid less dense, to explain simple applications of convection.*
b)	Energy may be transferred by evaporation and condensation. *Candidates should be able to explain evaporation, and the cooling effect this causes, using the kinetic theory. Candidates should be able to discuss the factors that affect the rate of evaporation.*
c)	The rate at which an object transfers energy by heating depends on: - its surface area and volume - the material from which the object is made - the nature of the surface with which the object is in contact. *Candidates should be able to explain the design of devices in terms of energy transfer, for example cooling fins.* *Candidates should be able to explain animal adaptations in terms of energy transfer, for example relative ear size of animals in cold and warm climates.*
d)	The bigger the temperature difference between an object and its surroundings, the faster the rate at which energy is transferred by heating.
e)	Most substances expand when heated. *Candidates should understand that the expansion of substances on heating may be a hazard (for example, the expansion of roofs and bridges) or useful (for example, the bi-metallic strip thermostat).*

Ref	Content
P3.3 Infrared radiation	
a)	All objects emit and absorb infrared radiation.
b)	The hotter an object is the more infrared radiation it radiates in a given time.
c)	Dark, matt surfaces are good absorbers and good emitters of infrared radiation.
d)	Light, shiny surfaces are poor absorbers and poor emitters of infrared radiation.
e)	Light, shiny surfaces are good reflectors of infrared radiation.
P3.4 Energy transfers and efficiency	
a)	Energy can be transferred usefully, stored or dissipated, but cannot be created or destroyed.
b)	When energy is transferred only part of it may be usefully transferred; the rest is 'wasted'.
c)	Wasted energy is eventually transferred to the surroundings, which become warmer. This energy becomes increasingly spread out and so becomes less useful.
d)	The efficiency of a device can be calculated using: $\text{efficiency} = \frac{\text{useful energy out}}{\text{total energy in}} (\times 100\%)$ and $\text{efficiency} = \frac{\text{useful power out}}{\text{total power in}} (\times 100\%)$ *Candidates may be required to calculate efficiency as a decimal or as a percentage.*
e)	The energy flow in a system can be represented using Sankey diagrams. *Candidates should be able to draw and interpret Sankey diagrams.*
P3.5 Heating and insulating buildings	
a)	Solar panels may contain water that is heated by radiation from the Sun. This water may then be used to heat buildings or provide domestic hot water.
b)	There are a range of methods used to reduce energy loss and consumption. *Candidates should be familiar with different methods of insulating a building and with the idea of payback time as a means of evaluating the cost effectiveness of each method.*
c)	U-values measure how effective a material is as an insulator. *Knowledge of the U-values of specific materials is* ***not*** *required, nor is the equation that defines U-value.*
d)	The lower the U-value, the better the material is as an insulator.

P4 Electricity

Ref	Content
P4.1 Electrical circuits	
a)	Electrical charges can move easily through some substances, for example metals.
b)	Electric current is a flow of electric charge.
c)	The relationship between current I, charge Q and time t is: $I = \frac{Q}{t}$
d)	**The relationship between potential difference V, energy transferred E and charge Q is:** $\boldsymbol{V = \frac{E}{Q}}$ ***Teachers can use either of the terms potential difference or voltage. Questions will be set using the term potential difference. Candidates will gain credit for the correct use of either term.***

Ref	Content
e)	Circuit diagrams use standard symbols. *Candidates will be required to interpret and draw circuit diagrams. Candidates should know the following standard symbols:*  *Candidates should understand the use of thermistors in circuits, for example thermostats.* *Candidates should understand the use of light-dependent resistors (LDRs) in circuits, for example switching lights on when it gets dark.*
f)	Current–potential difference graphs are used to show how the current through a component varies with the potential difference across it.
g)	The resistance of a component can be found by measuring the current through and potential difference across the component.
h)	The current through a component depends on its resistance. The greater the resistance the smaller the current for a given potential difference across the component.
i)	The relationship between potential difference V, current I and resistance R is: $V = I \times R$
j)	The current through a resistor (at a constant temperature) is directly proportional to the potential difference across the resistor. 

Ref	Content
k)	The resistance of a filament bulb increases as the temperature of the filament increases.  ***Higher Tier candidates should be able to explain change in resistance in terms of ions and electrons.***
l)	The current through a diode flows in one direction only. The diode has a very high resistance in the reverse direction. 
m)	The potential difference provided by cells connected in series is the sum of the potential difference of each cell (depending on the direction in which they are connected).
n)	For components connected in series: - the total resistance is the sum of the resistance of each component - there is the same current through each component - the total potential difference of the supply is shared between the components.
o)	For components connected in parallel: - the potential difference across each component is the same - the total current through the whole circuit is the sum of the currents through the separate components.
p)	An LED emits light when a current flows through it in the forward direction. *Candidates should be aware that the use of LEDs for lighting is increasing, as they use a much smaller current than other forms of lighting.*
q)	When an electrical charge flows through a resistor, the resistor gets hot. *Candidates should understand that a lot of energy is wasted in filament bulbs by heating. Less energy is wasted in power saving lamps such as Compact Fluorescent Lamps (CFLs).* *Candidates should understand that there is a choice when buying new appliances in how efficiently they transfer energy.*
P4.2 Household electricity	
a)	Cells and batteries supply current that always passes in the same direction. This is called direct current (d.c.).
b)	An alternating current (a.c.) is one that is constantly changing direction. *Candidates should be able to determine the period, and hence the frequency, of a supply from diagrams of oscilloscope traces.* *Candidates should be able to compare and calculate potential differences of d.c. supplies and the peak potential differences of a.c. supplies from diagrams of oscilloscope traces.*
c)	Mains electricity is an a.c. supply. In the UK it has a frequency of 50 cycles per second (50 hertz) and is about 230 V.
d)	A diode may be used for half wave rectification of a.c.

3

Ref	Content
e)	Most electrical appliances are connected to the mains using a cable and a three-pin plug. *Candidates should be familiar with the structure of both two-core and three-core cable* *Candidates should be familiar with the structure and wiring of a three-pin plug. Knowledge and understanding of the materials used in three-pin plugs is required, as is the colour coding of the covering of the three wires.*
f)	If an electrical fault causes too great a current to flow, the circuit is disconnected by a fuse or a circuit breaker in the live wire.
g)	When the current in a fuse wire exceeds the rating of the fuse it will melt, breaking the circuit. *Candidates should have an understanding of the link between cable thickness and fuse value.*
h)	Some circuits are protected by Residual Current Circuit Breakers (RCCBs), which operate much faster than a fuse. *Candidates should understand that RCCBs operate by detecting a difference in the current between the live and neutral wires. Knowledge of the mode of operation of how the devices do this is **not** required.*
i)	Appliances with metal cases are usually earthed. *Candidates should be aware that some appliances are double insulated, and therefore have no earth wire connection.*
j)	The earth wire and fuse together protect the wiring of a circuit.

P4.3 Transferring electrical energy

Ref	Content
a)	The rate at which energy is transferred by an appliance is called the power.
b)	The relationship between power P, energy transferred E and time t is: $P = \frac{E}{t}$
c)	The relationship between power P, current I and potential difference V is: $P = I \times V$ *Candidates should be able to calculate the current through an appliance from its power and the potential difference of the supply and from this determine the size of fuse needed.*
d)	**The relationship between energy transferred E, potential difference V and charge Q is:** $\boldsymbol{E = V \times Q}$
e)	Everyday electrical appliances are designed to bring about energy transfers. *Candidates should be able to give examples of such devices and energy transfers.*
f)	The amount of energy an appliance transfers depends on how long the appliance is switched on for and its power.
g)	The relationship between energy transferred E from the mains, power P and time t is: $E = P \times t$ *Candidates will **not** be required to convert between kilowatt-hours and joules.* *Candidates should be able to calculate the cost of mains electricity given the cost per kilowatt-hour and interpret and use electricity meter readings to calculate total cost over a period of time.*

P4.4 The National Grid

Ref	Content
a)	Electricity is distributed from power stations to consumers along the National Grid. *Candidates should be able to identify and label the essential parts of the National Grid.*
b)	For a given power increasing the voltage reduces the current required and this reduces the energy losses in the cables.
c)	Step-up and step-down transformers are used to change voltages in the National Grid. *Candidates should know why transformers are an essential part of the National Grid.*

3

Ref Content

P5 Nuclear physics

P5.1 Atomic structure

a) The basic structure of an atom is a small central nucleus composed of protons and neutrons surrounded by electrons.

b) The relative masses and relative electric charges of protons, neutrons and electrons are as follows:

	Relative mass	Relative charge
Proton	1	1
Neutron	1	0
Electron	Very small	–1

c) In an atom the number of electrons is equal to the number of protons in the nucleus. The atom has no overall electrical charge.

d) Atoms may lose or gain electrons to form charged particles called ions.

e) The atoms of an element always have the same number of protons, but have a different number of neutrons for each isotope.

The total number of protons in an atom is called its proton number or atomic number.

The total number of protons and neutrons in an atom is called its mass number.

Atoms can be represented as shown:

(Mass number) 23

Na

(Atomic number) 11

P5.2 Atoms and radiation

a) Some substances give out radiation from the nuclei of their atoms all the time, whatever is done to them. These substances are said to be radioactive.

Candidates should be aware of the random nature of radioactive decay.

b) Background radiation is around us all of the time. It comes from:

- natural sources such as rocks and cosmic rays from space
- man-made sources such as the fallout from nuclear weapons testing and nuclear accidents.

c) An alpha particle consists of two neutrons and two protons, the same as a helium nucleus. A beta particle is an electron from the nucleus. Gamma radiation is electromagnetic radiation from the nucleus.

d) Nuclear equations may be used to show single alpha and beta decay.

Candidates will be required to balance such equations, limited to the completion of atomic number and mass number. The identification of daughter elements from such decays is not required.

e) Properties of the alpha, beta and gamma radiations, limited to their relative ionising power, their penetration through materials and their range in air.

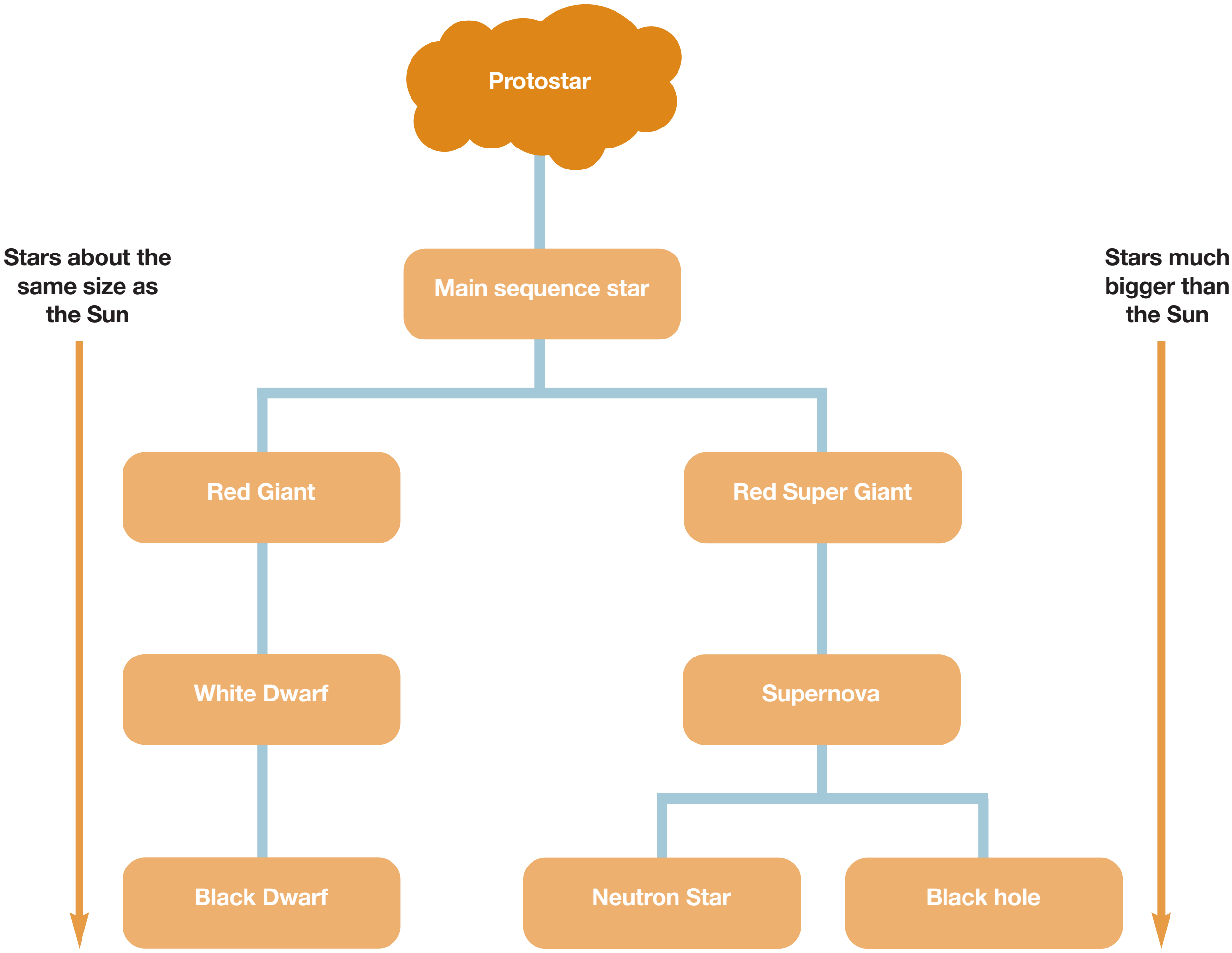
f) Alpha and beta radiations are deflected by both electric and magnetic fields.

Candidates should know that alpha particles are deflected less than beta particles and in an opposite direction.

Higher Tier candidates should be able to explain this in terms of the relative mass and charge of each particle.

Ref	Content
g)	Gamma radiation is not deflected by electric or magnetic fields.
h)	There are uses and dangers associated with each type of nuclear radiation. *Candidates should be able to describe the dangers and some uses of each type of radiation.*
i)	The half-life of a radioactive isotope is: ■ either the average time it takes for the number of nuclei of the isotope in a sample to halve ■ or the time it takes for the count rate from a sample containing the isotope to fall to half its initial level.
P5.3 Nuclear fission	
a)	Nuclear fission is the splitting of an atomic nucleus.
b)	There are two fissionable substances in common use in nuclear reactors, uranium-235 and plutonium-239. *Candidates should be aware that the majority of nuclear reactors use uranium-235.*
c)	For fission to occur the uranium-235 or plutonium-239 nucleus must first absorb a neutron.
d)	The nucleus undergoing fission splits into two smaller nuclei, releasing two or three neutrons and energy.
e)	These neutrons may go on to start a chain reaction. *Candidates should be able to sketch or complete a labelled diagram to illustrate how a chain reaction may occur.*
P5.4 Nuclear fusion	
a)	Nuclear fusion is the joining of two atomic nuclei to form a larger one.
b)	Nuclear fusion is the process by which energy is released in stars.
c)	Stars form when enough dust and gas from space is pulled together by gravitational attraction. Smaller masses may also form and be attracted by a larger mass to become planets.
d)	During the ‘main sequence’ period of its life cycle a star is stable because the forces within it are balanced. *The term ‘radiation pressure’ will* ***not*** *be required.*

Ref	Content
e)	A star goes through a life cycle. This life cycle is determined by the size of the star.



Candidates should be familiar with the chart that shows the life cycles of stars.

Ref	Content
f)	Fusion processes in stars produce all of the naturally occurring elements. These elements may be distributed throughout the Universe by the explosion of a massive star (supernova) at the end of its life. *Candidates should be able to explain how stars are able to maintain their energy output for millions of years.* *Candidates should be able to explain why the early Universe contained only hydrogen but now contains a large variety of different elements.* *Candidates should know that elements heavier than iron are formed in a supernova.*

3d Experimental and investigative skills

During this course, students should be encouraged to develop their understanding of the scientific process and the skills associated with scientific enquiry. In Paper 2, students will be assessed on aspects of the skills listed below, and may be required to read and interpret information from scales given in diagrams and charts, present data in appropriate formats, design investigations and evaluate information that is presented to them.

a) Design a practical procedure to answer a question, solve a problem or test a hypothesis.

b) Comment on/evaluate plans for practical procedures.

c) Select suitable apparatus for carrying out experiments accurately and safely.

d) Appreciate that, unless certain variables are controlled, experimental results may not be valid.

e) Recognise the need to choose appropriate sample sizes, and study control groups where necessary.

f) Identify possible hazards in practical situations, the risks associated with these hazards, and methods of minimising the risks.

g) Make and record observations and measurements with appropriate precision and record data collected in an appropriate format (such as a table, chart or graph).

h) Recognise and identify the cause of anomalous results and suggest what should be done about them.

i) Appreciate when it is appropriate to calculate a mean, calculate a mean from a set of at least three results and recognise when it is appropriate to ignore anomalous results in calculating a mean.

j) Recognise and identify the causes of random errors and systematic errors.

k) Recognise patterns in data, form hypotheses and deduce relationships.

l) Use and interpret tabular and graphical representations of data.

m) Draw conclusions that are consistent with the evidence obtained and support them with scientific explanations.

n) Evaluate data, considering its repeatability, reproducibility and validity in presenting and justifying conclusions.

o) Evaluate methods of data collection and appreciate that the evidence obtained may not allow a conclusion to be made with confidence.

p) Suggest ways of improving an investigation or practical procedure to obtain extra evidence to allow a conclusion to be made.

3e Mathematical and other requirements

Mathematical requirements

This specification provides learners with the opportunity to develop their skills in communication, mathematics and the use of technology in scientific contexts. In order to deliver the mathematical element of this outcome, assessment materials for this specification contain opportunities for candidates to demonstrate scientific knowledge using appropriate mathematical skills.

The areas of mathematics that arise naturally from the science content are listed below. This is not a checklist for each question paper, but assessments reflect these mathematical requirements, covering the full range of mathematical skills over a reasonable period of time.

Candidates are permitted to use calculators in all assessments.

Candidates are expected to use units appropriately. However, not all questions reward the appropriate use of units.

All candidates should be able to:

1 Understand number size and scale and the quantitative relationship between units.

2 Understand when and how to use estimation.

3 Carry out calculations involving +, –, ×, ÷, either singly or in combination, decimals, fractions, percentages and positive whole number powers.

4 Provide answers to calculations to an appropriate number of significant figures.

5 Understand and use the symbols =, <, >, ~.

6 Understand and use direct proportion and simple ratios.

7 Calculate arithmetic means.

8 Understand and use common measures and simple compound measures such as speed.

9 Plot and draw graphs (line graphs, bar charts, pie charts, scatter graphs, histograms) selecting appropriate scales for the axes.

10 Substitute numerical values into simple formulae and equations using appropriate units.

11 Translate information between graphical and numeric form.

12 Extract and interpret information from charts, graphs and tables.

13 Understand the idea of probability.

14 Calculate area, perimeters and volumes of simple shapes.

In addition, Higher Tier candidates should be able to:

15 Interpret order and calculate with numbers written in standard form.

16 Carry out calculations involving negative powers (only –1 for rate).

17 Change the subject of an equation.

18 Understand and use inverse proportion.

19 Understand and use percentiles and deciles.

Units, symbols and nomenclature

Units, symbols and nomenclature used in examination papers will normally conform to the recommendations contained in the following:

- *The Language of Measurement: Terminology used in school science investigations.* Association for Science Education (ASE), 2010. ISBN 978 0 86357 424 5.
- *Signs, Symbols and Systematics – the ASE companion to 16–19 Science.* Association for Science Education (ASE), 2000. ISBN 978 0 86357 312 5.
- *Signs, Symbols and Systematics – the ASE companion to 5–16 Science.* Association for Science Education (ASE), 1995. ISBN 0 86357 232 4.

Data Sheet

A data sheet will be provided for both of the chemistry papers. This is a copy of the periodic table. Candidates will be expected to select the appropriate information to answer the question.

Equations Sheet

An equations sheet will be provided for both of the physics papers. Candidates will be expected to select the appropriate equation to answer the question.

3f Units of physical quantities

The table gives details of units that candidates are expected to know.

Where a unit is given, eg second (s), candidates should be familiar with relevant subdivisions of the unit, eg millisecond (ms) and microsecond (μs). In addition, where appropriate, candidates should be aware of larger units where the basic unit is given, eg joule (J) and kilojoule (kJ).

What the unit measures	Unit	Symbol
length	metre	m
area	square metre	m^2
volume	cubic metre	m^3
time	second hour	s h
speed velocity	metres per second or kilometres per hour	m/s or km/h
acceleration	metres per second squared	m/s^2
mass	kilogram	kg
weight force	newton	N
momentum	kilogram metre per second	kg m/s
power	watt	W
energy	joule kilowatt-hours	J kWh
current	ampere (amp)	A
charge	coulomb	C
potential difference	volt	V
resistance	ohm	Ω
temperature	degree Celsius	°C
specific heat capacity	joules per kilogram per degree Celsius	J/(kg °C)
specific latent heat of vaporisation	**joules per kilogram**	**J/kg**
specific latent heat of fusion	**joules per kilogram**	**J/kg**
frequency	hertz	Hz

4 Scheme of Assessment

This specification is designed to be taken with all assessment at the end of the course. It is a traditional linear specification and, as such, individual components may not be retaken, neither can results for individual examination papers be carried forward or re-used.

Examinations and certification for this specification are available for the first time in June 2013 and then every January and June thereafter throughout the life of the specification.

4a Aims and learning outcomes

The AQA Level 1/2 Certificate in Science: Double Award should encourage students to be inspired, motivated and challenged by following a broad, coherent, practical, satisfying and worthwhile course of study. It should encourage students to develop their curiosity about the living world, enable students to engage with science in their everyday lives and to make informed choices about further study in science and related disciplines.

The AQA Level 1/2 Certificate in Science: Double Award should enable students to:

- develop their knowledge and understanding of science
- develop and apply their knowledge and understanding of the scientific process
- develop their understanding of the relationships between hypotheses, evidence, theories and explanations
- develop and apply their observational, practical, modelling, enquiry and problem-solving skills, and their understanding in laboratory, field and other learning environments
- develop their ability to evaluate claims based on science through critical analysis of the methodology, evidence and conclusions both qualitatively and quantitatively
- develop their skills in reporting and presenting information clearly and logically in different formats
- develop their skills in communication, mathematics and the use of technology in scientific contexts.

4b Assessment Objectives (AOs)

The examination papers will assess the following assessment objectives in the context of the content and skills set out in Section 3 (Subject Content).

AO1:

Recall, select and communicate their knowledge and understanding of science.

AO2:

Apply skills, knowledge and understanding of science in practical and other contexts.

AO3:

Analyse and evaluate evidence, make reasoned judgements and draw conclusions based on evidence.

Weighting of Assessment Objectives

The table below shows approximate weighting of each of the Assessment Objectives in the AQA Level 1/2 Certificate in Science: Double Award assessments.

Assessment Objective	Paper weightings (%)		Overall weighting of AOs (%)
	Paper 1	Paper 2	
AO1	27.5	15.0	**42.5**
AO2	19.5	15.5	**35.0**
AO3	3.0	19.5	**22.5**
Overall weighting of papers (%)	**50**	**50**	**100**

4c National criteria

This specification is in line with the following.

- The Code of Practice.
- The Arrangements for the Statutory Regulation of External Qualifications in England, Wales and Northern Ireland: Common Criteria.
- The requirements for qualifications to provide access to Levels 1 and 2 of the National Qualifications Framework.

4d Previous learning requirements

There are no prior learning requirements.

However, any requirements set for entry to a course based on this specification are at your centre's discretion.

4e Access to assessment: diversity and inclusion

This qualification and subject criteria were reviewed to see whether any of the skills or knowledge needed by the subject presented a possible difficulty to any candidates, whatever their ethnic background, religion, sex, age, disability or sexuality. If there were difficulties, the situation was reviewed again to make sure that such tests of specific competences were only included if they were important to the subject.

Arrangements are made for candidates with special needs to help them access the assessments as long as the competences being tested are not changed. Because of this, most candidates will be able to access any part of the assessment. More details are given in Section 5d.

4

5 Administration

5a Availability of assessment components and certification

Examinations and certification for this specification are available for the first time in June 2013, and then each January and June thereafter.

5b Entries

Please check the current version of **Entry Procedures and Codes** for up-to-date entry procedures. You should use the following entry codes for the components and for certification.

A single entry is all that is needed for all examination papers and certification.

The entry code is dependent on the combination of tiers being entered. Students must sit the same tier for examination papers in the same subject, eg a student may sit the Foundation Tier paper for Biology paper 1 **and** 2, the Higher Tier paper for Chemistry paper 1 **and** 2 and the Foundation Tier paper for Physics paper 1 **and** 2.

AQA Level 1/2 Certificate in Science: Double Award

Biology Paper 1 & 2	Chemistry Paper 1 & 2	Physics Paper 1 & 2	Entry Code
Foundation	Foundation	Foundation	8404A
Foundation	Foundation	Higher	8404B
Foundation	Higher	Foundation	8404C
Foundation	Higher	Higher	8404D
Higher	Foundation	Foundation	8404E
Higher	Foundation	Higher	8404F
Higher	Higher	Foundation	8404G
Higher	Higher	Higher	8404H

5c Private candidates

This specification is available to private candidates. Private candidates should write to us for a copy of Supplementary Guidance for Private Candidates (for specifications without controlled assessment).

5d Access arrangements, reasonable adjustments and special consideration

We have taken note of the equality and discrimination legislation and the interests of minority groups in developing and administering this specification.

We follow guidelines in the Joint Council for Qualifications (JCQ) document: *Access Arrangements, Reasonable Adjustments and Special Consideration: General and Vocational Qualifications*. This is published on the JCQ website **jcq.org.uk** or you can follow the link from our website **aqa.org.uk**

Access arrangements

We can arrange for candidates with special needs to access an assessment. These arrangements must be made **before** the examination. For example, we can produce a Braille paper for a candidate with sight problems.

Reasonable adjustments

An access arrangement which meets the needs of a particular disabled candidate would be a reasonable adjustment for that candidate. For example, a Braille paper would be a reasonable adjustment for a Braille reader but not for a candidate who did not read Braille. The Equality Act requires us to make reasonable adjustments to remove or lessen any disadvantage affecting a disabled candidate. Further detailed information is available in the JCQ regulations *Access arrangements, reasonable adjustments and special consideration.* The needs of individual candidates covered by the Equality Act will vary considerably. For queries relating to individual candidates' needs and what reasonable adjustments may be approved you can contact our Access Arrangements team for specialist advice.

Special consideration

We can give special consideration to candidates who have had a temporary illness, injury or serious problem such as the death of a relative at the time of the examination. We can only do this **after** the examination.

The Examinations Officer at the centre should apply online for access arrangements and special consideration by following the e-AQA link from our website **aqa.org.uk**

5e Examination language

We only provide components for this specification in English.

5f Qualification title

The qualification based on this specification is:

- AQA Level 1/2 Certificate in Science: Double Award

5g Awarding grades and reporting results

The qualification will be graded on a 15-point grade scale: A*A*, A*A, AA, AB, BB, BC, CC, CD, DD, DE, EE, EF, FF, FG and GG. Candidates who fail to reach the minimum standard for grade GG will be recorded as U (unclassified) and will not receive a qualification certificate.

We will publish the minimum raw mark for each grade, for each paper and for the overall qualification, when we issue candidates' results. We will report a candidate's results to your centre in terms of uniform marks and qualification results in terms of uniform marks and grades. A candidate's grade is determined solely by their overall mark. There is no requirement to achieve the grade boundary in each paper in order to achieve a particular grade overall. Hence, a strong performance in one paper can compensate for a weaker performance in the other.

For each question paper, the uniform mark corresponds to a grade as follows:

Grade	Uniform Mark Range
A*	90 – 100
A	80 – 89
B	70 – 79
C	60 – 69
D	50 – 59
E	40 – 49
F	30 – 39
G	20 – 29
U	0 – 19

We calculate a candidate's total uniform mark by adding together the uniform marks for the units. We convert this total uniform mark into a grade as follows

AQA Level 1/2 Certificate in Science: Double Award
(maximum uniform mark = 600)

Grade	Uniform Mark Range
A*A*	540 – 600
A*A	510 – 539
AA	480 – 509
AB	450 – 479
BB	420 – 449
BC	390 – 419
CC	360 – 389
CD	330 – 359
DD	300 – 329
DE	270 – 299
EE	240 – 269
EF	210 – 239
FF	180 – 209
FG	150 – 179
GG	120 – 149
U	0 – 119

5h Grading and tiers

Within each subject area (Biology, Chemistry and Physics) that make up the whole qualification, candidates can take either the Foundation Tier or the Higher Tier. For example, candidates could take both of the Foundation Tier question papers in Biology, both of the Higher Tier question papers in Chemistry and both of the Higher Tier question papers in Physics. Candidates are not allowed to take different tiers within Biology or within Chemistry or within Physics.

For candidates entered for the Foundation Tier, grades C–G are available; for candidates entered for the Higher Tier, A*–D are available. There is a safety net for candidates entered for the Higher Tier, where an allowed grade E will be awarded if candidates just fail to achieve grade D. Candidates who fail to achieve grade E on the Higher Tier or grade G on the Foundation Tier will be reported as unclassified.

For the tiered question papers, candidates cannot obtain a UMS score corresponding to a grade that is above the range for the tier entered. The maximum UMS score for candidates on the Foundation Tier written papers is 69. In other words, they cannot achieve a UMS score corresponding to a grade B. Candidates who just fail to achieve a grade E on the Higher Tier paper receive the UMS score corresponding to their raw mark (ie they do not receive a UMS score of zero).

During the awarding procedures the relationship between raw marks and UMS score is decided for each tier separately. Where grades are available on two tiers, for example grade C, the two raw marks chosen as the boundary for the grade on the two tiers are given the same Uniform Mark Scale score. Therefore, candidates receive the same UMS score for the same achievement whether this is demonstrated on the Foundation or the Higher Tier assessments.

5i Re-sits

This is a traditional linear specification and, as such, individual components may not be retaken, neither can results for individual examination papers be carried forward or re-used.

Candidates can re-sit the whole qualification as many times as they wish.

Candidates' grades are based on the work they submit for assessment.

Appendices

A Grade Descriptions

Grade descriptions are provided to give a general indication of the standards of achievement likely to have been shown by candidates who were awarded particular grades. The descriptions should be considered in relation to the content outlined in the specification – they are not designed to define that content. The grade awarded will depend on how well the candidate has met the Assessment Objectives (see Section 4b). If a candidate has performed less well in some areas this may be balanced by better performance in others.

Grade	Description
A	Candidates recall, select and communicate precise knowledge and detailed understanding of science. They demonstrate a comprehensive understanding of scientific laws, principles and applications. They use scientific and technical knowledge, terminology and conventions appropriately and consistently. They apply appropriate skills, including communication, mathematical, technical and observational skills, knowledge and understanding effectively in a wide range of contexts. They are confident with a wide range of appropriate methods, sources of information and data, consistently applying relevant skills to address scientific questions, solve problems and recognise appropriate hypotheses. They analyse, interpret and critically evaluate a broad range of quantitative and qualitative data and information. They evaluate information systematically to develop arguments and explanations, taking account of the limitations of the available evidence. They make reasoned judgements consistently and draw detailed, evidence-based conclusions.
C	Candidates recall, select and communicate secure knowledge and understanding of science. They demonstrate understanding of scientific laws, principles and applications. They use scientific and technical knowledge, terminology and conventions appropriately. They apply appropriate skills, including communication, mathematical, technical and observational skills, knowledge and understanding in a range of contexts. They are familiar with a range of appropriate methods, sources of information and data, applying their skills to address scientific questions, solve problems and usually recognise appropriate hypotheses. They analyse, interpret and evaluate a range of quantitative and qualitative data and information. They understand the limitations of evidence and use evidence and information to develop arguments with supporting explanations. They make judgements and draw conclusions based on the available evidence.

F	■ Candidates recall, select and communicate limited knowledge and understanding of science. ■ They demonstrate some understanding of scientific laws, principles and applications. ■ They use limited scientific and technical knowledge, terminology and conventions. ■ They apply skills, including limited communication, mathematical, technical and observational skills, knowledge and understanding in some contexts. ■ They use a limited range of methods, sources of information and data to address straightforward scientific questions and problems. ■ They interpret limited quantitative and qualitative data and information from a narrow range of sources. ■ They have some understanding of the limitations of evidence. ■ They can draw elementary conclusions having collected limited evidence.

B Spiritual, Moral, Ethical, Social, Legislative, Sustainable Development, Economic and Cultural Issues, and Health and Safety Considerations

We have taken great care to make sure that any wider issues (for example, spiritual, moral, ethical, social, legal, sustainable development, economic and cultural issues), including those relevant to the education of students at Key Stage 4, have been taken into account when preparing this specification. They will only form part of the assessment requirements where they are relevant to the specific content of the specification and have been identified in Section 3: Subject Content.

European Dimension

We have taken the 1988 Resolution of the Council of the European Community into account when preparing this specification and associated specimen components.

Environmental Education

We have taken the 1988 Resolution of the Council of the European Community and the Report *Environmental Responsibility: An Agenda for Further and Higher Education* (1993) into account when preparing this specification and associated specimen components.

Avoiding bias

We have taken great care to avoid bias of any kind when preparing this specification and specimen components.

C Overlaps with other qualifications

Much of the content in the AQA Level 1/2 Certificates in Biology, Chemistry and Physics is contained in the AQA Level 1/2 Certificate in Science: Double Award.

D The replacement of Key Skills with Functional Skills

The Key Skills qualifications have been replaced by the Functional Skills. However, centres may claim proxies for Key Skills components and/or certification in the following series: January, March and June 2012. The **Administration Handbook for the Key Skills Standards 2012** has further details. All Examination Officers in centres offering AQA Key Skills and Wider Key Skills have been sent a letter outlining the details of the end dates of these subjects. Copies of the letters have also been sent to the Head of Centre and Key Skills coordinator. This is a brief outline of that information. It is correct as at August 2011 and replaces the information on the same subject found in other documents on the AQA website:

Key Skills Levels 1, 2 and 3 Test and Portfolio

The final opportunity for candidates to enter for a level 1, 2 or 3 Key Skills test or portfolio was June 2011 with last certification in 2012.

Key Skills Level 4

The last series available to candidates entering for the Key Skills Level 4 test and portfolio was June 2010 with the last certification in the June series 2012.

Wider Key Skills

The AQA Wider Key Skills qualifications are no longer available. The last portfolio moderation took place in June 2010.

Further updates to this information will be posted on the website as it becomes available:

http://web.aqa.org.uk/qual/keyskills/wider_noticeboard.php

E The periodic table

Key

relative atomic mass **atomic symbol** name atomic (proton) number

1	2											3	4	5	6	7	0
							1 **H** hydrogen 1										4 **He** helium 2
7 **Li** lithium 3	9 **Be** beryllium 4											11 **B** boron 5	12 **C** carbon 6	14 **N** nitrogen 7	16 **O** oxygen 8	19 **F** fluorine 9	20 **Ne** neon 10
23 **Na** sodium 11	24 **Mg** magnesium 12											27 **Al** aluminium 13	28 **Si** silicon 14	31 **P** phosphorus 15	32 **S** sulfur 16	35.5 **Cl** chlorine 17	40 **Ar** argon 18
39 **K** potassium 19	40 **Ca** calcium 20	45 **Sc** scandium 21	48 **Ti** titanium 22	51 **V** vanadium 23	52 **Cr** chromium 24	55 **Mn** manganese 25	56 **Fe** iron 26	59 **Co** cobalt 27	59 **Ni** nickel 28	63.5 **Cu** copper 29	65 **Zn** zinc 30	70 **Ga** gallium 31	73 **Ge** germanium 32	75 **As** arsenic 33	79 **Se** selenium 34	80 **Br** bromine 35	84 **Kr** krypton 36
85 **Rb** rubidium 37	88 **Sr** strontium 38	89 **Y** yttrium 39	91 **Zr** zirconium 40	93 **Nb** niobium 41	96 **Mo** molybdenum 42	[98] **Tc** technetium 43	101 **Ru** ruthenium 44	103 **Rh** rhodium 45	106 **Pd** palladium 46	108 **Ag** silver 47	112 **Cd** cadmium 48	115 **In** indium 49	119 **Sn** tin 50	122 **Sb** antimony 51	128 **Te** tellurium 52	127 **I** iodine 53	131 **Xe** xenon 54
133 **Cs** caesium 55	137 **Ba** barium 56	139 **La*** lanthanum 57	178 **Hf** hafnium 72	181 **Ta** tantalum 73	184 **W** tungsten 74	186 **Re** rhenium 75	190 **Os** osmium 76	192 **Ir** iridium 77	195 **Pt** platinum 78	197 **Au** gold 79	201 **Hg** mercury 80	204 **Tl** thallium 81	207 **Pb** lead 82	209 **Bi** bismuth 83	[209] **Po** polonium 84	[210] **At** astatine 85	[222] **Rn** radon 86
[223] **Fr** francium 87	[226] **Ra** radium 88	[227] **Ac*** actinium 89	[261] **Rf** rutherfordium 104	[262] **Db** dubnium 105	[266] **Sg** seaborgium 106	[264] **Bh** bohrium 107	[277] **Hs** hassium 108	[268] **Mt** meitnerium 109	[271] **Ds** darmstadtium 110	[272] **Rg** roentgenium 111	Elements with atomic numbers 112 – 116 have been reported but not fully authenticated						

* The Lanthanides (atomic numbers 58 – 71) and the Actinides (atomic numbers 90 – 103) have been omitted.

Cu and **Cl** have not been rounded to the nearest whole number.

E

F Physics Equations Sheet

$v = \frac{s}{t}$	v velocity s displacement t time
$a = \frac{v - u}{t}$	a acceleration v final velocity u initial velocity t time taken
$F = m \times a$	F force m mass a acceleration
$p = m \times v$	p momentum m mass v velocity
$F = \frac{\Delta \rho}{t}$	F force $\Delta \rho$ change in momentum t time
$W = m \times g$	W weight m mass g gravitational field strength (acceleration of free fall)
$F = k \times e$	F force k spring constant e extension
$W = F \times d$	W work done F force d distance moved in the direction of the force
$P = \frac{W}{t}$	P power W work done t time
$E_p = m \times g \times h$	E_p change in gravitational potential energy m mass g gravitational field strength (acceleration of free fall) h change in height
$E_k = \frac{1}{2} \times m \times v^2$	E_k kinetic energy m mass v speed
$v = f \times \lambda$	v speed f frequency λ wavelength
$E = m \times c \times \theta$	E energy m mass c specific heat capacity θ temperature change

$\boldsymbol{E = m \times L_V}$	$\boldsymbol{E}$ **energy** $\boldsymbol{m}$ **mass** $\boldsymbol{L_V}$ **specific latent heat of vaporisation**
$\boldsymbol{E = m \times L_F}$	$\boldsymbol{E}$ **energy** $\boldsymbol{m}$ **mass** $\boldsymbol{L_F}$ **specific latent heat of fusion**
$\text{efficiency} = \dfrac{\text{useful energy out}}{\text{total energy in}} (\times 100\%)$	
$\text{efficiency} = \dfrac{\text{useful power out}}{\text{total power in}} (\times 100\%)$	
$I = \dfrac{Q}{t}$	I current Q charge t time
$\boldsymbol{V = \dfrac{E}{Q}}$	$\boldsymbol{V}$ **potential difference** $\boldsymbol{E}$ **energy transferred** $\boldsymbol{Q}$ **charge**
$V = I \times R$	V potential difference I current R resistance
$P = \dfrac{E}{t}$	P power E energy transferred t time
$P = I \times V$	P power I current V potential difference
$\boldsymbol{E = V \times Q}$	$\boldsymbol{E}$ **energy transferred** $\boldsymbol{V}$ **potential difference** $\boldsymbol{Q}$ **charge**
$E = P \times t$	E energy transferred from the mains P power t time

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Qualification Accreditation Number: 600/7167/9

For updates and further information on any of our specifications, to find answers or ask us a question, register with

Ask AQA at:
aqa.org.uk/askaqa

Download a copy of this specification from our website at:
aqa.org.uk/igcse-science

Free launch meetings are available in 2012 followed by further support meetings through the life of the specification.

Further information is available at:
http://events.aqa.org.uk/ebooking

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