BIOLOGY

UNIT 1 ANSWERS

CHAPTER 1

1 ▶ B **2 ▶** A **3 ▶** A

4 ▶ a Diagram should show each part of a plant cell and its function, e.g. cell wall (maintains shape of cell), cell membrane (controls entry and exit of substances), cytoplasm (where metabolism/reactions take place), vacuole (stores dissolved substances), nucleus (controls activities of cell), chloroplasts (photosynthesis), mitochondria (respiration).

b An animal cell lacks a cell wall, a large permanent vacuole and chloroplasts.

5 ▶ Description, in words or diagrams, should include the following points:

- enzymes are biological catalysts
- they speed up reactions in cells without being used up
- each enzyme catalyses a different reaction
- the production of enzymes is controlled by genes
- enzymes are made of protein
- the substrate attaches to the enzyme at the active site
- the substrate fits into the active site like a key in a lock
- this allows the products to be formed more easily
- intracellular enzymes catalyse reactions inside cells
- extracellular enzymes are secreted out of cells (e.g. digestive enzymes)
- they are affected by changes in pH and temperature.

6 ▶ a About 75 °C.

b At 60 °C the molecules of enzyme and substrate have more kinetic energy and move around more quickly. There are more frequent collisions between enzyme and substrate molecules, so more reactions are likely to take place.

c The microorganism lives at high temperatures, so it needs 'heat-resistant' enzymes with a high optimum temperature.

d It is denatured.

7 ▶ Diffusion is the net movement of particles (molecules or ions) from a high to low concentration. It does not need energy from respiration. Active transport uses energy from respiration to transport particles against a concentration gradient.

8 ▶ a They carry out most of the reactions of respiration in the cell, providing it with energy.

b Active transport. This uses the energy from the mitochondria.

c Diffusion. The removal of glucose at A lowers the concentration inside the cell, so that the concentration at B is higher than inside the cell. Therefore glucose can diffuse down a concentration gradient.

d Increases the surface area for greater absorption.

CHAPTER 2

1 ▶ D **2 ▶** A **3 ▶** B **4 ▶** C

5 ▶ a i Fungi **ii** Protoctists **iii** Plants **iv** Bacteria

b Like most protoctists, *Euglena* is a microscopic, single-celled organism. It has features of both plant and animal cells: like plants, it contains chloroplasts; like animals, it can move.

6 ▶ a Diagram should show a core of DNA or RNA surrounded by a protein coat. (It may also have an outer envelope or membrane derived from the host cell.)

b A virus can be considered either as living or as a chemical. It does not have any of the normal characteristics of living things, except that it is able to reproduce.

c Viruses can reproduce only inside a host cell, by taking over the cell's genetic machinery to make more virus particles. So viruses are all parasites.

7 ▶ a An animal that does not have a vertebral column (backbone).

b Fine, thread-like filaments forming the feeding network of cells of a fungus.

c A type of nutrition used by most fungi and some bacteria, where the organism feeds on dead organic material by digesting it using extracellular enzymes.

END OF UNIT 1 QUESTIONS

1 ▶ a i nucleus, mitochondrion (both needed for 1)

ii nucleus, chloroplast, mitochondrion (all needed for 1)

iii nucleus, mitochondrion (both needed for 1).

b The cells in a root have no chloroplasts because they don't receive any light and so can't carry out photosynthesis (1).

c Nucleus controls the activities of the cell (1); chloroplast absorbs light energy for photosynthesis (1); mitochondrion carries out some reactions of respiration to release energy (1).

2 ▶ a The artery is an organ because it is made of several tissues (1); the capillary is made up of only one type of cell (1).

b i Two from: Breaks down large insoluble molecules (1) into smaller soluble molecules (1) that can be absorbed (1)

ii (1 mark for organ, 1 mark for function).

Three from:

- mouth: chews / breaks down food into smaller pieces / produces saliva
- oesophagus (gullet): moves food from mouth to stomach
- stomach: produces digestive enzymes
- pancreas: produces digestive enzymes
- liver: makes bile

- ileum (small intestine): produces digestive enzymes / absorbs products of digestion
- colon (large intestine): absorbs excess water
- rectum: stores waste (faeces).

iii (1 mark for system, 2 marks for organs).
Two from:

- breathing system: trachea, lung, diaphragm
- circulatory system: artery, vein, heart
- musculoskeletal system: muscle, joint, (named) bone
- nervous system: brain, spinal cord
- reproductive system: testis, ovary, uterus, penis
- excretory system: kidney, bladder.

3 ▶ a i 4 g (1). Mass at start was 100 g, decreased to 96 g due to oxygen lost (1).

ii Half this mass = 2 g (1). This loss in mass occurs by (approximately) 0.5 minutes / 30 seconds (1).

iii At the start there are a lot of enzyme and substrate molecules, so there are a lot of successful collisions (1). As the reaction proceeds, the number of substrate molecules decreases, so there are fewer successful collisions (1).

b i There would be no difference / 4 g formed (1); because the temperature affects only the reaction rate, not the end point (1).

ii The time would be shorter (1) because the rate of reaction is speeded up by the increase in temperature (1).

4 ▶ a 1 mark for each correct row in the table.

Feature	Active transport	Osmosis	Diffusion
particles must have kinetic energy	✗	✓	✓
requires energy from respiration	✓	✗	✗
particles move down a concentration gradient	✗	✓	✓

b i (As the temperature rises) ions gain kinetic energy (1), so they move faster (1).

ii Above this temperature the cell membranes are being denatured (1) so are more permeable to ions (1).

5 ▶ a i So that each of the two cells produced (1) will have the correct number of chromosomes / correct amount of DNA after the division (1).

ii The nucleus has divided into two (1).

b i They increase the surface area for absorption (1).

ii They (further) increase the surface area for absorption (1).

iii As the glucose moves out of the cell, the concentration inside the cell decreases (1) and increases the concentration gradient for diffusion of glucose into the cell (1).

6 ▶ a $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ (1 for each correct part)

b It is the same (1), because there are six molecules of each / same number of molecules / same number of moles (1), 1 mole of any gas has the same volume (1).

c Any sensible experimental error stated (1) with brief explanation (1).

d No oxygen would be used up (1), so distance moved would be less / bead would not move (1).

7 ▶ (1 mark for each correct row)

Feature	Type of organism		
	Plant	Fungus	Virus
they are all parasites	✗	✗	✓
they are made up of a mycelium of hyphae	✗	✓	✗
they can only reproduce inside living cells	✗	✗	✓
they feed by extracellular digestion by enzymes	✗	✓	✗
they store carbohydrate as starch	✓	✗	✗

8 ▶ (One mark for each correct underlined term)
Plants have cell walls made of cellulose. They store carbohydrate as the insoluble compound called starch or sometimes as the sugar sucrose. Plants make these substances as a result of the process called photosynthesis. Animals, on the other hand, store carbohydrate as the compound glycogen. Both animals' and plants' cells have nuclei, but the cells of bacteria lack a true nucleus, having their DNA in a circular chromosome. They sometimes also contain small rings of DNA called plasmids, which are used in genetic engineering. Bacteria and fungi break down organic matter in the soil. They are known as decomposers / saprotrophs. Some bacteria are pathogens, which means that they cause disease.

9 ▶ a Germinating seeds produce heat (1) from respiration (1).

b To kill bacteria on the seeds (1)

c To allow oxygen into the flask (1)

d Mass of seeds / number of seeds / age of seeds (1)

10 ▶ Any six for 6 marks, from:

- Use solution of ATP, compare with (control using) water (1)
- Same type of meat fibres / named type (1)
- Several replicates / number of replicates suggested, e.g. 10 (1)
- Measure length before treatment (1)
- Measure length after treatment / change in length / % change (1)
- Other controlled variables: temperature / volume of solutions / starting length (max. 2)

UNIT 2 ANSWERS

CHAPTER 3

1 ▶ C **2 ▶** A **3 ▶** B **4 ▶** B

5 ▶

	Action during inhalation	Action during exhalation
external intercostal muscles	(contract)	relax
internal intercostal muscles	relax	contract
ribs	move up and out	(move down and in)
diaphragm	contracts and flattens	relaxes and becomes dome-shaped
volume of thorax	increases	decreases
pressure in thorax	decreases	increases
volume of air in lungs	increases	decreases

6 ▶ When we breathe in, the external intercostal muscles between our ribs contract, pulling the ribs up and out. The diaphragm muscles contract, flattening the diaphragm. This increases the volume in the chest cavity (or thorax), lowering the pressure there, and causing air to enter from outside the body, through the nose or mouth. This is called ventilation. In the air sacs (or alveoli) of the lungs, oxygen enters the blood. The blood then takes the oxygen around the body, where it is used by the cells. The blood returns to the lungs, where carbon dioxide leaves the blood and enters the alveoli. When we breathe out, the external intercostal muscles relax and the ribs move down and in. The diaphragm muscles relax, and the diaphragm returns to a dome shape. These changes decrease the volume of the chest cavity, increasing the pressure in the thorax, pushing the air out of the lungs.

7 ▶ a When the volume of the chest is increased by the movements of the ribs and diaphragm, the drop in pressure in the chest cavity draws air into the pleural cavity through the puncture in the chest wall, instead of through the mouth or nose into the lung.

b Each lung is isolated from the other by being in a separate pleural cavity, so a pneumothorax on one side will not affect the opposite lung.

c A tube is inserted through the chest wall into the pleural cavity on the side of the injured lung. This stops ventilation in that lung, while the other lung is ventilated normally.

8 ▶ a The rings support the trachea so that it does not collapse during inhalation.

The gap in the 'C' allows food to pass down the oesophagus, which runs next to the trachea, without catching on the rings.

b The short distance allows easy diffusion of oxygen into the blood, and diffusion of carbon dioxide out of the blood.

c The mucus traps bacteria and dirt particles. The cilia beat backwards and forwards to sweep these towards the mouth, preventing them entering the lungs.

d Smoke contains carbon monoxide, which displaces oxygen from the haemoglobin of the red blood cells of the smoker.

e The addictive drug in tobacco smoke is nicotine. Smokers who are trying to give up can use patches or gum to provide the nicotine they normally get from cigarettes, reducing the craving to smoke.

f The large surface area is provided by the alveoli. It allows for efficient diffusion of oxygen into the large blood supply, and efficient removal of the waste product, carbon dioxide.

9 ▶ Bronchitis is a lung disease caused by irritation of the linings of the airways to the lungs. It may be made worse by bacteria infecting the bronchial system.

Emphysema is a lung disease where the walls of the alveoli break down and then fuse together, reducing their surface area. (Both diseases may be caused by smoking.)

10 ▶ a Some points are:

- non-smokers have a low death rate from lung cancer at all ages
- the death rate from lung cancer among smokers increases with age
- the death rate increases with the number of cigarettes smoked per day.

(Numbers should be used from the graph to illustrate any of these points.)

b For 55-year-olds smoking 25 a day: about 4.5 per 1000 men (or 45 per 10 000 men)

For 55-year-olds smoking 10 a day: less than 1 per 1000 men

c Probably this investigation. The graph shows a direct relationship between number of cigarettes smoked and incidence of lung cancer, in one particular type of person (middle-aged male doctors): in other words, a more controlled group. In Table 3.2 the patients were matched for age, sex etc. but were from a more varied background. There could be other reasons for the correlation that had not been considered. However, they both show a strong link.

11 ▶ The leaflet should not be too complicated or have too much information so that it puts the reader off. It must have a clear message.

CHAPTER 4

1 ▶ D **2 ▶** A **3 ▶** D **4 ▶** B

5 ▶ a Starch: Take a sample of the water in a spotting tile and add a drop of iodine solution. If starch is present, the colour will change from orange to blue-black.

Glucose: Take a sample of the water in a test tube and add blue Benedict's solution. Place the tube in a water

bath and heat until it boils. If glucose is present, a brick-red precipitate will form.

b The starch molecules are too large to pass through the holes in the Visking tubing. Glucose molecules are smaller, so they can pass through.

c The blood

d Large, insoluble food molecules are broken down into small, soluble ones.

6 ▶ a It is body temperature.

b It had been broken down into smaller molecules called peptides (short chains of amino acids) forming the clear solution.

c The enzyme pepsin does not work in alkaline conditions: it is denatured.

d The experiment is looking at the effects of pepsin on the egg white. The Control is carried out without the enzyme; all other factors are the same. This shows that it is the enzyme that breaks down the protein. In other words, the egg white does not break down by itself.

e The enzyme works more slowly at a lower temperature. There are fewer collisions between enzyme and substrate molecules, because they have less kinetic energy.

f Hydrochloric acid kills bacteria in the food entering the stomach.

g By alkaline secretions in the bile and pancreatic juice.

7 ▶

Enzyme	Food on which it acts	Products
(amylase)	starch	maltose
(trypsin)	protein	peptides
lipase	fats	(fatty acids and glycerol)

8 ▶ Descriptions of any four of the following:

- length, which increases time and surface area for absorption
- folds in lining, which increase surface area
- villi covering lining, which increase surface area
- microvilli on lining cells, which increase surface area
- capillary networks in villi, where products are absorbed
- lacteals in villi, which absorb fats.

9 ▶ The account should include full descriptions of most of the following points:

- digestion of starch to maltose in the mouth, action of saliva in moistening food
- mechanical digestion by the teeth
- movement through the gut by peristalsis (diagram useful)
- digestion of protein by pepsin in the stomach and the role of hydrochloric acid
- emulsifying action of bile from the liver on fats
- pancreatic enzymes (amylase, trypsin, lipase) and their role in digestion of starch, protein and fats
- adaptations of the ileum for the absorption of digested food (see question 8)
- role of the colon in absorption of water.

CHAPTER 5

1 ▶ B **2 ▶** C **3 ▶** A **4 ▶** B

5 ▶ a Single: fish; double: human or other named mammal.

b i (Either) The blood passes once through the heart in a single system, and twice through the heart in a double system for every complete circulation of the body.

(Or) In a double system the blood flows from the heart through one circuit to the lungs, then back to the heart and out through another circuit to the rest of the body.

ii A double circulatory system pumps the blood twice per circulation so higher pressures can be maintained.

c Diffusion can take place because a single-celled organism has a large surface area compared with its volume and the distances for substances to move inside the cell are short.

6 ▶ a A red blood cell has a large surface area compared with its volume; contains haemoglobin; and has no nucleus, so more space is available for haemoglobin.

b i Oxygen dissolves in the liquid lining the alveoli and then diffuses down a concentration gradient through the walls of the alveoli and capillaries into the plasma and into the red blood cells.

ii Oxygen dissolves in the plasma and then diffuses down a concentration gradient through the walls of the capillaries into the muscle cells.

c Dissolved in plasma

7 ▶ a Arteries have thick walls containing much muscle tissue and elastic fibres. These adaptations allow their walls to stretch and recoil under pressure.

b Veins have valves, thin walls with little muscle, and a large lumen; arteries have no valves (except at the start of the aorta and pulmonary artery), thick muscular walls with many elastic fibres, and a narrow lumen.

c Capillaries have thin walls / walls one cell thick, to allow exchange of materials. They have a very small diameter to fit between other cells of the body.

8 ▶ a A = left atrium, B = (atrioventricular) valves, C = left ventricle, D = aorta, E = right atrium

b To ensure blood keeps flowing in one direction / prevent backflow of blood

c i A **ii** E

9 ▶ a i A (red blood cell), identified by its colour (red) and biconcave disc shape

ii B (lymphocyte), identified by its colour (white) and large nucleus (to produce antibodies quickly)

iii C (phagocyte), identified by its colour (white), variable shape (shows it is flowing) and lobed nucleus

b Platelets – blood clotting

10 ▶ a C: heart rate is increasing so more blood can be pumped to muscles

b E: brief jump in heart rate

c A: lowest rate

d B: increases from minimum to steady

11 ▶ a i Low rate (75 beats/minute) because body is at rest, need for oxygen is low

ii Rate increases because more blood carrying oxygen for respiration needs to be pumped to muscles

iii Rate decreases as need for oxygen is reduced / lactate produced during exercise is removed (repaying oxygen debt)

b The shorter the recovery period, the fitter the person

CHAPTER 6

1 ▶ D **2 ▶** B

3 ▶ C **4 ▶** D

5 ▶ a Changes that take place in the shape of the lens to allow the eye to focus upon objects at different distances.

b The replacement artificial lens cannot change shape.

c The ciliary muscles contract and the suspensory ligaments slacken. The shape of the lens becomes more convex, refracting the light more.

6 ▶ a

Function	Letter
refracts light rays	G
converts light into nerve impulses	A
contains pigment to stop internal reflection	B
contracts to change the shape of the lens	E
takes nerve impulses to the brain	D

b i H

ii Contraction of circular muscles in the iris reduces the size of the pupil, letting less light into the eye. Contraction of radial muscles increases the size of the pupil, letting more light into the eye.

iii To protect the eye from damage by bright light, and to allow vision in different light intensities.

7 ▶ a i Sensory neurone

ii Relay neurone

iii Motor neurone

b The sensory neurone carries impulses from sensory receptors towards the central nervous system. The motor neurone carries impulses out from the CNS to effector organs (muscles and glands). The relay neurone links the other two types of neurone in the CNS.

c X: white matter, Y: grey matter, Z: dorsal root ganglion

d Electrical impulses

e The gap between one neurone and another is called a synapse. An impulse arrives at the end of an axon and causes the release of a chemical called a neurotransmitter into the synapse. The neurotransmitter diffuses across the synapse and attaches to the membrane of the next neurone. This starts an impulse in the second nerve cell.

f Many drugs imitate or block a neurotransmitter; therefore, they can stop the pain impulse from passing across the synapse.

8 ▶ a P: cell body, Q: dendrite, R: axon

b $\text{Speed} = \frac{\text{distance}}{\text{time}}$

$= \frac{1.2\text{ m}}{0.016\text{ s}}$

$= 75\text{ m/s}$

c Insulation / prevents short circuits with other actions. (Also speeds up conduction).

d Person would not be able to control their muscle contractions / would not be able to coordinate body movements / 'wrong' muscles would contract

9 ▶ a A wide variety of answers are possible, such as:

- dust in the eye – secretion of tears
- smell of food – secretion of saliva
- touching a pin – withdrawal of hand
- attack by a predator – increased heart rate
- object thrown at head – ducking.

b Nature and role of receptor and effector correctly explained, e.g. for 'dust in the eye' above:

i The receptors consist of touch receptors in the eye. They respond by generating nerve impulses (which eventually stimulate the tear glands).

ii Tear glands are the effectors. They secrete tears, washing the irritant dust out of the eyes.

c Chain of events correctly described, e.g. for 'dust in the eye' above:

Dust enters the eye and stimulates a touch receptor in the surface of the eye. The receptor sends nerve impulses along sensory neurones to the CNS (brain). In the CNS, impulses pass from sensory neurones to motor neurones via relay neurones. Impulses pass out from the CNS to the tear glands via motor neurones. These impulses stimulate the tear glands to secrete tears.

CHAPTER 7

1 ▶ B **2 ▶** B **3 ▶** C

4 ▶ a 'Hormones' are chemical messenger substances, carried in the blood. 'Secreted' refers to the process where a cell makes a chemical that passes to the outside of the cell. 'Glands' are organs that secrete chemicals, and 'endocrine' glands secrete their products into the blood.

b A = insulin, B = adrenaline, C = testosterone, D = progesterone

5 ▶ a Glucose has been absorbed into the blood following a meal (lunch!).

b The high concentration of glucose in the blood is detected by the pancreas, which secretes the hormone insulin into the blood. Insulin stimulates the uptake of blood glucose into the liver, where it is converted into an insoluble storage carbohydrate called glycogen.

c i Untreated diabetes leads to weakness and loss of weight, and eventually coma and death.

ii Coloured test strips to detect glucose in the urine, and direct measurement of blood glucose using a sensor

iii Reducing the amount of carbohydrate in the diet, and injections of insulin

CHAPTER 8

1 ▶ D **2 ▶** C

3 ▶

Changes taking place	Hot environment	Cold environment
(sweating)	increased sweat production so that evaporation of more sweat removes more heat from the skin	decreased sweat production so that evaporation of less sweat removes less heat from the skin
(blood flow through capillary loops)	vasodilation increases blood flow through surface capillaries so that more heat is radiated from the skin	(vasoconstriction decreases blood flow through surface capillaries so that less heat is radiated from the skin)
(hairs in skin)	hairs lie flat due to relaxed muscles, trapping less air next to the skin	hairs are pulled erect by muscles, trapping a layer of insulating air next to the skin
(shivering)	no shivering occurs	shivering occurs; respiration in muscles generates heat
(metabolism)	metabolism slows down, e.g. in organs such as the liver, reducing heat production	metabolism speeds up, e.g. in organs such as the liver, generating heat

4 ▶ a The average body temperatures of birds is slightly higher than that of mammals. This is because they have a higher metabolic rate, needed for flight (note that the flightless birds have a lower body temperature).

b No. For example, the temperatures of the camel and the polar bear are the same, despite their different habitats.

c The fur traps air, providing insulation. The colour acts as camouflage (so they are not so easily seen by prey).

CHAPTER 9

1 ▶ C **2 ▶** D **3 ▶** D **4 ▶** C

5 ▶ a A = placenta, B = umbilical cord, C = amnion, D = amniotic fluid, E = uterus (womb), F = cervix

b The function of the placenta is the transfer of oxygen and nutrients from the mother's blood to the blood of the embryo / fetus, and the removal of waste products such as carbon dioxide and urea from the fetus to the mother.

c Just before birth, contractions of the muscle of the uterus (E) cause the amnion to rupture, allowing the amniotic fluid (D) to escape. This is the 'breaking of the waters'.

d During birth, the cervix (F) becomes fully dilated, and strong contractions of the muscles of the uterus (E) push the baby out.

6 ▶ a Method B: the formation of a new individual (the bud) does not involve sex cells from sex organs (as shown in method A).

b In asexual reproduction, all the cells of the new individual are produced by mitosis from one cell in the parent. When cells divide by mitosis, all the new cells are genetically identical to the parent cell, and to each other.

c If *Hydra* is well adapted to its environment, and the environment is stable, asexual reproduction will produce offspring that are also well adapted. However, if the environment changes, the offspring may not be well adapted and may die out. Sexual reproduction produces offspring that show variation, so some of the new *Hydra* may be better adapted to survive in the new conditions.

7 ▶ a i A **ii** B **iii** D **iv** A

b i oestrogen

ii Approximately 29–30 days. This can be seen by counting the days from the start of the first menstruation (day 0) to the start of the next menstruation.

iii Fertilisation is most likely to have taken place about 15 days after the day when the last menstruation started. The last menstruation started on about day 57, so fertilisation probably took place on about day 72. (Note – this is very approximate!) After day 72 there is no menstruation, so the uterus lining becomes thicker.

iv To prepare for implantation of the fertilised egg.

8 ▶ There is evidence for and against the involvement of pollutants in lowering the sperm count, and indeed whether or not the count has become lower at all. A good account of the student's findings should be a balanced one, giving both sides of the argument. It should be illustrated with some graphs or tables of data.

9 ▶ a A = oestrogen, B = progesterone

b corpus luteum

c To prepare for the implantation of a fertilised embryo

d 13

e Progesterone maintains the thickened uterus lining and prevents menstruation, as well as preventing further ovulation by inhibiting release of FSH and LH.

i Progesterone is secreted by the corpus luteum.

ii Progesterone is secreted by the placenta.

END OF UNIT 2 QUESTIONS

1 ▶ a (1 mark for each correct row)

Gas	Inhaled air / %	Exhaled air / %
nitrogen	(78)	(79)
oxygen	21	16
carbon dioxide	0.04	4
other gases (mainly argon)	(1)	(1)

b It increases in exhaled air (1) because carbon dioxide is produced in respiration (1).

c Excretion is getting rid of a waste product of metabolism (1); carbon dioxide is a waste product of respiration (1).

d i Short distance (1) allows rapid / efficient diffusion of oxygen and carbon dioxide (1)

ii Blood brings carbon dioxide and takes away oxygen (1) maintaining a diffusion gradient (1)

iii Increases the surface over which diffusion of oxygen and carbon dioxide can occur (2)

2 ▶ a i A = stomach (1) because it is an acidic pH (1)
B = small intestine (1) because it is an alkaline pH (1)

ii Protein (1)

b i Liver (1)

ii Proteins (1)

iii Proteins (from the urea) are a source of nutrients for the cattle (1).

3 ▶ a A = pulmonary vein, B = aorta, C = right atrium, D = left ventricle, E = renal vein (5)

b X (artery) has narrow lumen / muscular wall (1); Y (vein) has large lumen / little muscle (1)

c i Increases heart rate (1) and volume of blood pumped with each heart beat (1)

ii Two from: increases breathing rate, diverts blood away from intestine to muscles, converts glycogen to glucose in the liver, dilates pupils, causes body hair to stand on end, increases mental awareness, increases rate of metabolism (1 mark for each correct point, maximum 2 marks)

d Reflex action is automatic / involuntary (1), voluntary action is one a person chooses to carry out / is initiated by the brain (1)

e Lactate produced in muscles during exercise needs to be oxidised / removed / oxygen debt needs oxygen (1); oxygen is supplied by increased breathing rate and increased heartbeat (1)

4 ▶ a Labels: cell membrane (1), lobed nucleus (1), cytoplasm (1)

b Two from: has a nucleus (1), irregular shape / not biconcave (1), no haemoglobin (1)

c Two from: ingest / engulf / surround (bacteria) (1), digest / break them down (1), using enzymes (1)

d Three from: lymphocytes (1), make antibodies (1), specific to antigens (1), form memory cells (1)

5 ▶ a All chemical reactions taking place in cells can continue at a steady rate / metabolism doesn't slow down in cold conditions (1)

b i Arterioles: blood remains in core of body and doesn't lose heat (1). Sweat: no heat lost in evaporating the sweat (1). Shivering: increases heat production by respiration (1).

ii They have a lot of muscle fibres in their walls (1).

6 ▶ a i B **ii** C **iii** B **iv** D **v** A (5).

b Pregnancy is most likely to result from sexual intercourse around the time of ovulation (1), i.e. in the middle of the menstrual cycle / around day 14 (1). If a couple avoid having sexual intercourse at this time, the woman is less likely to become pregnant (1).

7 ▶ a B (1). Cell division has reduced the chromosome number (1) from 46 to 23 / to the number present in gametes (1).

b The fertilised egg / zygote has 46 chromosomes (1). It divides by mitosis (1), so that all the cells of the body also have 46 chromosomes (1). In the sex organs, gametes are produced by meiosis (1), which halves the chromosome number to 23 (1). Fertilisation of an egg by a sperm restores the chromosome number to 46 (1).

c Any three for 3 marks, from:

- mitosis involves one division, meiosis involves two
- mitosis forms two cells, meiosis forms four
- mitosis forms cells with the same chromosome number as the parent cell / diploid, meiosis forms cells with half the chromosome number of the parent cell / haploid
- mitosis forms body cells, meiosis forms sex cells / gametes
- mitosis forms cells that are genetically identical, meiosis forms cells showing genetic variation.

8 ▶ Any six for 6 marks, from:

- rats given protein supplement / range of amounts of protein supplement, and rats given no supplement (Control)
- rats same age / same sex / same health / same variety
- several rats in each group (allow 6 or more per group)
- weigh before and after treatment / take other suitable measurement before and after treatment, such as circumference of leg muscles
- suggested time period for treatment (minimum one week)
- calculate (mean) % change in mass
- same diet (apart from supplement)
- same water / same amount of exercise / other suitable controlled factor.

UNIT 3 ANSWERS

CHAPTER 10

1 ▶ A **2 ▶** C **3 ▶** A

4 ▶ **a** Iodine solution, turns from yellow-orange to blue-black.

b Only the green areas that are not covered would contain starch.

c Photosynthesis needs light and chlorophyll. These are only both available in green, uncovered areas.

d A storage carbohydrate. It is insoluble, so can be stored in cells and has no osmotic effects.

5 ▶

Part of leaf	Function	How the part is adapted for its function
palisade mesophyll layer	(main site of photosynthesis)	(cells contain many chloroplasts for photosynthesis)
spongy mesophyll layer	gas exchange surface: uptake of CO_2 and release of O_2 during photosynthesis, some photosynthesis	large surface area to volume ratio; air spaces between cells; many chloroplasts in cells for photosynthesis (but fewer than in palisade layer)
stomata	pores which exchange gases (CO_2, O_2 and water vapour) with the atmosphere	pores formed between two guard cells; guard cells can change shape to open and close pores
xylem	transport of water and minerals	cells consist of dead, hollow vessels, allows transport through the lumen of each vessel; lignified walls for strength, preventing cells collapsing under suction pressure
phloem	transport of products of photosynthesis	sieve tubes with sieve plates forming continuous tubes to transport solutes; cells living, so can exercise control over movement

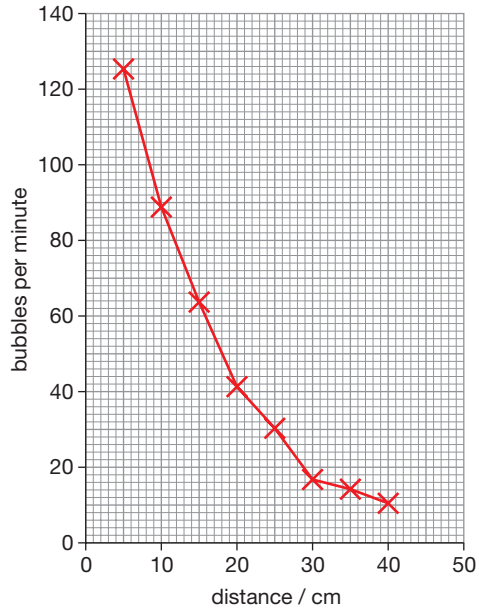
6 ▶

Substance	Use
glucose	oxidised in respiration to give energy
sucrose	main sugar transported in the phloem
starch	storage carbohydrate
cellulose	makes up plant cell walls
protein	growth and repair of cells
lipid	energy store in some plants, e.g. nuts, seeds; part of all cell membranes

7 ▶ **a** The aeration tube supplies oxygen to allow the roots to respire. The foil stops light entering the tube, preventing the growth of algae.

b Phosphate

8 ▶ **a**



b About 54 bubbles per minute

c
- The gas is not pure oxygen, although it has a high oxygen content.
- The bubbles may not be all the same size.
- The water in the test tube may have increased in temperature as the lamp was brought nearer to the tube.

9 ▶ The account should include:
- Description of photosynthesis as a chemical reaction where CO_2 and water are combined using light energy trapped by chlorophyll, forming glucose and oxygen
- Equation for the reaction
- Leaf adaptations: details of palisade mesophyll, spongy mesophyll, stomata and epidermis, xylem and phloem (diagram needed)
- Photosynthesis supplies oxygen for respiration in animals and other organisms; it is needed at the start of food chains; how energy is harnessed by plants as the producers, and then passed to consumers (note: these topics are covered fully in Chapter 14)

CHAPTER 11

1 ▶ C **2 ▶** B

3 ▶ a Loss in mass = (8.2 – 8.0) g = 0.2 g

Percentage change = $\frac{-0.2}{8.2} \times 100 = -2.4\%$

b Osmosis **c** Solution A

d Solution C **e** Solution B

f It is permeable to small molecules such as water, but not permeable to large molecules such as sucrose.

4 ▶ a A = epidermis, B = phloem, C = xylem

b C. Xylem carries water up the stem. The dye is likely to be carried in this water.

CHAPTER 12

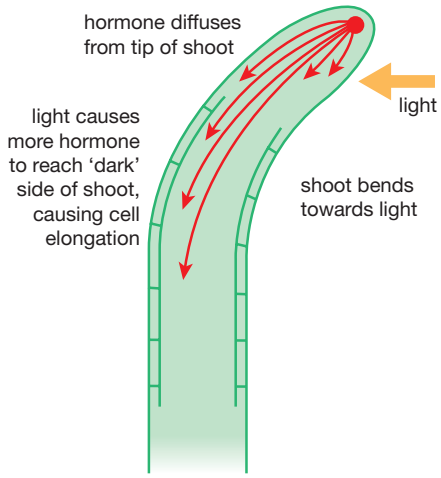
1 ▶ B **2 ▶** B **3 ▶** D **4 ▶** A

5 ▶ a i The direction of light and the direction of gravity

ii The direction of gravity

b The stem grows towards the light, which allows more photosynthesis, and growth of the plant.

6 ▶



7 ▶ a The coleoptile would not bend towards the light. The movement of auxin on the left (dark) side would be interrupted by the mica sheet.

b The coleoptile would grow (bend) towards the source of light. The greater amounts of auxin diffusing down the left side would be unaffected by the placement of the mica sheet. (It might even bend more than a control, with no sheet).

c The coleoptile would grow (bend) towards the source of light. The mica would not interrupt the movement of auxin away from the light.

8 ▶ a Decapitated coleoptiles would produce the least increase in length, because the tip is the source of auxin, which normally stimulates growth. No tip means that there is no auxin, so there will be reduced growth. The tip with the greatest growth is more difficult to predict. The coleoptiles with the tips covered would probably produce the most growth, since auxin is still made by the tip, but none is moved to the left side of the shoot, so there will be no bending, just upward growth.

b Decapitated coleoptiles – no bending, since no auxin produced.

Coleoptiles with tips covered – no bending, since light does not reach the region behind the tip and auxin remains evenly distributed either side of the shoot (you could argue that bending may still occur if the covers are not long enough down the coleoptiles to prevent this).

Untreated coleoptiles – bend towards the right, because auxin is produced by the tip and diffuses away from the light on the left, stimulating growth on that side.

c Each coleoptile is a different starting length. Therefore to allow a fair comparison between treatments we need to find the increase in length in comparison to the starting length. We can do this by calculating a percentage increase.

CHAPTER 13

1 ▶ B **2 ▶** A **3 ▶** D **4 ▶** D

5 ▶ a Stigma

b Any two from: by the coloured petals, scent and nectar

c Pollen tube should be shown growing down through the rest of the style and entering the ovary.

6 ▶ a Independent: temperature

Dependent: height of seedlings and % of seeds that germinated

b $\frac{3.4 + 4.5 + 2.5 + 3.7 + 2.8 + 4.4 + 4.3 + 2.9 + 2.1 + 3.7}{10}$

= 3.43 cm

c Higher temperatures (20 °C or 30 °C) are needed for germination to take place. At a low temperature (4 °C) few seeds germinated or grew. Growth of seedlings was greater at 30 °C than at 20 °C.

d Temperature affects the activity of enzymes and the rate of metabolic reactions. It increases the kinetic energy of molecules, so there are more collisions between enzyme and substrate molecules, resulting in an increase in successful reactions. Germination depends on metabolic reactions, so temperature affects germination.

e The light intensity is not controlled. Tube A is in the light, while B and C are in the dark. All three tubes should be in the light (or all three in the dark).

7 ▶ a This method of reproduction does not involve flowers / seeds / pollen and ovules, so it is not sexual. It involves the tubers growing from body cells of the parent plant.

b The tubers grow from body cells of the parent plant by mitosis, which produces cells that are genetically identical.

c Growth may be affected by the environment of the plants, e.g. different soil minerals or different light intensity.

d Sexual reproduction produces offspring that show genetic variation, allowing them to survive if the environment changes.

8 ▶ **a** A = stigma, B = ovary, C = anther, D = filament

b Any three from:
- lack of large petals (no need to attract insects)
- lack of brightly coloured petals (no need to attract insects)
- exposed stamens (to catch the wind and blow pollen away)
- exposed stigma (to catch windborne pollen)
- stigma feathery (to catch pollen).

c The pollen grain produces a pollen tube, which grows down through the tissue of the style and into the ovary. The pollen tube enters an opening in an ovule. The tip of the pollen tube breaks down and the pollen grain nucleus moves out of the pollen tube into the ovule, where it fertilises the nucleus of the egg cell (ovum).

d Any four from:
- large petals
- brightly coloured petals
- stamens enclosed within flower
- stigma enclosed within flower
- stigma sticky
- nectaries present
- large, sticky pollen grains.

9 ▶ **a** Method A. Fruits are produced by flowers via sexual reproduction, which introduces genetic variation.

b Insect-pollinated. The flower has large, brightly coloured petals to attract insects.

10 ▶ **a** The banana plants reproduce asexually, so they are all genetically identical. Therefore all the plants are susceptible to the fungus, none is resistant to it.

b If the plants reproduced sexually, this would introduce genetic variation. Some of the plants might then have resistance to the fungus and would be able to survive.

c Asexual reproduction is faster than sexual reproduction, so more banana plants can be produced more quickly. (Also, if the plants *are* resistant to a disease, they all will be, so won't be killed by it.)

END OF UNIT 3 QUESTIONS

1 ▶ **a i** Any four points from:

As light intensity increases, the rate of photosynthesis increases (1). The rate of increase is faster at high CO_2 concentration than at low CO_2 concentration (1).

(At both CO_2 concentrations) the rate of photosynthesis reaches a plateau / maximum / levels off (1). At low CO_2 concentration this happens below light intensity X (1) whereas at high CO_2 concentration it happens at / above light intensity X (1).

The maximum rate of photosynthesis is higher at high CO_2 concentration than at low CO_2 concentration (1).

ii Up to X the limiting factor is light (1), because increasing light intensity increases the rate of photosynthesis (1). Beyond X the limiting factor is CO_2 (1), as increasing light intensity has no effect on the rate of photosynthesis (1) whereas increased CO_2 increases the rate (1).

b i Temperature (1), water availability (1)

ii Reactions are slow at low temperatures (1), because the molecules have little kinetic energy (1) and therefore there are fewer successful collisions between enzyme molecules and substrates (1). Water is a raw material for photosynthesis (1).

c The photosynthesis reaction uses / takes in light energy (1) and converts it into chemical energy stored in the glucose / starch produced (1).

2 ▶ **a i** To remove any water / sap on the outside of the cylinder (1)

ii To allow an average to be calculated / to check reliability of results (1)

iii So they all had the same surface area to volume ratio (1)

b i 3 mol per dm^3 sucrose solution has a lower water potential / lower concentration of water / higher concentration of solutes than potato cells (1), so water moves out of the cells and into the sucrose solution (1), resulting in a decrease in mass of the cylinder (1).

ii (Approximately) 0.75 mol per dm^3 (1), because there is no change in mass (1), as there is no net movement of water (1).

c Repeat experiment with more cylinders (1), use more concentrations of sucrose between 0 and 1 mol per dm^3 (such as 0.2 mol per dm^3, 0.4 mol per dm^3, etc.) (1)

3 ▶ **a i** (Positive) phototropism (1)

ii Any three from:

Auxin produced in tip of shoot (1) diffuses back down the shoot (1), auxin moves away from light source (1), causing growth on the dark side of the shoot (1)

iii The plant receives more light for photosynthesis (1)

b i Any two from:

Most curvature takes place at a wavelength of about 430 nm (1), light wavelengths above about 500–550 nm produce no curvature (1), there is a smaller increase in curvature with a peak at about 370 nm (1)

ii Any two for 2 marks from:

The tip / something in the tip only absorbs these wavelengths of light (1), cannot absorb other wavelengths (1), these wavelengths are present in sunlight (1)

c i Gravity (1)

ii Root grows towards gravity / positive geotropism (1), shoot (in some species) grows away from gravity / shows negative geotropism (1)

iii Shoots grow upwards towards light needed for photosynthesis (1), roots grow down towards source of water (1)

4 ▶ a i B (1) ii F (1) iii E (1)

b Any two for 2 marks:
- large petals
- brightly coloured petals
- stamens enclosed within flower
- stigma enclosed within flower.

c i H (1) ii G (1) iii C (1)

d i Pollination is the transfer of pollen from the anther to the stigma (1). Fertilisation is the fusion of the nucleus of the pollen grain with the nucleus of the ovum (1).

ii Self-pollination means transfer of pollen from the anther of a plant to the stigma of the same plant (1). Cross-pollination is when pollen from one plant is transferred to the stigma of another plant (1).

5 ▶ Any six points for 6 marks:
- pollen grains placed in sucrose solution / in range of concentrations of sucrose solutions, and pollen grains placed in water (Control)
- grains from same species / same plant / same flower
- stated number of grains in each treatment (minimum 10)
- (use microscope to) count the number of grains that germinate / grow pollen tube
- (after) suggested time period (minimum 1 hour)
- calculate % germination in each treatment
- same temperature / light intensity / other suitable controlled variable

UNIT 4 ANSWERS

CHAPTER 14

1 ▶ D **2 ▶** B **3 ▶** A

4 ▶ a Habitat: place where an organism lives; community: all the populations of living organisms in an ecosystem; environment: the non-biological components of an ecosystem; population: all the organisms of a particular species in an ecosystem

b Plants = producers; animals = consumers; decomposers = breakdown of dead material

5 ▶ a i Plankton ii Krill

b Quaternary consumer / top carnivore

c Very large amounts of photosynthesis / production by the plankton can support this number of trophic levels

6 ▶ a Any two from:
- trees → moths → small birds → owls
- trees → moths → small birds → weasels
- trees → moths → beetles → shrews

b Vole or small bird

c Reduction in dead leaves means there will be fewer earthworms and beetles, so less food for shrews

d In the pyramid of numbers there are only 200 trees, compared to hundreds of thousands of small consumers at the higher levels. However, each tree has a huge mass compared to the mass of each insect / bird / beetle, etc. so the overall mass of the trees is much larger.

7 ▶ a $\frac{125}{3050} \times 100 = 4.1\%$

b As urine / faeces and as heat from metabolic processes / respiration

c Eaten by other herbivores, or 'lost' in dead matter / passes to decomposers.

CHAPTER 15

1 ▶ B **2 ▶** A **3 ▶** C

4 ▶ Because of the great increase in the human population, the need to produce food to sustain the population, and the industrial revolution and growth of technology

5 ▶ a The concentration of carbon dioxide is increasing.

b The increase is due to increased burning of fossil fuels.

c In the summer there is more photosynthesis, which lowers the concentration of carbon dioxide. In the winter there is less photosynthesis, so carbon dioxide levels increase.

6 ▶ a Any two from: carbon dioxide, methane, water vapour, CFCs

b Without the greenhouse effect, the temperature on the Earth's surface would be much colder than it is now, and life would not be able to exist. (One estimate is that the average temperature would be 30 °C lower.)

c Malaria is spread by mosquitoes, which are found in warmer regions of the world. If global warming occurs, mosquitoes will spread to more northerly parts of Europe.

7 ▶ a Rain washes fertiliser into the pond, causing the algae to grow.

b Rain washes the fertiliser downhill away from the pond.

c Algae are photosynthetic organisms (protoctists). An increased temperature increases their rate of photosynthesis, so they grow more quickly.

8 ▶ The nitrates in sewage cause rapid growth of bacteria in the water. The bacteria need oxygen for growth – they use up the oxygen in the water, so that the fish suffocate / die.

9 ▶ a Pesticides kill pests (insects etc.) so less crop is eaten; fertilisers supply minerals that increase the growth of crops.

b Use manure as fertiliser. After the crop is has been harvested, dig in the remains of plants, allowing them to decay and release nutrients. Use crop rotation including leguminous plants to produce nitrates. Use biological control methods to reduce pests.

END OF UNIT 4 QUESTIONS

1 ▶ a i Any of the following for 1 mark:
- plankton → sea butterfly → arrow worm → herring
- plankton → small crustaceans → large crustaceans → herring
- plankton → copepods → sand eel → herring

ii Primary consumer = sea butterfly / small crustaceans / copepods (1 mark for correct organism from food chain used)
Secondary consumer = arrow worm / large crustaceans / sand eel (1 mark for correct organism from food chain used)

iii Herring (1). It is a secondary consumer when it feeds on other small crustaceans or copepods, and a tertiary consumer when it feeds on sand eels, large crustaceans or arrow worms (1).

b i Pyramid drawn correctly, with relative amounts of energy at each trophic level approximately correct (1)

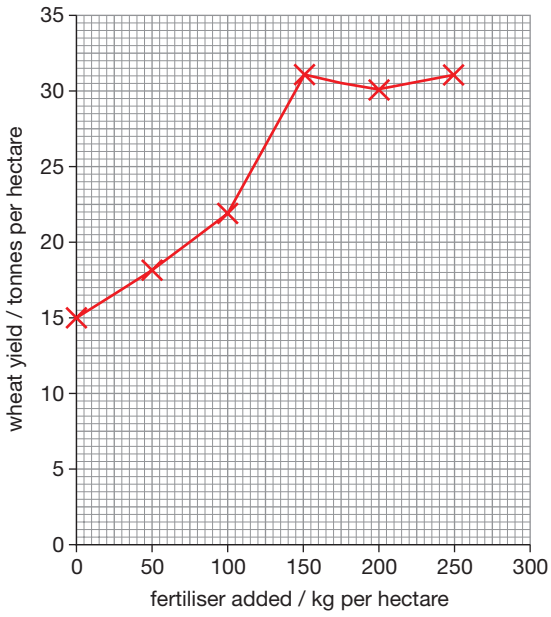
ii $\frac{892}{8869} \times 100 = 10.1\%$ (1 for correct values in calculation, 1 for answer)

iii $\frac{91}{892} \times 100 = 10.2\%$ (1 for correct values in calculation, 1 for answer)

iv $\frac{8869}{0.1} \times 100 = 8\,869\,000$ kJ (1 for correct values in calculation, 1 for answer)

v Two from: losses from respiration / in movement / as faeces / undigested food (2)

2 ▶



a Axes correct way round, scales correct (1); axes labelled, with units (1); points plotted correctly (1); points joined with straight lines (1)

b 150 kg per hectare (1). This amount gives maximum yield (1); any higher concentration would waste fertiliser / waste money (1) (since yield is not higher).

c To make proteins (1)

d Any of the following to a maximum of 5 marks:
- causes plants / algae to grow / form algal bloom
- reference to eutrophication
- plants /algae prevent light penetrating into the water
- submerged plants / algae underneath cannot photosynthesise so they die
- bacteria break down the dead plants / algae
- respiration of the bacteria uses up oxygen
- oxygen level of the water falls / water becomes anoxic
- aerobic animals / fish in the water die.

3 ▶ a i The insecticide becomes less effective / kills fewer insects over the three years (1). This is because some insects were resistant to the pesticide (1) so these reproduced / more resistant insects survived (1).

ii Intermediate concentration (1), as almost as effective as the strongest concentration (1) and will be cheaper / less polluting (1)

b i When amounts of pesticide in body tissues build up over time (1)

ii Named pesticide, e.g. DDT (1) accumulated in top carnivores / named example (e.g. osprey) (1) and caused death / other named problem (1)

iii Could bioaccumulate in human tissues / cause illness / death (1)

4 ▶ a Plants carry out photosynthesis (1), which converts carbon dioxide into organic carbon compounds (1).

b Combustion of fossil fuels, which increases carbon dioxide levels (1); deforestation, which increases carbon dioxide levels (1)

c i The bodies are broken down by respiration (1), which produces carbon dioxide (1).

ii Insects chew bodies into smaller pieces (1), providing a larger surface area (1) for enzymes produced by decomposers (1).

iii 4 marks for two sensible points from the curve, with reasons. e.g.
- curve 1 rises rapidly to a peak of CO_2 production by 7 days, whereas curve 2 shows little production during this time due to the slower action of decomposers on the intact bodies (2)
- curve 1 falls from the peak after 7 days due to material in the dead bodies being used up (1), while curve 2 shows little CO_2 production in this time (2)
- curve 2 starts to rise only at 9–12 days due to the slower action of decomposers on the intact bodies; CO_2 production in curve 1 has nearly fallen back to zero by 11 days (2)

5 ▶ a 2 marks for examples of competition, e.g. for same food source / nest sites, etc. (animals), light / minerals / water (plants) (2). Less well-adapted individuals die / best adapted survive (1) preventing population increasing / population numbers remain stable (1) (maximum 3 marks).

b i 2 marks for two from:
- mineral ions / named ion, for healthy growth
- light for photosynthesis
- water for photosynthesis / turgidity / transport.

ii To kill the weeds before they produce seeds (1) reducing the need to use more herbicide later in the season (1).

c i Species A (1), because there are more adult beetles when the parasite is absent (1)

ii The parasite kills species A (1) but does not affect numbers of species B (1). The first graph shows that species A is better at competing for resources than species B (1). The second graph shows that when species A is removed, species B can do better / increase in numbers (1).

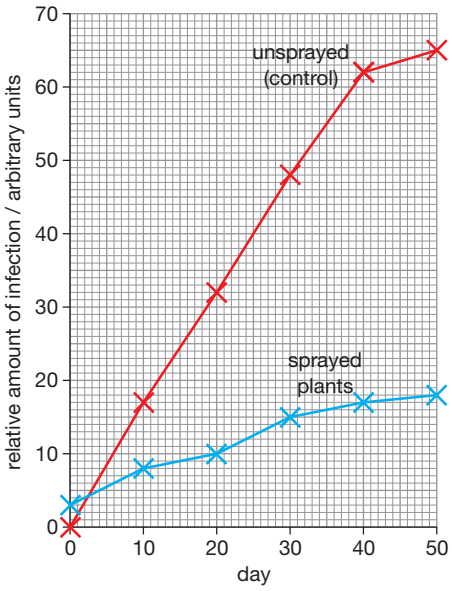
6 ▶ a $\frac{88\,600 - 886}{88\,600} \times 100 = 99\%$ (1 mark for calculation, 1 mark for answer; allow 1 mark if answer given is 1%)

b Sulfur dioxide and nitrogen oxides are acidic gases (1). They are blown long distances by winds (1) and dissolve in rain (so acidifying ground water) (1). (Deduct 1 mark if carbon monoxide given as acidic gas.)

c Dissolved / suspended solids make water cloudy / dirty (1), preventing light reaching plants (1), so plants are unable to photosynthesise (1) and therefore die (1).

7 ▶ a Reduced growth / photosynthesis (1), affecting the appearance of the crop so not harvested / unfit for sale (1)

i



Axes correct way round, labelled (1), all points correctly plotted on both curves (2), key to each curve (1), points joined by straight lines (1)

ii Sprayed: 12 (1), unsprayed 39 (1)

iii The Control shows whether there is any infection without the fungicide (1). It is needed to be able to see how much effect the fungicide is having on the infection, i.e. as a comparison (1).

iv By day 30, the infection in the unsprayed (Control) plants was approximately the same as in Year 1 (1). However the infection in the sprayed plants had increased (1). This was probably because the plants had developed resistance to the fungicide (1).

UNIT 5 ANSWERS

CHAPTER 16

1 ▶ D

2 ▶ a i A gene is a length of DNA that codes for a protein.

ii Alleles are different forms of a gene.

b A chromosome is a structure in the nucleus of a cell composed of DNA (and proteins).

c i Both have 23 pairs of chromosomes in each cell.

ii A woman's skin cells contain XX sex chromosomes, a man's contain XY.

CHAPTER 17

1 ▶ D 2 ▶ B 3 ▶ C 4 ▶ B

5 ▶ a Both types of division start with each chromosome copying itself / DNA replicating / DNA copying itself / chromatids forming.

Plus any two from:

- Mitosis produces two daughter cells, meiosis produces four daughter cells.
- Daughter cells from mitosis are genetically identical to each other and the parent cell; daughter cells from meiosis are genetically different from each other and the parent cell.
- Mitosis produces daughter cells with the same number of chromosomes as the parent cell / diploid to diploid; meiosis halves the chromosome number / diploid to haploid.

b Mitosis: they are formed by division of body cells to produce more body cells.

c Because the number of chromosomes per cell is reduced by half.

6 ▶ a They have been formed by mitosis, so are genetically identical.

b Meiosis is used to form pollen and egg cells, so fertilisation results in seeds that are genetically different from each other.

7 ▶ a Control

b Plants from cuttings will be genetically identical, so it will be easier to see the effects of the treatment with nitrogen-fixing bacteria. Plants from seeds would be genetically different, so their growth might depend on their genes, rather than the treatment.

c The nitrogen-fixing bacteria provide nitrates needed for growth. This is an environmental effect on growth, rather than a genetic one. Therefore the environment plays a big part in the growth of these plants.

8 ▶ a Meiosis, because sperm are gametes that are haploid / contain half the number of chromosomes of body cells.

b Mitosis, because body cells are dividing to produce more body cells with the normal chromosome number.

c Mitosis, because body cells are dividing to produce more body cells with the normal chromosome number.

d Meiosis, because pollen grains are gametes that are haploid / contain half the number of chromosomes of the plant's body cells.

e Mitosis, because the zygote must divide to produce more body cells with the normal chromosome number.

9 ▶ a Genetic – eye colour is inherited and not affected by the environment.

b Genetic – it depends on inheriting XX or XY chromosomes.

c Environmental – the pH of soil is a feature of the plant's environment.

d Both – genes determine whether a plant falls into the tall or dwarf category, but environmental factors affect how well each plant grows.

e Both – genes affect the risk level, but environmental factors such as diet, smoking, etc. also have an effect.

10 ▶ a Chromosomes align themselves along the equator of the cell, attached to the spindle fibres.

b Spindle fibres shorten and pull chromatids towards opposite poles of the cell.

c Chromosomes reach the opposite poles of the cell. Nucleus starts to re-form.

CHAPTER 18

1 ▶ D **2 ▶** A **3 ▶** D

4 ▶ a All tall

b All tall

c All tall

d 3 tall : 1 short

e 1 tall : 1 short (or 2 : 2)

f All short

5 ▶ a i Homozygous

ii A dominant gene hides the expression of the recessive gene in heterozygous individuals; a recessive gene is expressed only in homozygous individuals.

b i B and b **ii** All Bb

c i Heterozygous

ii

	B	b
B	BB	Bb
b	Bb	bb

Phenotypes = 3 black : 1 red.

6 ▶ a Gametes of parents = R and r
Genotypes of F1 = Rr
Genotypes of F1 parents = Rr and Rr
Gametes of F1 parents R, r and R, r
Genotypes of F2 =

	R	r
R	RR	Rr
r	Rr	rr

b A, B and C are red, D is yellow

7 ▶ a Individual 8 has cystic fibrosis, but neither of his parents does, so they must be heterozygous and the allele must be recessive. If the allele was dominant, he would have to have inherited at least one dominant allele from one parent, so that parent would have cystic fibrosis too.

b 3 and 4 must be heterozygous for the gene, as they do not have the disease, but their son does. 11 must be homozygous for the gene, since she has the disease.

c i Probability that the next child will be male is 1 in 2, or 0.5:

	X	Y
X	XX	XY
X	XX	XY

ii Let A = the normal allele of the gene and a = cystic fibrosis gene.

Individual 11's genotype = aa. Individual 10's genotype could be AA or Aa.

So there are two possible outcomes:

AA × aa

	A	A
a	Aa	Aa
a	Aa	Aa

Aa × aa

	A	a
a	Aa	aa
a	Aa	aa

Depending on whether 10 is AA or Aa, there could be no chance, or a 1 in 2 chance (0.5 probability) of their next child having cystic fibrosis. It could also be argued that, since the genotype of 10 is unknown, the probability of the child having cystic fibrosis is 1 in 4, or 0.25.

8 ▶ a Both parents must be heterozygous. Let S = allele for short hair and s = allele for long hair.

	S	s
S	SS	Ss
s	Ss	ss

There is a 1 in 4 chance of producing a long-haired guinea pig (ss).

b Breed the short-haired guinea pig with a homozygous long-haired guinea pig (ss). If it is heterozygous (Ss), both long-haired and short-haired offspring will be produced (in a 1:1 ratio):

	S	s
s	Ss	ss
s	Ss	ss

If it is homozygous (SS), all offspring will have short hair:

	S	S
s	Ss	Ss
s	Ss	Ss

CHAPTER 19

1 ▶ D **2** ▶ B **3** ▶ A **4** ▶ D
5 ▶ D **6** ▶ B

7 ▶ **a** It means that the organisms that are best adapted to their environment are more likely to survive and reproduce.

b Darwin and Wallace

8 ▶ **a** An organism that causes disease

b Fungi and bacteria

c Random mutations produce some bacteria that are resistant to an antibiotic. If the antibiotic continues to be used, the resistant bacteria will survive and the non-resistant ones will be killed. The resistant bacteria have a selective advantage over the non-resistant bacteria; they quickly reproduce and cause disease.

9 ▶ **a** Rats with the mutant allele, that made them resistant to warfarin, survived and reproduced, so now many more rats carry the allele. Rats without the allele did not survive to reproduce.

b It would decrease as it would not give an advantage; rats that don't have the allele will breed equally well. (In fact, rats with the warfarin-resistant allele have a selective disadvantage when warfarin is not being used, although students will not know this.)

10 ▶ **a** They have a heavy beak, which is adapted to crush seeds.

b They have a long, narrow beak, which can be used to probe under the bark of trees for insects.

c Ancestors showed slight variations in their beaks. Where the variation enabled a bird to catch insects, or eat leaves and other food better than birds with other types of beak, the birds survived better and reproduced (survival of the fittest), passing on their genes for the adaptation. Eventually groups of birds became so different from members of other groups that they couldn't interbreed, and formed new species.

11 ▶ **a** As a result of (random) mutations

b **i** Selection pressure: a factor in the environment that affects the fitness of an organism. In this case the presence of toxic metals means that the non-tolerant plants will be killed and so do not reproduce to pass on their genes.

ii Selective advantage: varieties that survive in the presence of a selection pressure are said to have a selective advantage. In this example the plants that are tolerant to toxic metals have a selective advantage when compared with the non-tolerant plants.

iii Natural selection: the overall process that, when metals are present, results in fewer non-tolerant plants and an increase in the number of tolerant plants. If it continues, natural selection results in evolution.

c When there are no toxic metals, the metal-tolerant plants must have some sort of selective disadvantage over the non-tolerant ones. For example, they may need to use metabolic energy (ATP) to protect their cells against metals or get rid of metal ions. If there are no metal ions in the soil, this is a waste of resources.

12 ▶ **a** Both involve selection of which animals or plants survive to breed.

b In selective breeding the farmer / breeder does the selection. In natural selection it is the survival of the fittest in a habitat that leads to selection.

13 ▶ **a** Milk yield and feed to milk conversion rate

b Choose a cow with the best characteristics (i.e. feed to meat conversion rate, meat : fat ratio, growth rate and total body mass) and give hormone / FSH injections to cause multiple ovulations. Collect ova and use IVF to fertilise with sperm collected from a bull with the best characteristics. Separate cells of embryos that develop and produce large numbers of embryos. Screen for sex (males) and implant into surrogate mother cows.

14 ▶ **a** Hybrid G was produced by selective breeding. Individual plants from pure lines of A and B were selected (for size of cobs) and crossed to produce hybrid E. Similarly, individual plants from pure lines of C and D were selected and crossed to produce hybrid F. Plants from hybrids E and F were then selected for their cob size and crossed to produce hybrid G. (Crossing would be done by transfer of pollen from anthers to stigmas of plants.)

b Cobs from hybrid G are larger, they have more seeds and the cobs are more uniform size / shape.

c Any sensible suggestion, e.g. breed from each under identical environmental conditions, or sequence the genes to show differences.

15 ▶ The essay should include:

- examples of traditional selective breeding of crop plants or domestic animals
- advantages of this type of artificial selection, e.g. to crop yield, characteristics of animals
- cloning of plants and its advantages
- cloning animals and its uses
- causes for concern with cloned organisms (e.g. cloned plants all genetically identical, so susceptible to same pathogens; cloned animals like 'Dolly' may have genetic defects; ethical issues).

END OF UNIT 5 QUESTIONS

1 ▶ **a** Toxic copper ions (1), only copper-tolerant plants will grow and reproduce / non-tolerant plants will die (1)

b Predation by lions (1), only those wildebeest that are fast runners (or equivalent) will survive and reproduce / slow animals will be killed and not reproduce (1)

c Presence of pesticide (1), only those pests resistant to the pesticide will grow and reproduce / non-resistant pests will die (1)

2 ▶ **a** Both 1 and 2 are tasters (1). If the gene was recessive, all their children would also be tasters, but 4 is a non-taster (1 mark for explanation or correct genetic diagram).

b Individual 3 is Tt (1), because if TT, she couldn't supply a 't' allele to have daughters who are non-tasters (1). Individual 7 is tt (1), because this is the only genotype that produces a taster (1).

c Individual 5 could be either TT or Tt (1), since her husband 6 is a non-taster (tt), and so she could donate a 'T' allele from either genotype to produce a son who is Tt (1 mark for explanation or correct genetic diagram).

d Individual 3 must have the genotype Tt (1). Individual 4 must be tt (1). So the cross produces a 1:1 ratio of tasters to non-tasters / probability is 0.5 that a child is a taster (1). (1 mark for correct genetic diagram):

	T	t
t	Tt	tt
t	Tt	tt

3 ▶ a D, C, B, E, F, A (all correct = 2 marks, 1 mark if one or more wrong)

b Mitosis (1), because there are only two cells produced / only one division / no reduction division / no pairing of homologous chromosomes (1)

c 46

d Any two from:

- mitosis produces two daughter cells; meiosis produces four daughter cells
- daughter cells from mitosis are genetically identical to each other and the parent cell; daughter cells from meiosis are genetically different from each other and the parent cell
- mitosis produces daughter cells with the same number of chromosomes as the parent cell / diploid to diploid; meiosis halves the chromosome number / diploid to haploid.

UNIT 6 ANSWERS

CHAPTER 20

1 ▶ A **2 ▶** B **3 ▶** C **4 ▶** D

5 ▶ a Using (hot) steam under high pressure

b The air is needed to supply oxygen for aerobic respiration of the microorganisms. It is filtered to prevent contamination by unwanted microorganisms.

c Microorganisms produce metabolic heat that could overheat the culture. The water jacket contains circulating cold water to cool the contents of the fermenter and maintain a constant temperature.

d Nutrients

e Growth would be reduced. The paddles mix the contents, so that the *Penicillium* cells are exposed to more nutrients, achieving a faster rate of growth.

6 ▶ a glucose → ethanol + carbon dioxide

b The fermentation air lock allows carbon dioxide to escape from the jar but prevents air from entering.

c To raise the temperature of fermentation. Enzymes in the yeast will work more quickly if they are near their optimum temperature.

d High concentrations of ethanol kill the yeast cells.

7 ▶ a To kill any natural bacteria in the milk.

b It is the optimum temperature for growth and activity of the yoghurt bacteria.

c Proteins in the milk coagulate due to the fall in pH.

d The drop in pH reduces the growth of the lactic acid bacteria.

e The low pH helps to prevent the growth of other spoiling microorganisms.

CHAPTER 21

1 ▶ B **2 ▶** C **3 ▶** D **4 ▶** A

5 ▶ a 1 = restriction endonuclease / restriction enzyme; 2 = (DNA) ligase

b It is a vector, used to transfer the gene into the bacterium.

c They are cultured in fermenters.

d It is identical to human insulin and gives better control of blood glucose levels.

6 ▶ The account should discuss how far xenotransplantation has been developed and what advantages have been suggested for it. It should look at what the biological problems might be, and the ethical objections. It should be a balanced account.

7 ▶ a Use *Agrobacterium* to insert plasmids containing the required gene into plant cells, or use a gene gun to fire a pellet of gold, coated with DNA containing the required gene, into the plant tissue.

b The plants are grown by micropropagation.

c Egg cell

8 ▶ Essay should describe a range of genetically engineered products, such as:

- products from bacteria: human insulin, enzymes, human growth hormone, etc.
- genetically modified plants, such as 'golden rice' and crops resistant to herbicide
- genetically modified animals, e.g. sheep used to produce human proteins, xenotransplantation.

The benefits of each example should be discussed.

The risks from genetic engineering should also be discussed, such as:

- 'escape' of genes from crop plants into natural plant populations
- transfer of 'hidden' pathogens in xenotransplanted organs.

END OF UNIT 6 QUESTIONS

1 ▶ a Restriction endonuclease / restriction enzyme (1)

b An egg cell / egg (1), with its nucleus removed (1)

c An organism containing a gene / DNA / an allele from a different species (1)

d Any three points for 3 marks:
- all sheep will be genetically identical / have same genes / have same DNA
- all sheep will produce Factor IX
- could be used to make more Factor IX
- faster reproduction of sheep
- only need to genetically modify the sheep once.

e Prevents blood loss (1); prevents entry of pathogens / bacteria / microorganisms (1)

f Plasma and platelets (2)

2 ▶ a It would not be possible to destroy these plants (1), and the genes could jump to other species so that they would also not be able to be destroyed (1).

b The plants could spread to other areas and would increase in numbers, as they were resistant to pests (1). The genes could jump to other species and they would also spread (1).

c The plants could spread to other areas and would compete with other species and take over other habitats (1). The genes could jump to other species and they would also compete with other species (1).

3 ▶ a To supply oxygen for aerobic respiration of the microorganisms (1).

b The temperature must be at the optimum for the enzymes in the microorganisms to work (1). If temperature is too low, reactions will be slow / if too high enzymes will be denatured / microorganisms killed (1).

c pH / supply of nutrients (1)

d Disinfectants are difficult to wash out of the fermenter (1) and might kill the microorganism being grown (1) (steam just leaves harmless water).

e 2 marks for any two from: human insulin works better than insulin from animal pancreases / there is no risk of transfer of pathogens using human insulin / using human insulin from microorganisms is acceptable to people who object to using animal tissues.

4 ▶ a i A small ring of DNA (1) in (the cytoplasm of) a bacterium (1)

ii A virus (1) that infects bacterial cells (1)

b i Four points from the following, for maximum of 4 marks: restriction endonucleases are enzymes that cut DNA at specific points (1). They are used to cut out genes from the DNA (1) by recognising a certain base sequence (1). Different restriction enzymes cut DNA at different places (1). Use of the same restriction enzyme on a plasmid allows the DNA to be inserted into the plasmid (1).

ii Ligases are enzymes that join cut ends of DNA (1) allowing genes to be put into plasmids (1).

5 ▶ a Yeast / fungus (1)

b In beer making, the yeast respires to produce ethanol (1);

glucose → ethanol + carbon dioxide (1 mark per side of equation)

c Barley contains starch (1), which is broken down to maltose (1), which is used by the yeast for respiration (1).

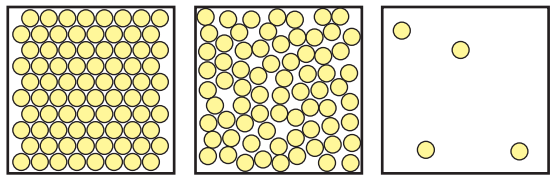
CHEMISTRY

UNIT 1 ANSWERS

CHAPTER 1

1 ▶ **a** melting **b** freezing
c subliming / sublimation **d** subliming / sublimation

2 ▶ **a**



solid liquid gas

Note: Solids should have regularly packed particles touching. Liquids should have most of the particles touching at least some of their neighbours, but with gaps here and there, and no regularity. Gases should have the particles well spaced.

b Solids: vibration around a fixed point. Liquids: particles can move around into vacant spaces, but with some difficulty because of the relatively close packing.

c Evaporation: Some faster moving particles break away from the surface of the liquid. Boiling: Attractive forces are broken throughout the liquid to produce bubbles of vapour.

3 ▶ **a** **i** A – gas; B – liquid; C – solid; D – liquid; E – solid
ii A – gas; B – solid; C – solid; D – liquid; E – solid
iii A – gas; B – liquid; C – solid; D – gas; E – solid

b A, because it is a gas.

c It sublimes and therefore is converted directly from a solid to a gas without going through the liquid stage.

d D – it has a lower boiling point, so the forces of attraction between particles will be weaker and it will evaporate more easily than substance B (the only other substance that is a liquid at 25 °C).

4 ▶ **a** The ammonia and hydrogen chloride particles have to diffuse through the air in the tube, colliding with air particles all the way.

b **i** Its particles will move faster.
ii It would take slightly longer for the white ring to form, because the gas particles would be moving more slowly at the lower temperature.

c Ammonia particles are lighter than hydrogen chloride particles and so move faster. The ammonia covers more distance than the hydrogen chloride in the same time.

d **i** Ammonium bromide
ii The heavier hydrogen bromide particles would move more slowly than the hydrogen chloride particles, and so the ring would form even closer to the hydrobromic acid end than it was to the hydrochloric acid end. The ring will also take slightly longer to form because of the slower moving particles.

CHAPTER 2

1 ▶

Element	Compound	Mixture
hydrogen	magnesium oxide	sea water
calcium	copper(II) sulfate	honey
		blood
		mud
		potassium iodide solution

2 ▶ **a** mixture **b** mixture **c** element
d element **e** compound **f** compound

3 ▶ Substance X is the pure substance – it melts at a fixed temperature. Substance Y is impure – it melts over a range of temperatures.

4 ▶ **a** crystallisation **b** (simple) distillation
c fractional distillation **d** chromatography
e filtration

5 ▶ For example: Stir with a large enough volume of cold water to dissolve all the sugar. Filter to leave the diamonds on the filter paper. Wash on the filter paper with more water to remove any last traces of sugar solution. Allow to dry.

6 ▶ **a** M **b** R
c 0.45 ±0.01 (measure to the centre of the spot and remember to measure from the base line and not from the bottom of the paper)
d G and T **e** P

CHAPTER 3

1 ▶ **a** the nucleus **b** electrons
c proton **d** proton and neutron

2 ▶ **a** 9
b sum of protons + neutrons in the nucleus
c 9 p, 10 n, 9 e
d The protons and electrons have equal but opposite charges. The atom has no overall charge, therefore there must be equal numbers of protons and electrons.

3 ▶ **a** 26 p, 30 n, 26 e
b 41 p, 52 n, 41 e
c 92 p, 143 n, 92 e

4 ▶ **a** Atoms with the same atomic number but different mass numbers. They have the same number of protons, but different numbers of neutrons.
b 35Cl: 17 p, 18 n, 17 e; 37Cl: 17 p, 20 n, 17 e

5 ▶ $\frac{6 \times 7 + 93 \times 7}{100} = 6.93$

6 ▶ $\frac{24 \times 78.99 + 25 \times 10.00 + 26 \times 11.01}{100} = 24.32$

7 ▶ $\frac{204 \times 1.4 + 206 \times 24.1 + 207 \times 22.1 + 208 \times 52.4}{100} = 207.241$

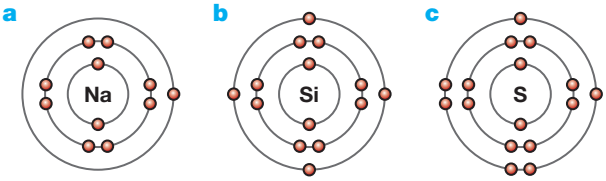
8 ▶ **a** 77 protons, 114 neutrons, 77 electrons
b Iridium-193 has 2 more neutrons in the nucleus.
c More iridium-193 because the relative atomic mass is closer to 193 than 191.

9 ▶ This statement is true – it only applies to 1 element, hydrogen (^{1}H).

CHAPTER 4

1 ▶ **a** **i** strontium **ii** chlorine **iii** nitrogen **iv** caesium **v** neon
b metals: caesium, molybdenum, nickel, strontium, tin
non-metals: chlorine, neon, nitrogen

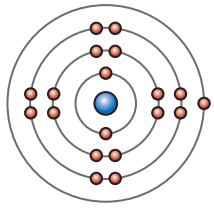
2 ▶ **a** **b** **c**



3 ▶ **a** 2, 7 **b** 2, 8, 3 **c** 2, 8, 8, 2

4 ▶ **a** 5 **b** 7 **c** 4 **d** 8

5 ▶ **a** A and F because they have 4 electrons in their outer shell
b A
c C and D because 5 shells are occupied
d C because there are 7 electrons in the outer shell (energy level)
e B, D
f Calcium – it has 20 electrons, so it must have 20 protons in the nucleus. The atomic number is therefore 20. Calcium is the element with atomic number 20.
g 82, lead
h



6 ▶ Palladium is a metal and so is likely to have any of the following properties:
- good conductor of electricity
- forms a basic oxide
- is shiny when polished or freshly cut
- is malleable
- is ductile
- is a good conductor of heat

The first two are mentioned specifically on the syllabus.

7 ▶ They have a full outer shell (energy level) and so they have no tendency to form compounds by losing / gaining electrons or sharing electrons.

8 ▶ Argon and potassium OR iodine and tellurium.
The elements would then be in a different group in the Periodic Table. They would not have the same number of electrons in the outer shell as other members of the group and would react in a completely different way. For example, potassium would be in Group 0 with the noble gases, and argon, which is very unreactive, would be in Group 1, with the highly reactive alkali metals.

CHAPTER 5

1 ▶ **a** $Fe + 2HCl \rightarrow FeCl_2 + H_2$
b $Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$
c $Ca + 2H_2O \rightarrow Ca(OH)_2 + H_2$
d $2Al + Cr_2O_3 \rightarrow Al_2O_3 + 2Cr$
e $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$
f $2NaHCO_3 + H_2SO_4 \rightarrow Na_2SO_4 + 2CO_2 + 2H_2O$
g $2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$
h $Fe_3O_4 + 4H_2 \rightarrow 3Fe + 4H_2O$
i $Pb + 2AgNO_3 \rightarrow Pb(NO_3)_2 + 2Ag$
j $2AgNO_3 + MgCl_2 \rightarrow Mg(NO_3)_2 + 2AgCl$
k $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

2 ▶ **a** 44 **b** 60 **c** 142 **d** 132
e 286 (The common mistake would be not to multiply the whole water molecule by 10. So the mass of the $10H_2O$ is 180. Students will commonly and wrongly come up with 36 for this by multiplying the H_2 by 10 but not the O as well. Work out the mass of the whole H_2O first and then multiply it by the number in front. That way you won't make this mistake.)
f 392

3 ▶ **a** 13.9% **b** 35%
c 21.2% (Be careful of the cases where there are two nitrogen atoms in the fertiliser (all except KNO_3). The masses of the nitrogen in those cases will be 28 and not 14.)

4 ▶ In each case, work out the M_r by adding up the relative atomic masses (A_r values), and then attach the unit 'g' to give the mass of 1 mole.
a 27 g
b 331 g
c 4.30 × 16 = 68.8 g
d 0.70 × 62 = 43.4 g
e 0.015 × 85 = 1.275 g
f 0.24 × 286 = 68.64 g (Don't forget the water of crystallisation)
Strictly speaking the answers to *d)*, *e)* and *f)* shouldn't be quoted to more than 2 significant figures, because the number of moles is only quoted to that precision.)

5 ▶ In each case, work out the mass of 1 mole as above, and then work out how many moles you've got in the stated mass. You can use the equation:

$$\text{number of moles} = \frac{\text{mass}}{\text{mass of 1 mole}}$$

a $\frac{20}{40} = 0.5\,\text{mol}$

b $\frac{3.20}{160} = 0.0200\,\text{mol}$

c $\frac{2000}{79.5} = 25.2\,\text{mol}$ (Don't forget to convert kg to g.)

d $\frac{50}{249.5} = 0.2\,\text{mol}$

e $\frac{1\,000\,000}{56} = 17\,900\,\text{mol}$ (or 17 857, although this is precise to more significant figures than the A_r).

f $\frac{0.032}{64} = 5.0 \times 10^{-4}\,\text{mol}$ (0.0005 mol)

6 ▶ a $4 \times 58.5 = 234\,\text{g}$

b $\frac{37}{74} = 0.5\,\text{mol}$

c $\frac{1000}{40} = 25\,\text{mol}$

d $0.125 \times 79.5 = 9.94\,\text{g}$ (9.9375 g)

e $\frac{4}{0.1} = 40\,\text{g}$

f $\frac{1}{0.004} = 250\,\text{g}$

7 ▶ a

	P	H
Combining mass	9.39 g	0.61 g
No. of moles of atoms	$\frac{9.39}{31} = 0.30$	$\frac{0.61}{1} = 0.61$
Ratio of moles	1	2

Empirical formula is PH_2

b

	K	N	O
Combining mass	5.85 g	2.10 g	4.80 g
No. of moles of atoms	$\frac{5.85}{39} = 0.15$	$\frac{2.10}{14} = 0.15$	$\frac{4.80}{16} = 0.3$
Ratio of moles	1	1	2

Empirical formula is KNO_2

c

	Na	S	O
Combining mass	3.22 g	4.48 g	3.36 g
No. of moles of atoms	$\frac{3.22}{23} = 0.14$	$\frac{4.48}{32} = 0.14$	$\frac{3.36}{16} = 0.21$
Ratio of moles	1 simplifies to 2	1 2	1.5 3

Empirical formula is $Na_2S_2O_3$

d

	C	H	Br
Given %	22.0	4.6	73.4
No. of moles of atoms	$\frac{22.0}{12} = 1.833$	$\frac{4.6}{1} = 4.6$	$\frac{73.4}{80} = 0.9175$
Ratio of moles	2	5	1

Empirical formula is C_2H_5Br

8 ▶ a The mass of oxygen is 2.84–1.24 = 1.60 g

	P	O
Combining mass	1.24 g	1.60 g
No. of moles of atoms	$\frac{1.24}{31} = 0.04$	$\frac{1.60}{16} = 0.10$
Ratio of moles	1	2.5

Whole numbers must be used, therefore multiply by 2 to get the empirical formula P_2O_5.

b P_2O_5 has an M_r of 142

$\frac{284}{142} = 2$

Therefore there must be two lots of the empirical formula in a molecule.

Molecular formula is P_4O_{10}

9 ▶ a

	Carbon	Hydrogen	Oxygen
Given %	66.7	11.1	22.2
Combining mass in 100 g	66.7 g	11.1 g	22.2 g
No. of moles of atoms	$\frac{66.7}{12} = 5.558$	$\frac{11.1}{1} = 11.1$	$\frac{22.2}{16} = 1.3875$
Ratio of moles	4	8	1

Empirical formula is C_4H_8O

b The mass of the empirical formula is $4 \times 12 + 8 \times 1 + 16 = 72$. Since this is equal to the relative formula mass, the molecular formula is the same as the empirical formula, that is C_4H_8O.

10 ▶ You know the mass of anhydrous sodium sulfate (1.42 g).
You can work out the mass of water of crystallisation (3.22 – 1.42 g = 1.8 g).
You can work out the mass of 1 mole of sodium sulfate, Na_2SO_4 = 142 g;
and the mass of 1 mole of water = 18 g

Number of moles of sodium sulfate = $\frac{1.42}{142} = 0.01\,\text{mol}$

Number of moles of water = $\frac{1.8}{18} = 0.1\,\text{mol}$

So for every 1 mole of sodium sulfate, there are 10 moles of water.
The value of n is 10.

11 ▶ mass of anhydrous calcium sulfate = 44.14 – 37.34 = 6.80 g
mass of water of crystallisation = 45.94 – 44.14 = 1.80 g

mass of 1 mole of calcium sulfate, $CaSO_4$ = 136 g

number of moles of sodium sulfate = $\frac{6.80}{136}$ = 0.05 mol

mass of 1 mole of water = 18 g

number of moles of water = $\frac{1.8}{18}$ = 0.1 mol

number of moles of water = 0.1

number of moles of calcium sulfate = 0.05

the value of n = 2

12 ▶ a 0.36 mol

b From the chemical equation, the number 2 in front of the HCl indicates that 2 mol HCl react with 1 mol $CaCO_3$, therefore 0.4 mol $CaCO_3$ react with $2 \times 0.4 = 0.8$ mol HCl.

c 6 mol HCl react to form 3 mol H_2S

Therefore the number of moles of H_2S is half the number of moles of HCl.

0.4 mol HCl form 0.2 mol H_2S

d 3 mol CO form 2 mol Fe

The number of moles of Fe is $\frac{2}{3}$ the number of moles of CO.

$0.9 \times \frac{2}{3}$ = 0.6 mol iron

e $0.8 \times \frac{3}{2}$ = 1.2 mol hydrogen

13 ▶ a number of moles of iron = $\frac{10}{56}$ = 0.179 mol

b From the chemical equation, the number of moles of bromine that reacted with this number of moles of iron is $\frac{3}{2} \times 0.179 = 0.277$ mol.

c From the chemical equation, the number of moles of $FeBr_3$ will be the same as the number of moles of iron = 0.179 mol.

d mass of 1 mol $FeBr_3 = 56 + 3 \times 80 = 296$

mass of $FeBr_3 = 0.179 \times 296 = 53$ g

(A common mistake here is to multiply the number of moles of $FeBr_3$ by the mass of $2FeBr_3$. The 2 has already been used when you worked out that 2 mol Fe formed 2 mol $FeBr_3$ – do not use it again. The equation for working out the mass is

mass = number of moles × mass of **1** mole.)

14 ▶ a $\frac{1.0}{190}$ = 0.0053 mol

b 0.0053 mol

c $0.0053 \times 48 = 0.25$ g

d number of moles of NaCl = $0.0053 \times 4 = 0.0212$ mol

mass of NaCl = $0.0212 \times 58.5 = 1.2$ g

e You can carry out a moles calculation as above:

1 tonne = 1 000 000 g

moles of $TiCl_4$ = $\frac{1\,000\,000}{190}$ = 5300 mol

moles of Ti = 5300 mol

mass of Ti = $5300 \times 48 = 254\,400$ g

Alternatively, you can reason that, if 1 g $TiCl_4$ forms 0.25 g Ti, 1 tonne $TiCl_4$ will form 0.25 tonne Ti.

15 ▶ mass of 1 mole of $AlCl_3 = 27 + 3 \times 35.5 = 133.5$ g

moles of aluminum chloride = $\frac{2.67}{133.5}$ = 0.0200 mol

moles of AgCl = $3 \times 0.0200 = 0.0600$ mol

mass of 1 mole of AgCl = 108 + 35.5 = 143.5 g

mass of AgCl = $0.0600 \times 143.5 = 8.61$ g

16 ▶ a mass of 1 mol $Cr_2O_3 = 2 \times 52 + 3 \times 16 = 152$ g

number of moles of Cr_2O_3 = $\frac{50}{152}$ = 0.33 mol

number of moles of Al = $2 \times 0.33 = 0.66$ mol

mass of Al = $0.66 \times 27 = 17.8$ g

b number of moles of Cr = $2 \times 0.33 = 0.66$ mol

mass of Cr = $0.66 \times 52 = 34.3$ g

c 5 kg is 5000 g

number of moles of Cr_2O_3 = $\frac{5000}{152}$ = 33 mol

number of moles of Cr = $2 \times 33 = 66$ mol

mass of Cr = $66 \times 52 = 3430$ g or 3.43 kg

Alternatively, we can reason that 5 kg is 100 times as much as 50 g. If we start with 100 times as much Cr_2O_3, we will make 100 times as much Cr.

d 5 tonnes is 5 000 000 g

number of moles of Cr_2O_3 = $\frac{5\,000\,000}{152}$ = 33 000 mol

number of moles of Cr = $2 \times 33\,000 = 66\,000$ mol

mass of Cr = $66\,000 \times 52 = 3\,430\,000$ g or 3.43 tonnes

Alternatively, we can reason that, if 5 kg of Cr_2O_3 produces 3.43 kg Cr, then 5 tonnes of Cr_2O_3 will produce 3.43 tonnes of Cr.

17 ▶ a mass of 1 mol CuO = 63.5 + 16 = 79.5 g

number of moles of CuO = $\frac{4.00}{79.5}$ = 0.0503 mol

number of moles of $CuSO_4$ = 0.0503 mol

number of moles of $CuSO_4.5H_2O$ = 0.0503 mol

mass of 1 mol $CuSO_4.5H_2O = 63.5 + 32 + 4 \times 16 + 5 \times (16 + 2) = 249.5$ g

mass of $CuSO_4.5H_2O = 0.0503 \times 249.5 = 12.55$ g

b the theoretical yield is 12.55 g

the actual yield is 11.25 g

$\frac{11.25}{12.55} \times 100 = 89.64\%$

18 ▶ a mass of 1 mol ethanol = $2 \times 12 + 6 \times 1 + 16 = 46$ g

number of moles of ethanol = $\frac{20.0}{46}$ = 0.435 mol

number of moles of ethyl ethanoate = 0.435 mol

mass of 1 mol ethyl ethanoate = $4 \times 12 + 2 \times 16 + 8 \times 1 = 88$ g

mass of ethyl ethanoate = $0.435 \times 88 = 38.3$ g

b theoretical yield = 38.3 g

actual yield = 30.0 g

percentage yield = $\frac{30.0}{38.3} \times 100 = 78.3\%$

19 ▶ a 0.5 mol HCl would react with 0.25 mol Na_2CO_3.

There is more than 0.25 mol Na_2CO_3, therefore Na_2CO_3 is in excess.

b 0.02 mol O_2 would react with $\frac{0.02}{5} = 0.004$ mol C_3H_8.

There is more than 0.004 mol C_3H_8, therefore C_3H_8 is in excess.

c 28 g of CO is $\frac{28}{28} = 1$ mol

1 mol CO would react with $\frac{1}{3} = 0.33$ mol Fe_2O_3.

There is more than 0.33 mol Fe_2O_3, therefore Fe_2O_3 is in excess.

d 16 g O_2 is $\frac{16}{32} = 0.5$ mol

16 g SO_2 is $\frac{16}{64} = 0.25$ mol

0.25 mol SO_2 would react with 0.125 mol O_2

There is more than 0.125 mol O_2, therefore O_2 is in excess.

20 ▶ a 1.0 g of $CaCO_3$ is $\frac{1.0}{100} = 0.010$ mol

0.010 mol $CaCO_3$ would react with $2 \times 0.010 =$ 0.020 mol HCl

There is less than 0.020 mol HCl, therefore there is not enough HCl to react with all the $CaCO_3$. Therefore $CaCO_3$ is in excess.

b To calculate the number of moles of CO_2 you must use the number of moles of HCl because not all the $CaCO_3$ reacted.

moles of HCl = 0.015 mol

moles of $CO_2 = 0.5 \times 0.015 = 0.0075$ mol

mass of $CO_2 = 0.0075 \times 44 = 0.33$ g

(If you got the answer 0.44 g you used the number of moles of $CaCO_3$. $CaCO_3$ was in excess; therefore not all of it will react.)

CHAPTER 6

1 ▶ a i An atom or group of atoms which carries an electrical charge.

ii Attractions between positively and negatively charged ions holding them together.

b Correct electronic structures for:

i Na 2,8,1 and Cl 2,8,7

ii Li 2,1 and O 2,6

iii Mg 2,8,2 and F 2,7.

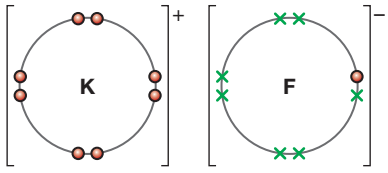
Diagrams (similar to those in the chapter) showing transfer of electrons, and the charges and electronic structures of the ions formed (or words to the same effect).

In (i), show 1 electron transferred from Na to Cl leaving Na^+ $[2,8]^+$ and Cl^- $[2,8,8]$

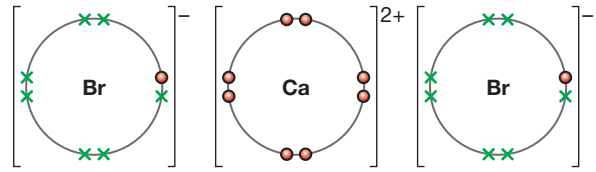
In (ii), show 2 lithium atoms each giving 1 electron to O leaving $2 \times Li^+$ $(2)^+$ and O^{2-} $[2,8]^{2-}$

In (iii), show 1 Mg giving an electron each to 2 fluorines leaving Mg^{2+} $[2,8]^{2+}$ and $2 \times F^-$ $[2,8]^-$

2 ▶ a



b



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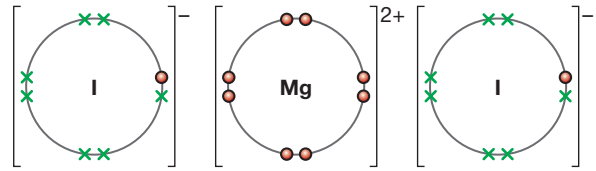


3 ▶

	a formula	b name
i magnesium	Mg^{2+}	
ii strontium	Sr^{2+}	
iii potassium	K^+	
iv oxygen	O^{2-}	oxide
v sulfur	S^{2-}	sulfide
vi caesium	Cs^+	
vii chlorine	Cl^-	chloride
viii iodine	I^-	iodide
ix aluminium	Al^{3+}	
x calcium	Ca^{2+}	
xi nitrogen	N^{3-}	nitride

4 ▶

PbO	NaBr
$MgSO_4$	$ZnCl_2$
K_2CO_3	$(NH_4)_2S$
$Ca(NO_3)_2$	$Fe(OH)_3$
$FeSO_4$	$CuCO_3$
$Al_2(SO_4)_3$	$Ca(OH)_2$
$CoCl_2$	CaO
$AgNO_3$	FeF_3
NH_4NO_3	RbI
Na_2SO_4	Cr_2O_3

5 ▶ a The electrostatic forces of attraction between oppositely charged ions are strong and require a lot of energy to break.

b The ions are held tightly in place in the giant lattice structure and are not free to move.

c The ions are free to move (it is important to use the word **ions** here; any mention of electrons will score 0 in an exam).

6 ▶ Potassium chloride will have a lower melting point than calcium oxide. The charges on the ions in KCl (K^+ and Cl^-) are lower than in CaO (Ca^{2+} and O^{2-}). There are weaker electrostatic forces of attraction between oppositely charged ions in KCl than in CaO; these forces require less energy to break than the forces in CaO.

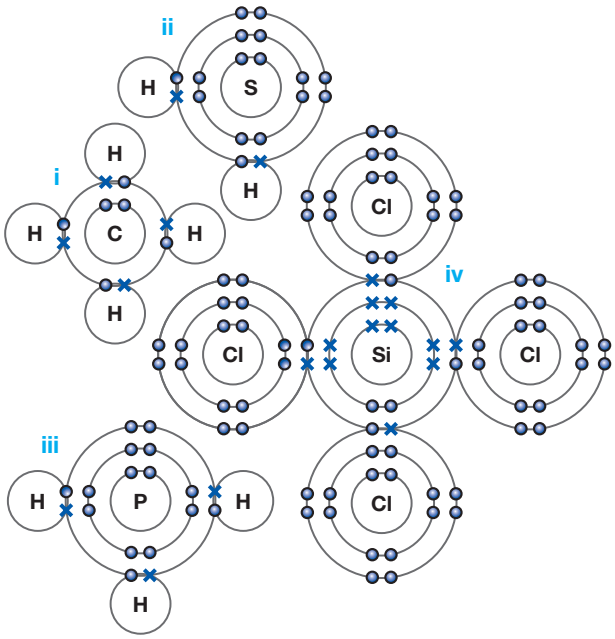
CHAPTER 7

1 ▶

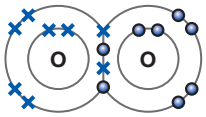
a	MgO	ionic
b	CH_3Br	covalent
c	H_2O_2	covalent
d	$FeCl_2$	ionic
e	NaF	ionic
f	HCN	covalent

2 ▶ a A pair of electrons that is shared between two atoms. The atoms are held together because the nucleus of each is attracted to the shared pair.

b (It doesn't matter whether students use dots or crosses or just different colours, or what positions (N, S, E, W) the hydrogens occupy in the H_2S or PH_3.)



c i



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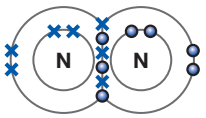
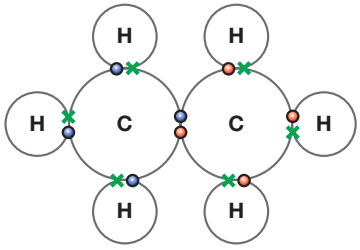
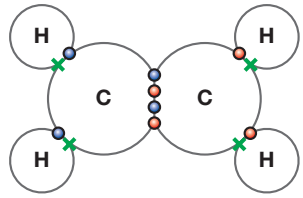


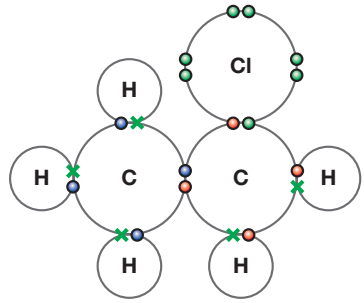
3 ▶ a



b



c



(It doesn't matter what variations of colours or dots and crosses are used. In the chloroethane case, the Cl could equally well have been drawn together with either of the other two hydrogen atoms on the right-hand carbon atom.)

4 ▶ Carbon dioxide has a simple molecular structure; diamond has a giant covalent structure. When carbon dioxide sublimes, only the weak intermolecular forces of attraction must be broken. When diamond sublimes, the strong covalent bonds must be broken. A lot more energy is required to break the strong covalent bonds in diamond than the weak intermolecular forces in carbon dioxide.

5 ▶ a Simple molecular because it is a liquid at room temperature. Only weak intermolecular forces of attraction must be broken to melt solid hexane. Compounds with giant structures have high melting points and boiling points and will be solids at room temperature.

b Pentane has a lower boiling point. The intermolecular forces of attraction are weaker in pentane because the relative formula mass is lower. Weaker intermolecular forces require less energy to break.

c It will not conduct electricity because there are no ions present and all the electrons are held tightly in atoms or covalent bonds.

6 ▶ a To break apart diamond, strong covalent bonds must be broken, which requires a large amount of energy. Much less energy is required to break the weak forces of attraction between the layers in graphite.

b C_{60} fullerene has a molecular structure but graphite has a giant structure. To melt C_{60} fullerene, only weak intermolecular forces must be broken, but to melt graphite strong covalent bonds must be broken. Much less energy is required to break the weak intermolecular forces in C_{60} fullerene than the strong covalent bonds in graphite.

c Each C atom in graphite forms only 3 bonds so there is one electron left over on each atom. These delocalised electrons are free to move throughout the layers.

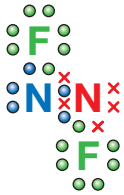
d All the outer shell electrons in diamond are held tightly in covalent bonds and unable to move around.

7 ▶ (Weakest intermolecular forces of attraction) hydrogen, phosphorus trifluoride, ammonia, ethanol, water, ethanamide (strongest intermolecular forces of attraction).

Higher intermolecular attractions produce higher boiling points – more energy has to be supplied to overcome stronger forces of attraction between molecules.

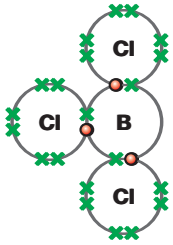
8 ▶ a Nitrogen usually forms 3 bonds because it has 5 electrons in its outer shell. Each N forms 1 bond to F, therefore there must be a double bond between the two N atoms. Formation of a double bond results in each N having 8 electrons in its outer shell.

b



(It doesn't matter what variations of colours or dots and crosses are used. The F atoms could also be drawn in different positions.)

9 ▶ a



b The B atom does not have 8 electrons in its outer shell.

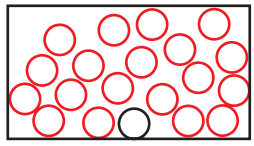
END OF UNIT 1 QUESTIONS

1 ▶ a –255 °C (1)

b

Particles randomly arranged (1) and mostly touching each other (1)

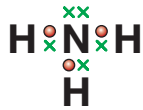
The diagram below would only score 1 mark – for the random arrangement



c number of protons: 1 (1)
number of neutrons: 2 (1)
number of electrons: 1 (1)

d i 2, 5 (1)

ii



three covalent bonds shown, each with a dot and a cross (1)

the remaining 2 electrons on N (1)

e NH_4SO_4 is incorrect (1) because the ammonium ion is NH_4^+ and the sulfate ion is SO_4^{2-}

f fractional distillation (1)

2 ▶ a atomic number (1); groups (1); electrons (1); outer shell (1)

b H (1) and Ar (1)

c i The second property is not a property of metals. Metal oxides are basic (1) and would react with acids rather than with alkalis such as sodium hydroxide. (1)

ii The grey circles represent silicon atoms. (1)
A silicon atom has 4 electrons in its outer shell and will form 4 covalent bonds. (1)
An oxygen atom has 6 electrons in its outer shell and will only form 2 covalent bonds. (1)
(Note: although some of the 'grey atoms' only appear to form 2 bonds this is because only part of the giant structure is shown. None of the 'red atoms' form 4 bonds.)

iii SiO_2 would be a solid at room temperature because it has a giant structure. (1)
A lot of energy is required to break all the strong covalent bonds. (1)

3 ▶ a idea of electron transfer (1)
electron transfer from Sr to Br (1)
the correct number of electrons transferred (1)

b high melting point (1)
strong electrostatic forces of attraction between oppositely-charged ions (1)
require a lot of energy to break (1)

c The relative atomic mass of an element is the weighted average mass of the isotopes of the element. (1)
It is measured on a scale on which a carbon-12 atom has a mass of exactly 12. (1)

d $\frac{50.69 \times 79 + 49.31 \times 81}{100}$ (1)
79.99 (1)

e $Sr(NO_3)_2$ (1)

4 ▶ a Diamond has a giant covalent structure (1), where all the atoms are held together by strong covalent bonds – a lot of energy is required to break these bonds. (1)

b i Graphite has the higher melting point. (1)
Graphite has a giant structure but C_{60} fullerene has a simple molecular structure. (1)
To melt graphite, all the strong covalent bonds between carbon atoms must be broken – this requires a lot of energy. (1)
To melt C_{60} fullerene, only the weak intermolecular forces of attraction must be broken – this requires less energy. (1)

ii Yes, because graphite has delocalised electrons. (1)
Delocalised electrons are free to move (throughout the structure). (1)

iii C_{60} fullerene has a molecular structure rather than a giant structure. (1)
Electrons cannot move between molecules. (1)

5 ▶ a

(1)

b K_2O (1)

c O=C=O (1)

6 ▶ **a** mass of lead = 24.16 – 17.95 = 6.21 g (1)

b mass of oxygen = 24.80 – 24.16 g = 0.64 g (1)

c

	Pb	O	
Combining masses	6.21 g	0.64 g	
No. of moles of atoms	$\frac{6.21}{207} = 0.03$	$\frac{0.64}{16} = 0.04$	(1)
Ratio of moles	3	4	(1)

Empirical formula: Pb_3O_4 (1)

7 ▶ **a** number of moles of copper = $\frac{2.00}{63.5} = 0.0315$ mol (1)

From the chemical equation, the same number of moles of copper(II) nitrate will be produced.

number of moles of $Cu(NO_3)_2$ is 0.0315 mol (1)

M_r of $Cu(NO_3)_2 = 63.5 + 2 \times (14 + 3 \times 16) = 187.5$

mass of $Cu(NO_3)_2 = 187.5 \times 0.0315 = 5.91$ g (1)

b The student would use crystallisation. (1)

Heat the solution in an evaporating basin to drive off some of the water until the solution becomes saturated. (1)

Allow to cool then filter off the crystals that form. (1)

c percentage yield = $\frac{\text{actual yield}}{\text{theoretical yield}} \times 100$

$= \frac{5.23}{7.61} \times 100$ (1)

$= 68.7\%$ (1)

UNIT 2 ANSWERS

CHAPTER 8

1 ▶ They have the same number of electrons in the outer shell (1 electron) and all react in the same way.

2 ▶ **a** A = lithium

b B = potassium; C = hydrogen; D = potassium hydroxide

c $2K(s) + 2H_2O(l) \rightarrow 2KOH(aq) + H_2(g)$

d The paper would turn blue / purple.

e Lots of heat is evolved. The melting point of potassium is low.

f E = sodium and F = sodium oxide

sodium + oxygen → sodium oxide

$4Na(s) + O_2(g) \rightarrow 2Na_2O(s)$

3 ▶ **a** False

b True

c True

d False: the formula of lithium chloride is LiCl

4 ▶ **a** More dense, as density increases down the group.

b 1

c Edexcelium hydroxide and hydrogen

d More reactive than francium, as reactivity increases down the group.

Reactivity increases as the size of the atom increases. An edexcelium atom is larger than a francium atom. The outer electron would be more easily lost from edexcelium – it is less strongly attracted by the nucleus.

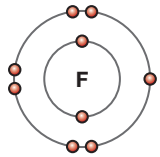
e $2Ed + 2H_2O \rightarrow 2EdOH + H_2$

f Alkaline, because OH^- ions are formed.

g Ed_2O

CHAPTER 9

1 ▶ **a**



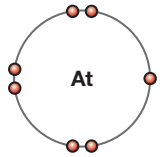
b A fluorine atom has 7 electrons in its outer shell – the group number indicates the number of outer shell electrons.

c

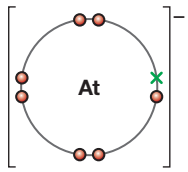
d There are weaker intermolecular forces of attraction between fluorine molecules than between chlorine molecules. Weaker forces require less energy to break. The intermolecular forces are weaker because fluorine has a lower relative molecular mass.

e No reaction because chlorine is less reactive than fluorine and therefore cannot displace it.

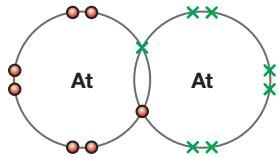
2 ▶ **a**



Astatine atom



Astatide ion



Astatine molecule

b Astatine would be a solid – melting point increases down the group and iodine is a solid.

c Reactivity decreases down the group so astatine would be less reactive than iodine.

Astatine is a larger atom than iodine and so has a lower attraction for electrons.

d pH 1–2

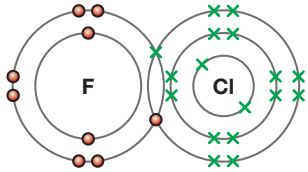
e Caesium astatide would be a colourless / white solid because it is an ionic compound. It would probably be soluble in water because many ionic compounds are soluble in water and most of the alkali metal halides are soluble in water (e.g. sodium chloride, potassium iodide etc.).

f $Cl_2(aq) + 2At^-(aq) \rightarrow At_2(s) + 2Cl^-(aq)$

The chlorine is reduced in this reaction because it gains electrons. The At^- is oxidised in the reaction because it loses electrons. Oxidation and reduction both occur, therefore it is a redox reaction.

3 ▶ a $Cl_2(g) + F_2(g) \rightarrow 2ClF(g)$

b



c $F_2 < ClF < Cl_2$

The boiling point increases as the relative molecular mass increases and the strength of the intermolecular forces increases.

d i ClF_3

ii $ClF_3(g) + 2H_2O(l) \rightarrow 3HF(aq) + HCl(aq) + O_2(g)$

CHAPTER 10

1 ▶ a 78.1 % **b** 21.0 % **c** 0.04 % **d** 0.9 %

2 ▶ a 95 – 80 = 15 cm^3 of oxygen

$\frac{15}{95} \times 100 = 15.8\%$

b The answer is less than expected. The apparatus was not left for long enough; there was not enough time for all the oxygen in the air to react. The experiment could be improved by leaving the apparatus set up for longer.

3 ▶ a The student should follow a procedure such as:

- Weigh a boiling tube.
- Pour 1 g of the metal carbonate into the boiling tube and weigh the boiling tube again.
- Connect a delivery tube to the boiling tube. Connect the other end of the delivery tube to a gas syringe or put in to a measuring cylinder filled with water.
- Heat the boiling tube.
- Allow the apparatus to cool.
- Record the volume of gas collected.
- Re-weigh the boiling tube and contents.

b Carbon dioxide

c $PbCO_3(s) \rightarrow PbO(s) + CO_2(g)$

d Thermal decomposition

e Sodium carbonate is more thermally stable than the other carbonates; it does not decompose when heated.

f The M_r of $PbCO_3$ is 267, whereas the M_r of $CuCO_3$ is 123.5.

1 g of $CuCO_3$ is more moles than 1 g of $PbCO_3$ – more than twice as many moles.

When more moles of solid are heated, more moles of gas will be produced, so a greater volume of gas will be produced.

g The mass goes down because CO_2 is given off. In the first experiment the mass goes down by 0.16 g, which must be the mass of 89 cm^3 of gas.

From the first experiment:

1 cm^3 of gas has a mass of $\frac{0.16}{89} = 0.00180$ g

100 cm^3 has a mass of $100 \times 0.00180 = 0.180$ g

h The student did not heat the carbonate for long enough so not all the carbonate decomposed.

Some of the gas escaped / leaked from the apparatus.

4 ▶ Carbon dioxide is one of the gases responsible for the greenhouse effect. These gases absorb IR (infrared) radiation that has been emitted from the Earth's surface. They then re-radiate it in all directions, warming the atmosphere. Heating of the atmosphere could lead to climate change.

CHAPTER 11

1 ▶ a sodium, aluminum, iron, copper

b i magnesium oxide, copper

ii $Mg(s) + CuO(s) \rightarrow MgO(s) + Cu(s)$ *(Include state symbols in all equations for preference.)*

iii Copper(II) oxide (CuO) has been reduced to copper (Cu) because it has lost oxygen – reduction is the loss of oxygen.

iv Copper(II) oxide (CuO) is the oxidising agent because it oxidises the magnesium (gives oxygen to it) and is, in the process, reduced.

c i Zinc is higher in the reactivity series because it takes the oxygen from the cobalt(II) oxide.

ii A reducing agent is a substance which reduces something else. Zinc removes oxygen from the cobalt(II) oxide. Removal of oxygen is reduction.

iii Zinc because it gains oxygen – oxidation is gain of oxygen.

d aluminium, manganese, chromium (Statement 1: Al is above Cr. Statement 2: Mn is below Al. Statement 3: Mn is above Cr. Putting this together gives the final list.)

2 ▶ a oxidised; gain of oxygen

b reduced; loss of oxygen

c oxidised; loss of electrons

d reduced; gain of electrons

3 ▶ Magnesium is above lead because it removes the oxygen from the lead(II) oxide.

4 ▶ a Either: grey iron filings become coated with brown solid. Or: solution fades from blue to colourless (very pale green).

b Iron (Fe) has been oxidised (to Fe^{2+}) because it has lost electrons – oxidation is loss of electrons.

c $Fe(s) + CuSO_4(aq) \rightarrow FeSO_4(aq) + Cu(s)$

5 ▶ a nickel, copper, silver

b i Either: colour of solution changes from blue to green. Or: nickel becomes coated with brown solid.

ii $Ni(s) + CuSO_4(aq) \rightarrow NiSO_4(aq) + Cu(s)$

iii $Ni(s) + Cu^{2+}(aq) \rightarrow Ni^{2+}(aq) + Cu(s)$

Nickel has been oxidised by loss of electrons.

6 ▶ a X is between iron and hydrogen in the reactivity series. It displaces hydrogen from dilute hydrochloric acid, and copper from copper(II) sulfate, so it must be above hydrogen and copper. It won't displace iron from iron(II) sulfate, so it must be below iron.

b i yes: X nitrate and silver

ii no reaction

iii no reaction (at least, not in the short term)

iv yes: X chloride and copper

v yes: X sulfate and hydrogen

7 ▶ a hydrogen

b aluminium chloride

c $2Al(s) + 6HCl(aq) \rightarrow 2AlCl_3(aq) + 3H_2(g)$

d Aluminium is covered by a very thin, but very strong, layer of aluminium oxide which prevents the acid getting at the aluminium underneath. On heating, the acid reacts with the oxide and removes it. The aluminium then shows its true reactivity, and produces a vigorous reaction.

8 ▶ Drop a very small piece into cold water. If it reacts, judge its reactivity relative to K, Na, Ca or Mg.

If it doesn't react, add a small piece to dilute hydrochloric acid and warm if necessary. Rapid reaction in the cold acid would place it as 'similar to magnesium'. A few bubbles of hydrogen in the cold acid, and more on heating would place it as 'similar to iron or zinc'.

If there is no reaction, then it is 'below hydrogen'.

9 ▶ a The iron / steel must be exposed to oxygen (air) and water.

b Painting prevents oxygen and water from coming into contact with the iron / steel.

c It is iron / steel coated with zinc.

d It will take much longer for the car to rust. Zinc is more reactive than iron and so corrodes in preference to the iron. The zinc prevents the iron rusting even if the coating is scratched. In the past, if the paint was scratched, the steel underneath would rust. This does not happen if the car is made of galvanised steel, so the life of the car is extended.

10 ▶ a

	Pearsonium chloride solution	Mollium chloride solution	Rosium chloride solution	Amelium chloride solution
pearsonium	✗	✗	✗	✗
mollium	✓	✗	✓	✓
rosium	✓	✗	✗	✗
amelium	✓	✗	✓	✗

b mollium > amelium > rosium > pearsonium

c mollium + pearsonium chloride → mollium chloride + pearsonium

CHAPTER 12

1 ▶

	methyl orange	phenolphthalein	litmus
a	yellow	pink	blue
b	red	colourless	red

2 ▶

solution	pH	strongly acidic	weakly acidic	neutral	weakly alkaline	strongly alkaline
potassium iodide	**7**			✓		
propanoic acid	**4.2**		✓			
sodium carbonate	**9.5**				✓	
potassium hydroxide	**13**					✓
iron(III) chloride	**2.4**	✓				
nitric acid	**1.3**	✓				

3 ▶ a $Na_2O + 2HNO_3 \rightarrow 2NaNO_3 + H_2O$

b $2KOH + H_2SO_4 \rightarrow K_2SO_4 + 2H_2O$

4 ▶ Neutralisation – reaction a) involves an acid reacting with a base (sodium oxide) and reaction b) involves an acid reacting with an alkali (KOH).

CHAPTER 13

1 ▶ a copper(II) oxide, copper(II) hydroxide, copper(II) carbonate

b $CuO(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + H_2O(l)$
$Cu(OH)_2(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + 2H_2O(l)$
$CuCO_3(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + CO_2(g) + H_2O(l)$

2 ▶ a A = copper; B = copper(II) oxide; C = copper(II) sulfate; D = copper(II) carbonate; E = carbon dioxide; F = copper(II) nitrate

b i $CuO(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + H_2O(l)$

ii $CuCO_3(s) + 2HNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + CO_2(g) + H_2O(l)$

3 ▶ a i Description could include: silvery metal; colourless acid; slow bubbles of gas on warming; formation of green solution; possible disappearance of nickel if very small quantities were used.

Testing for gas: pops with lighted splint held to mouth of tube.

ii hydrogen

iii $Ni(s) + H_2SO_4(aq) \rightarrow NiSO_4(aq) + H_2(g)$

b i Description could include: green solid; colourless acid; bubbles of gas produced in the cold acid; formation of green solution; green powder disappears if excess acid is used.

Testing for gas: bubble through limewater to give a white precipitate (milky, cloudy).

ii $NiCO_3(s) + 2HCl(aq) \rightarrow NiCl_2(aq) + CO_2(g) + H_2O(l)$

4 ▶

soluble	insoluble
sodium chloride	lead(II) sulfate
zinc nitrate	calcium carbonate
iron(III) sulfate	lead(II) chloride
potassium sulfate	copper(II) carbonate
aluminium nitrate	silver chloride
ammonium chloride	barium sulfate
magnesium nitrate	calcium sulfate (almost insoluble)
sodium phosphate	nickel(II) carbonate
potassium dichromate(VI)	chromium(III) hydroxide

5 ▶ a Dilute sulfuric acid in a beaker / flask. Heat gently. Add copper(II) oxide a little at a time until no more reacts. Filter into an evaporating basin. Evaporate gently until a sample will crystallise on cooling. Leave to crystallise. Separate and dry crystals.

b i $CuO(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + H_2O(l)$

ii $CuSO_4(aq) + 5H_2O(l) \rightarrow CuSO_4.5H_2O(s)$

6 ▶

	acid	base
a	H_3O^+	CO_3^{2-}
b	H_2SO_4	MgO
c	HNO_3	NH_3
d	H_2SO_4	H_2O
e	HCl	NH_3
f	CH_3COOH	NH_3

CHAPTER 14

1 ▶ a chlorine **b** ammonia **c** carbon dioxide **d** hydrogen **e** oxygen

2 ▶ a Clean a nichrome or platinum wire by dipping it into concentrated hydrochloric acid and then holding it in a flame until no colour shows. Moisten the wire with concentrated hydrochloric acid, dip it into the solid, and then hold it in the flame. Lithium ions give a red flame colour.

b Warm the solid very gently with sodium hydroxide solution. Test any gases given off with a piece of damp red litmus paper. If it turns blue, ammonia is being given off from an ammonium compound.

c Make a solution in pure water. Add dilute hydrochloric acid + barium chloride solution. A white precipitate shows the presence of sulfate ions.

d Add dilute hydrochloric acid or dilute nitric acid. (Not sulfuric acid – this will form an insoluble layer of calcium sulfate around the calcium carbonate, stopping the reaction.) Look for a colourless odourless gas which turns limewater milky.

e Make a solution in pure water. Add dilute nitric acid + silver nitrate solution. A yellow precipitate shows the presence of iodide ions.

3 ▶ a A = iron(III) chloride; B = iron(III) hydroxide; C = silver chloride

b B: $Fe^{3+}(aq) + 3OH^-(aq) \rightarrow Fe(OH)_3(s)$
or: $FeCl_3(aq) + 3NaOH(aq) \rightarrow Fe(OH)_3(s) + 3NaCl(aq)$
C: $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$
or $3AgNO_3(aq) + FeCl_3(aq) \rightarrow 3AgCl(s) + Fe(NO_3)_3(aq)$

4 ▶ a D = iron(II) sulfate; E = iron(II) hydroxide; F = barium sulfate

b E: $Fe^{2+}(aq) + 2OH^-(aq) \rightarrow Fe(OH)_2(s)$
or: $FeSO_4(aq) + 2NaOH(aq) \rightarrow Fe(OH)_2(s) + Na_2SO_4(aq)$
F: $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$
or $BaCl_2(aq) + MgSO_4(aq) \rightarrow BaSO_4(s) + MgCl_2(aq)$

5 ▶ a G = potassium carbonate; H = potassium nitrate; I = carbon dioxide *(Note: G could also be potassium hydrogencarbonate, but, because hydrogencarbonates haven't been covered in the course, a student is unlikely to come up with it.)*

b $CO_3^{2-}(s) + 2H^+(aq) \rightarrow CO_2(g) + H_2O(l)$
or: $K_2CO_3(s) + 2HNO_3(aq) \rightarrow 2KNO_3(aq) + CO_2(g) + H_2O(l)$

6 ▶ a J = ammonium bromide; K = ammonia; L = silver bromide

b $Ag^+(aq) + Br^-(aq) \rightarrow AgBr(s)$

7 ▶ a Dissolve the mixture in the minimum possible amount of hot water and then allow it to cool again. The small amount of the more soluble potassium carbonate will stay in solution, but crystals of potassium nitrate will be formed on cooling. Filter these off, and wash them on the filter paper with a small amount of very cold water. Allow them to dry.

b Take a sample and add any named dilute acid. If the crystals are free of potassium carbonate, there won't be any fizzing.

8 ▶ a Add a few drops of the liquid to some anhydrous copper(II) sulfate. If the colour changes from white to blue then water is present.

b Measure the boiling point of the liquid. If the liquid boils at 100 °C it is pure water. The freezing / melting point can also be measured – pure water freezes / melts at 0 °C.

c The test-tube becoming warm indicates that an exothermic reaction has occurred. An exothermic reaction with sodium hydroxide solution could mean that the colourless liquid is an acid – neutralisation reactions are exothermic. The fact that there is no other visible reaction indicates that there is no metal present that has an insoluble hydroxide.

The second test indicates that the solution does not contain carbonate ions – carbonate ions would produce fizzing with dilute hydrochloric acid.

The third test indicates that no sulfate ions are present – the solution cannot be sulfuric acid.

The last test indicates the presence of chloride ions. With the results of the other tests, this suggests that the solution is dilute hydrochloric acid.

The student could confirm this by adding an indicator, to see whether the liquid is acidic.

END OF UNIT 2 QUESTIONS

1 ▶ a They all have 1 electron in the outer shell. (1)

b Potassium oxide (1)

c The piece of lithium floats (1); hydrogen gas is formed (1); the final solution is alkaline (1)

d i It forms a 1+ ion in compounds (1); it reacts with water and air (1)

ii The density increases from lithium to sodium but decreases from sodium to potassium. (1)

The trend is not clear for the whole group. (1)

2 ▶ a Because there will be no reaction (1):

a halogen cannot react with its halide ion / chlorine cannot react with chloride ions / bromine cannot react with bromide ions / iodine cannot react with iodide ions (1).

b

	potassium chloride solution	**potassium bromide solution**	**potassium iodide solution**
chlorine solution		orange solution formed	brown solution formed
bromine solution	no reaction		brown solution formed
iodine solution	no reaction	no reaction	

(1 mark for each correct cell)

c chlorine + potassium bromide → potassium chloride + bromine (1)

d $Cl_2(aq) + 2Br^-(aq) \rightarrow 2Cl^-(aq) + Br_2(aq)$

$Cl^-(aq)$ (1)

$Br_2(aq)$ (1)

balancing (1)

e Chlorine gains electrons to form chloride ions. (1)

Bromide ions lose electrons to form bromine. (1)

Gain of electrons is reduction and loss of electrons is oxidation. (1)

f i 5 (1)

ii Test: damp litmus paper / universal indicator paper (1)

Positive result: the paper is bleached (goes white) (1)

iii Test: add dilute nitric acid (1) followed by silver nitrate solution (1)

Positive result: white precipitate (1)

3 ▶ a nitrogen (1)

b i The oxygen in the air is used up as it reacts with the iron. (1)

Water is pushed in by the atmosphere to take its place / the pressure in the measuring cylinder is reduced. (1)

ii All the oxygen has reacted and so there is nothing to react with the iron. (1)

iii Hydrated iron(III) oxide (1)

iv There is no oxygen present (1); oxygen is required for the splint to burn. (1)

v The total amount of oxygen present in the original sample of air is 94 – 75 = 19 cm^3 of oxygen. (1)

9 cm^3 of oxygen is used up after one day, therefore there is 19 – 9 = 10 cm^3 of oxygen still present after one day. (1)

This is in a total volume of 85 cm^3 (1) (reading on the measuring cylinder).

Percentage oxygen = $\frac{10}{85} \times 100 = 11.8\%$ (1)

vi These will produce hydrogen when they react with the water present. (1)

Hydrogen gas will take up space in the measuring cylinder, so the volume change will not show the volume of oxygen used up. (1)

vii Suggest one change that the student could make to the *apparatus* so he does not have to wait so long for the results. (1)

Use more iron filings / more finely-divided (higher surface area) iron filings / warm the apparatus. (1)

c i blue (1)

ii $S + O_2 \rightarrow SO_2$ (1)

iii The litmus solution will be red. (1)

Non-metal oxides are acidic and dissolve in water (if soluble, like SO_2) to form acidic solutions. (1)

d i $4Na + O_2 \rightarrow 2Na_2O$

all formulae (1)

balancing (1)

ii hydroxide ion (1)

4 ▶ a Put dilute sulfuric acid into a beaker and heat it on a tripod and gauze using a Bunsen burner. (1)

Add excess copper(II) oxide. (1)

Filter off the excess copper(II) oxide. (1)

b Test: add hydrochloric acid followed by barium chloride solution (1)

Positive result: white precipitate (1)

c copper(II) hydroxide (1)

d i Any two from:

Concentration of copper(II) sulfate (1)

Volume of copper(II) sulfate solution (1)

How finely divided the metal is (1) *(if the metal is very finely divided it will react more quickly and the heat will be given out more quickly, so there is less chance for heat to be lost to the surroundings. This will give a more accurate value for the temperature change)*

ii Zinc > nickel > silver (1)

iii The temperature rise would be zero. (1)

Copper will not react with copper(II) sulfate / copper ions. (1)

iv The mass of 1 mole of zinc (65 g) is very similar to the mass of 1 mole of nickel (59 g). (1)

Because the student used the same mass of each metal, the number of moles of nickel and zinc is very similar. (1)

Because silver does not react it does not matter how much the student uses. (1)

v Nickel is oxidised. (1)

Ni loses electrons to form Ni^{2+} and oxidation is loss of electrons. (1)

e Heat the solution to drive off the water and form (small) crystals of hydrated copper(II) sulfate. (1)

Keep heating the solid. (1)

f i Dip a piece of (nichrome) wire into concentrated hydrochloric acid and then into the solid. (1)

Hold the wire in the blue / roaring / non-luminous flame of a Bunsen burner. (1)

ii blue-green (1)

5 ▶ a

Dot and cross in the covalent bond (1)

All other electrons (1)

b A proton / hydrogen ion / H^+ is transferred from the HCl to the water. (1)

HCl is an acid because it donates a proton / hydrogen ion / H^+. (1)

H_2O is a base because it accepts a proton / hydrogen ion / H^+. (1)

c i A white precipitate would form. (1)

ii Hydrochloric acid contains chloride ions (1) so it will always give a positive test for chloride ions. (1)

d $CuCO_3(s) + 2HCl(aq) \rightarrow CuCl_2(aq) + H_2O(l) + CO_2(g)$

reactants (1)

products (1)

balancing (1)

6 ▶ a iron(II) (1) chloride (1)

b B = iron(II) hydroxide (1) $Fe(OH)_2$ (1)

c D = iron(III) hydroxide (1) $Fe(OH)_3$ (1)

d redox (1)

The iron(II) is oxidised to iron(III). (1)

UNIT 3 ANSWERS

CHAPTER 15

1 ▶ A reaction in which heat energy is given out to the surroundings.

Correctly balanced equations for any two exothermic reactions e.g. any combustion reactions (metals, hydrogen, hydrocarbons, etc. in oxygen), neutralisation reactions involving metal soxides or hydroxides and acids, magnesium and acids. For example, $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$ or $NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$

2 ▶ A reaction in which heat energy is absorbed from the surroundings.

3 ▶ a exothermic **b** exothermic **c** endothermic
d exothermic **e** endothermic **f** exothermic

4 ▶ The cans have two chambers. The outer chamber contains the beverage or food to be heated. The inner chamber contains calcium oxide and water. The calcium oxide and water are kept separate by a seal. Pushing a button on the bottom of the can breaks the seal and allows the calcium oxide and water to come into contact. The following exothermic reaction takes place:

$CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(s)$

5 ▶ a Her first two results weren't reliable. There was too much difference between them.

b Any two from: wear a lab coat; avoid touching the hot copper can; tie long hair back.

c Heat energy change = $Q = mc\Delta T$

Mass of water being heated = m = 100 g

c is the specific heat capacity of the water

c = 4.18 J/g/°C

Temperature change of water = ΔT = 55.0 – 19.0 = 36.0 °C

Heat evolved = $Q = mc\Delta T$ = 100 × 4.18 × 36.0 J = 15 048 J = 15.0 kJ to 3 significant figures

d Mass of hexane burnt = 35.62 – 35.23 g = 0.39 g

Heat evolved per gram = $\frac{15.048}{0.39}$ = 38.6 kJ/g to 3 significant figures

The combustion reaction is exothermic, therefore heat energy released per gram = –38.6 kJ/g

e Number of moles of hexane, C_6H_{14}, burnt =

$$n = \frac{\text{mass } (m)}{\text{relative molecular mass } (M_r)} = \frac{0.39}{86} = 0.00453 \text{ mol}$$

The molar enthalpy change of combustion of hexane (ΔH)

$$= \frac{\text{heat energy change } (Q)}{\text{number of moles of ethanol burned } (n)}$$

$$= \frac{15.048}{0.00453} = 3320 \text{ kJ/mol to 3 significant figures}$$

The combustion reaction is exothermic, therefore ΔH = –3320 kJ/mol

f Any two from: misreading one of the weighings of the spirit burner so that it looked as if less hexane had been burnt than was really the case; misreading the thermometer to give a final temperature higher than it should have been; adding less than 100 cm^3 of water to the flask, so that the temperature went up more than it should because the heat was going into a smaller volume of water.

g Any two from: heat loss to the surroundings; heat is lost to warm up the copper calorimeter or the thermometer; incomplete combustion of the fuel.

6 ▶ a Heat energy change = $Q = mc\Delta T$

Mass of solution being heated = m = 50 g (the mass of the lithium chloride is relatively small and it is ignored in the calculation)

c is the specific heat capacity of the diluted solution of lithium chloride, which we assume to be the same as the heat capacity of water: c = 4.18 J/g/°C

Temperature change of water = ΔT = 33.5 – 17.0 = 16.5 °C

Heat evolved = $Q = mc\Delta T = 50 \times 4.18 \times 16.5\,J = 3448.5\,J = 3.45\,kJ$ to 3 significant figures

b Number of moles of lithium chloride dissolved = $n = \frac{\text{mass } (m)}{\text{relative formula mass } (M_r)} = \frac{5.15}{42.5} = 0.121$ mol

c The enthalpy change of solution

$$\Delta H = \frac{\text{heat energy change } (Q)}{\text{number of moles of lithium chloride dissolved } (n)}$$

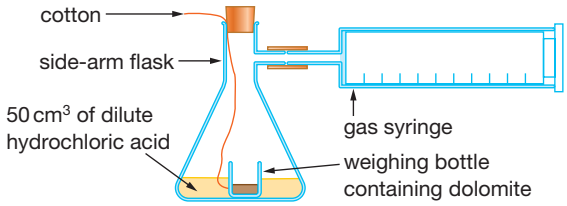
$$= \frac{3.45}{0.121} = 28.5\,kJ/mol \text{ to 3 significant figures}$$

The dissolving of lithium chloride is exothermic, so $\Delta H = -28.5\,kJ/mol$

d Any two from: heat loss to the surroundings; heat is lost to warm up the solution container or the thermometer; incomplete transfer of the salt from the weighing boat into the water; some salt does not dissolve completely in water.

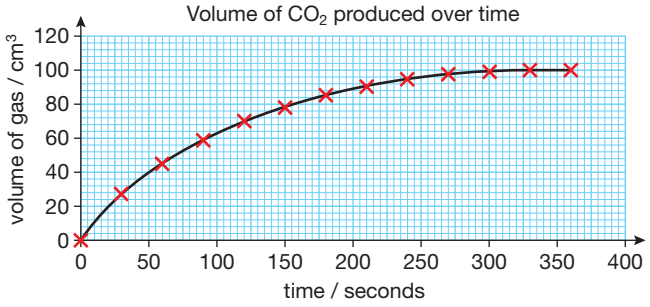
CHAPTER 16

1 ▶ a



Collection of gas over water into an inverted measuring cylinder is an acceptable alternative. Pieces of dolomite in a weighing bottle are put into the conical flask before the reaction starts. This is to make sure that the reaction can be started without losing any carbon dioxide.

b Graph should be completely smooth with the axes properly labelled.



c At the very beginning of the reaction. The reaction can only happen when acid particles collide with the solid dolomite. Numbers of acid particles per unit volume are greatest at the beginning of the reaction before any are used up. Therefore the greatest number of collisions per second and the fastest reaction are at the beginning.

d 70 seconds (read this off the graph; allow some tolerance depending on the size of graph paper available)

e Volume produced within the first 80 seconds = 55 cm

(The average rate = $\frac{55}{80} = 0.688\,cm^3/s$ to 3 significant figures)

f i There would be a lower initial rate; same volume of gas.

ii There would be a lower initial rate; half the volume of gas (50 cm^3).

iii The initial rate would be the same; half the volume of gas (50 cm^3). (The initial rate depends on the original concentration of the acid, which is the same.)

iv The initial rate would be faster; same volume of gas.

2 ▶ a The time taken for the reaction will increase. A reaction happens when acid particles collide with the magnesium. If the concentration of acid is reduced, there will be fewer acid particles per unit volume. This means there will be fewer collisions per second, and therefore a slower reaction.

b The time taken for the reaction will decrease. The acid particles will be moving faster, so they will collide with the magnesium more often. The reaction only happens if the energy of the collision equals or exceeds the activation energy. At higher temperatures more acid particles will have energy greater than or equal to the activation energy, so a greater proportion of the collisions will be successful.

c Answers could include: Acid will be used up quickly immediately around the magnesium – stirring brings fresh acid into contact with it; bubbles of hydrogen form around the magnesium, preventing acid from reaching it – stirring helps to dislodge the bubbles; bubbles of hydrogen lift the magnesium to the surface (sometimes above the surface) of the acid, lowering contact between acid and magnesium – stirring helps to prevent this.

3 ▶ a Reactions only happen if collisions have energies equalling or exceeding activation energy. Catalysts provide an alternative route for the reaction with a lower activation energy. More particles now have energy greater than or equal to the activation energy, so there will be more successful collisions per unit time.

b To find out whether it speeds the reaction up: Place equal volumes of the same hydrogen peroxide solution in two test-tubes side-by-side. Add some iron(III) oxide to one test-tube and see if bubbles are produced more quickly in that tube.

To show that it is unchanged: Use a known mass of iron(III) oxide. When the reaction stops, filter the mixture through previously weighed filter paper, allow to dry, and re-weigh. Show that the mass of iron(III) oxide is unchanged. (If the mass has changed, and you haven't lost any during the separation process, the iron(III) oxide must have reacted in some way.)

4 ▶ a The reversible symbol '⇌' shows that the reaction can go both ways. The reactants can react to form the products and the products can react to form the reactants.

b White solid decomposes to form colourless gases.

END OF UNIT 3 QUESTIONS

1 ▶ a i 19.3 (1), 16.6 (1), 2.7 (1)

ii A (1)

b i $Q = mc\Delta T = 100.0 \times 4.2 \times (23.2 - 15.9) = 3.066\,\text{kJ}$

calculation of temperature change (1)

using the correct mass (100 g, award mark if 105 g is used) (1)

correct answer for Q (1)

ii $n = \frac{\text{mass of calcium chloride}}{M_r} = \frac{5}{(40 + 35.5 * 2)}$

$= \frac{5}{111} = 0.0450\,\text{mol}$ to 3 significant figures

calculation of M_r (1)

correct answer to 2–4 significant figures (1)

iii $\Delta H = \frac{3.066}{0.0450} = 68.1\,\text{kJ/mol}$ to 3 significant figures

The molar enthalpy change is –68.1 kJ/mol as the dissolving is exothermic.

dividing Q by n (1)

correct answer (must have a negative sign) (1)

c Heat loss to the surrounding air through beaker (1)

Some magnesium chloride is left on the weighing boat / did not dissolve in water completely (1)

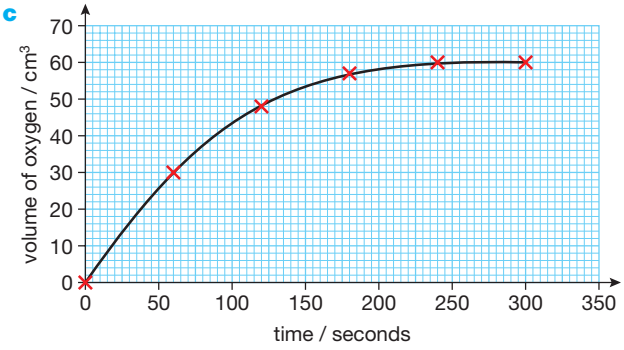
2 ▶ a $2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$

correct formulae of reactants and products (1)

correct balancing (1)

b To prevent the loss of oxygen at the beginning of the reaction (1)

c



correct labelling of axes with units (1)

correct points plotted (2)

a smooth curve of best fit, going through all of the points (1)

d i 125 seconds

ii $43\,\text{cm}^3$

iii $\frac{53}{150} = 0.353\,\text{cm}^3/\text{sec}$

correct numerical answer (1)

correct unit (1)

e The reaction has stopped (1) because all the hydrogen peroxide has been used up (1).

f i B (1)

ii Weigh a sample of manganese(IV) oxide and add to hydrogen peroxide (1). Oxygen is produced at a faster rate with manganese(IV) oxide than without (1). Filter the reaction mixture and dry the solid (1). Re-weigh the solid and the mass should be the same as before if it acts as a catalyst (1).

g Shallower curve than the original (1) but the end volume remains the same (1)

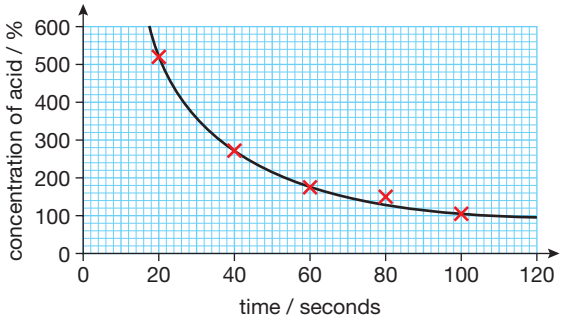
h Shallower curve than the original (1) and only $30\,\text{cm}^3$ (half the volume) of gas is produced (1)

3 ▶ a The mass (1) and the surface area / size (1)

b To let the gas escape but keep the liquid inside the conical flask (1)

c i B

ii



correct labelling of axes with units (1)

correct points plotted (2)

a smooth curve of best fit, going through all but one point (1)

iii 150 seconds

iv C

d i The mass of CO_2 given off is directly (1) proportional (1) to the concentration of the acid.

ii Increasing the concentration of the acid increases the rate of reaction. (1) This is because there are more acid particles within a fixed volume (1) so the frequency of successful collisions between the acid and the marble chips increases (1).

4 ▶ a i The gas particles have more kinetic energy (1) so more particles have energy greater than or equal to the activation energy (1). There are more successful collisions per unit time (1).

ii The rate will increase (1) as gas particles are closer together so there are more frequent collisions (or more successful collisions per unit time) (1).

iii Reactions happen on the surface of the catalyst (1) and gauzes have greater surface area (1).

b The catalyst increases the rate of the reaction without itself being used up (1). It saves money which would be spent on increasing temperature or pressure (1).

5 ▶ a reversible reaction (1), enthalpy change (1)

b The forward reaction is endothermic. (1)

c The reaction mixture becomes more brown in colour. (1)

UNIT 4 ANSWERS

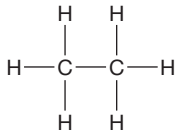
CHAPTER 17

1 ▶ a i methane

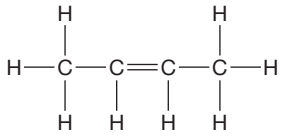
ii propane

iii hexane
iv propene
v ethene
vi but-1-ene

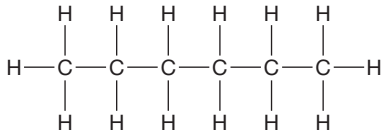
b i



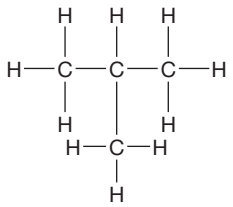
ii



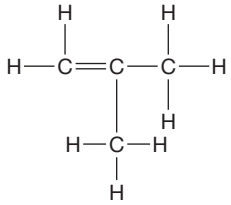
iii



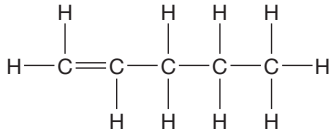
iv



v

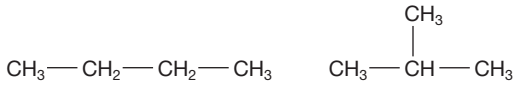


vi



2 ▶ a The existence of molecules with the same molecular formula but different structural formulae.

b

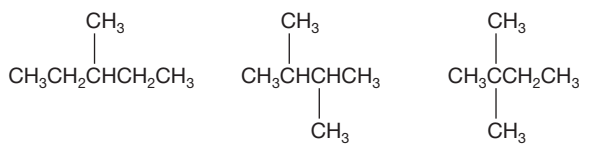


butane 2-methylpropane

(In these and subsequent formulae, if you aren't asked specifically for displayed formulae, these quicker forms are acceptable.)

c $CH_3CH_2CH_2CH_2CH_2CH_3$ $CH_3CHCH_2CH_2CH_3$ (CH_3 on the second C)

hexane 2-methylpentane

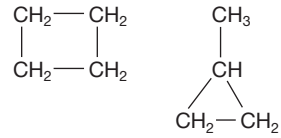


3-methylpentane 2,3-dimethylbutane 2,2-dimethylbutane

d $CH_3CH_2CH{=}CH_2$ $CH_3CH{=}CHCH_3$ $CH_3C(CH_3){=}CH_2$

but-1-ene but-2-ene (2-methylpropene)

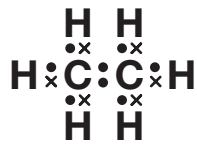
e



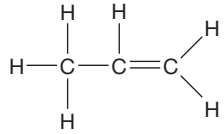
3 ▶ a addition
b combustion
c addition
d substitution
e substitution

4 ▶ a C: it contains an element other than carbon and hydrogen.

b



c



d C_nH_{2n+2}

e Same functional group / similar chemical properties; show a gradation in physical properties; each member differs from the next by a $–CH_2–$

f $C_5H_{12} + 8O_2 \rightarrow 5CO_2 + 6H_2O$

CHAPTER 18

1 ▶ a Carbon and hydrogen

b The crude oil (mixture of hydrocarbons) is heated until it boils. The vapour passes into a fractionating column. The temperature is higher at the bottom of the column than at the top. Different fractions condense and are drawn off at different heights in the column. The hydrocarbons with the highest boiling points (longer chains) condense towards the bottom of the column. The smaller hydrocarbon molecules travel further up the column until they condense and are drawn off.

c Gasoline – petrol for cars; diesel – fuel for lorries or buses

d Any two from: refinery gas, kerosene, fuel oil or bitumen

e The average size of the molecules in gasoline is smaller than in diesel. Diesel is darker in colour and more viscous than gasoline.

f Any between $n = 5 – 10$ for C_nH_{2n+2}

g i $2C_4H_{10} + 13O_2 \rightarrow 8CO_2 + 10H_2O$

ii Carbon monoxide is poisonous as it reduces the blood's ability to carry oxygen around the body.

2 ▶ a The sulfur (or sulfur compound) burns to make sulfur dioxide. The sulfur dioxide reacts with water and oxygen in the atmosphere to produce sulfuric acid that falls as acid rain.

b The spark in the engine causes nitrogen to react with oxygen to produce various oxides of nitrogen.

c Sulfur dioxide reacts with water and oxygen in the atmosphere to produce sulfuric acid. The sulfuric acid in acid rain can react with calcium carbonate and corrode the buildings.

3 ▶ a Crude oil produces too many larger hydrocarbons / not enough of the more useful smaller ones. Smaller alkanes can be used as fuel for cars. Cracking also produces alkenes that can be used to make polymers.

b Heat the vaporised fraction in the presence of a silicon dioxide or aluminium oxide catalyst at 600–700 °C.

c $C_{11}H_{24} \rightarrow 2C_2H_4 + C_7H_{16}$

d Any other valid cracking equation starting with $C_{11}H_{24}$. For example:

$C_{11}H_{24} \rightarrow C_2H_4 + C_9H_{20}$

or $C_{11}H_{24} \rightarrow C_2H_4 + C_3H_6 + C_6H_{14}$

or lots of other variants. In each case, at least one hydrocarbon should be an alkane (C_nH_{2n+2}), and at least one an alkene (C_nH_{2n}).

4 ▶ This is entirely open to your imagination and ability to think both logically and laterally. It is impossible to suggest 'right' answers.

CHAPTER 19

1 ▶ a Saturated hydrocarbons contain only C–C single bonds and have no double or triple bonds.

b i $C_{11}H_{24}$

ii Liquid

iii $C_{11}H_{24}(l) + 17O_2(g) \rightarrow 11CO_2(g) + 12H_2O(l)$

iv $2C_{11}H_{24} + 23O_2 \rightarrow 22CO + 24H_2O$

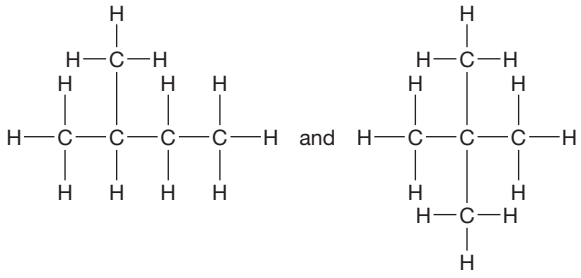
Carbon monoxide is poisonous, as it reduces the ability of the blood to carry oxygen around the body.

2 ▶ a C_5H_{12}

b C_4H_{10}

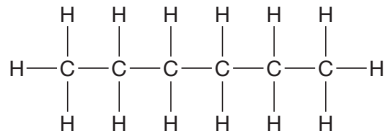
c C_6H_{14}

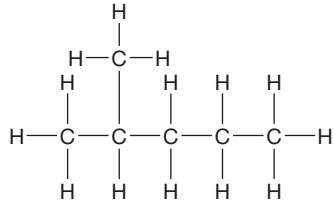
3 ▶ a

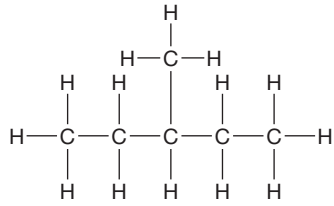


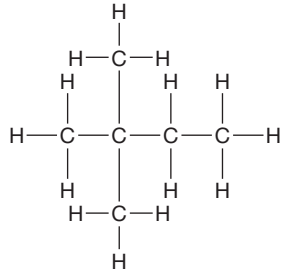
and

b Any 2 of the following:





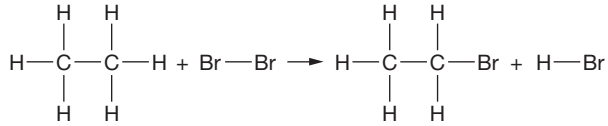




4 ▶ a UV light

b Substitution

c



(1-)bromoethane

5 ▶ a $C_4H_{10} + Cl_2 \rightarrow C_4H_9Cl + HCl$

b $CH_3CH_2CH_2CH_2Cl$ 1-chlorobutane $CH_3CH(Cl)CH_2CH_3$ 2-chlorobutane

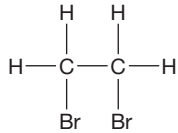
CHAPTER 20

1 ▶ a i Any two from: same general formula; same functional group or similar chemical properties; show a gradation in physical properties; each member differs from the next by a $–CH_2–$.

ii Unsaturated compounds contain one or more carbon–carbon double or triple bonds.

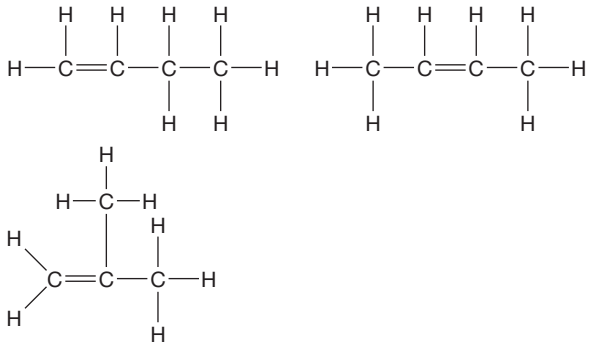
b i Starting: orange; Finishing: colourless

ii



1,2-dibromoethane

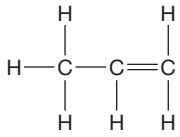
c



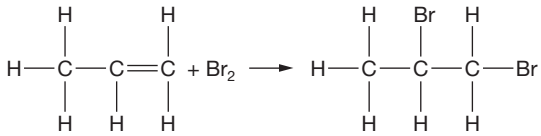
d

2 ▶ a a carbon–carbon double bond

b



c



d i $CH_3CH_3 + Br_2(g) \rightarrow CH_3CH_2Br + HBr(g)$

ii In this (substitution) reaction, one of the hydrogens has been replaced by a bromine during the reaction. In the previous (addition) reaction, nothing was lost when the two molecules combined together.

3 ▶ a 1,2-dichloropropane: $CH_2ClCHClCH_3$

b ethane: CH_3CH_3

4 ▶ a Cracking

Conditions: 1) The presence of a silicon dioxide (silica) or aluminium oxide (alumina) catalyst. 2) Heat the vaporised alkanes at high temperatures of 600–700 °C.

b Test: shake with bromine water

Result with propane: no colour change (solution remains orange)

Result with propene: solution changes colour from orange to colourless

5 ▶ a $CH_3CH_2CH_2CH_2OH$ (butan-1-ol) or $CH_3CH_2CH(OH)CH_3$ (butan-2-ol)

b $CH_3CH_2CH_2CH_2Cl$ (1-chlorobutane) or $CH_3CH_2CHClCH_3$ (2-chlorobutane)

c $CH_3CH_2CHBrCH_2Br$ (1,2-dibromobutane)

CHAPTER 21

1 ▶ a Unsaturated: containing one or more carbon–carbon double or triple bonds.

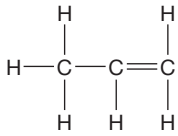
Hydrocarbon: compound containing carbon and hydrogen only

b $C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$

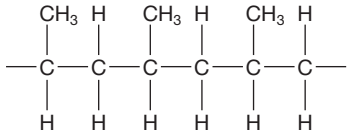
c Ethene can be used to make addition polymer polyethene, which is used for making plastic bags, milk bottles etc.

2 ▶ a Joining up lots of little molecules (monomers) to make one big molecule (a polymer).

b

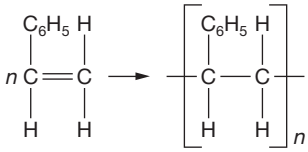


c The 'continuation' bonds at each end are an important part of this structure. Marks will be lost in an exam if they are omitted.

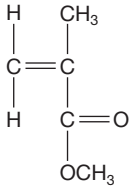


d Joining two or more molecules together without anything being lost in the process.

e



f Drawing the molecule to show its relationship with the structure of the polymer as drawn in the question:



g Either: buried in landfill sites because there is no emission of poisonous carbon monoxide or no carbon dioxide to contribute to global warming or no sulfur dioxide to contribute to acid rain. Or: incineration because no space is filled up in landfills or energy can be generated to provide heat for office buildings.

END OF UNIT 4 QUESTIONS

1 ▶ a D (1)

b Used as liquefied petroleum gas / domestic heating or cooking (1)

c Gasoline (1)

d Crude oil is separate into fractions by fractional distillation. (1)

It is heated until it boils and the vapour enters a fractionating column (1), which is cooler at the top and hotter at the bottom (1). The fractions with a lower boiling point condense nearer to the top of the column and can be tapped off / the fractions with a higher boiling point condense nearer to the bottom of the column and can be tapped off (1).

e As the number of carbon atoms increase, the boiling point of a hydrocarbon increases. (1)

This is because the intermolecular forces increase as the number of carbon atoms increases, so it takes more energy to break them during boiling. (1)

f $2C_{15}H_{32} + 31O_2 \rightarrow 30CO + 32H_2O$

correct formulae of products (1)

correct balancing of the equation (1)

g i 

ii B

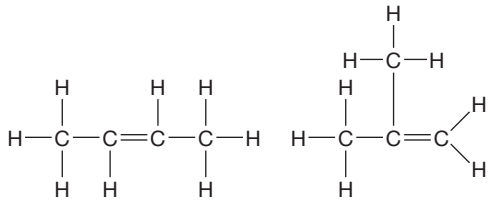
h i 600–700 °C (1); silica / alumina as a catalyst, accept 'aluminium oxide / silicon dioxide / aluminosilicate / zeolite or the correct formulae (1)

ii To make more of the smaller-chain fractions, for example, gasoline to use as petrol (1)

To produce more alkenes that can be used for making polymers (plastics) (1)

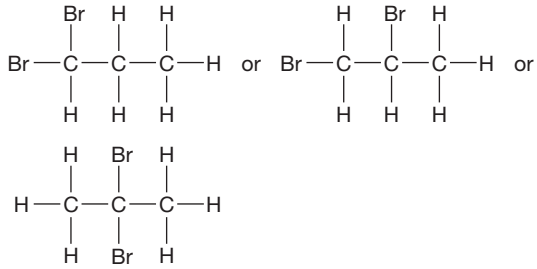
iii C_9H_{20} (1)

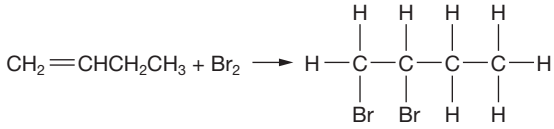
iv The compound contains one or more carbon–carbon double or triple bonds (1)

v 

2 ▶ a E contains an element that is not carbon or hydrogen. (1)

b i 1,3-dibromopropane (1 mark for dibromopropane)

ii 

c 

d i B and D

ii C_nH_{2n+2}

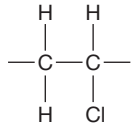
iii Any two from:

Same functional group / same or similar chemical properties (1)

Show a trend in physical properties (1)

Each member differs from the next by a $–CH_2–$ unit (1)

e i Poly(chloroethene) or polyvinylchloride (1)

ii 

iii Any two from:

They are inert. (1)

They are non-biodegradable. (1)

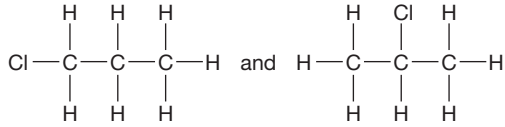
If they are burned, they release toxic gases including carbon monoxide or hydrogen chloride. (1)

iv No colour change / bromine water remains orange (1)

Polymer of compound A is saturated / contains no C=C bond (1)

f i UV light (1)

ii Substitution (1)

iii 

3 ▶ a

	C	H	O
Mass (in 100 g) / A_r	$\frac{55}{12}$	$\frac{9}{1}$	$\frac{36}{16}$
Number of moles / **Smallest number of moles**	$\frac{4.58}{2.25}$	$\frac{9}{2.25}$	$\frac{2.25}{2.25}$
Ratio	2	4	1

The empirical formula is C_2H_4O.

b $2 \times 12 + 4 \times 1 + 1 \times 16 = 44$

$\frac{88}{44} = 2$

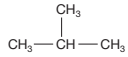
The molecular formula is $C_4H_8O_2$.

4 ▶ a Test: Add bromine water (1)

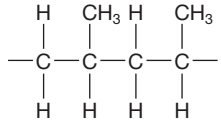
Result with compound 1: Solution changes colour from orange to colourless (1)

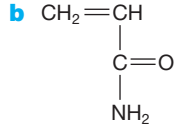
Result with compound 2: Solution stays orange (1)

b 1 mark for the correct structure; 1 mark for the continuation bonds



c Poly(but-2-ene) (1)

5 ▶ a 

b 

PHYSICS

UNIT 1 ANSWERS

CHAPTER 1

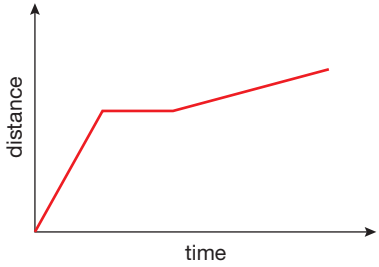
1 ▶ 8 m/s

2 ▶ **a** 10 500 m (10.5 km)
b 105 000 m (105 km)
c 630 000 m (630 km)

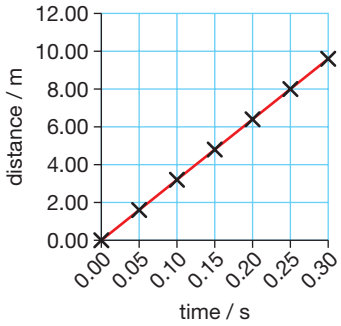
3 ▶ 4000 s

4 ▶ **a** D **b** C **c** A **d** B

5 ▶



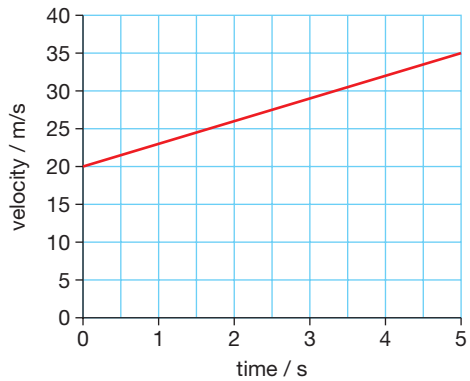
6 ▶



$$\text{gradient} = \frac{\text{distance}}{\text{time}}$$
$$= \frac{8\,\text{m}}{0.25\,\text{s}}$$
$$= 32\,\text{m/s}$$

7 ▶ **a** The car is moving at constant velocity (speed).
b Time interval between first and seventh drip is 15 s (6 × 2.5 s) so average speed is 135 m ÷ 15 s = 9 m/s.

8 ▶ **a**



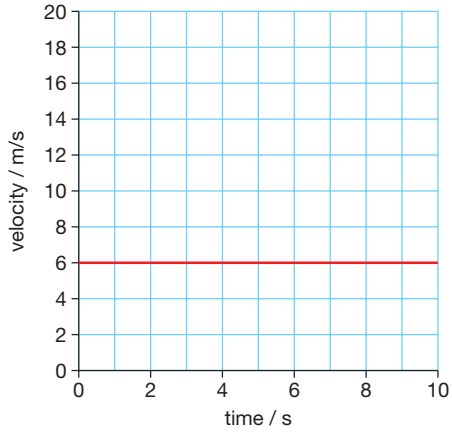
b Distance travelled is given by the area under the graph. (Divide area into a rectangle and a triangle.)
= (5 s × 20 m/s) + (0.5 × 5 s × 15 m/s) = 137.5 m

9 ▶ **a** Average speed is found by dividing the total distance a body has travelled by the time it has taken; the speed may vary from moment to moment during this time. The instantaneous speed is the speed at which the body is travelling at a moment in time.

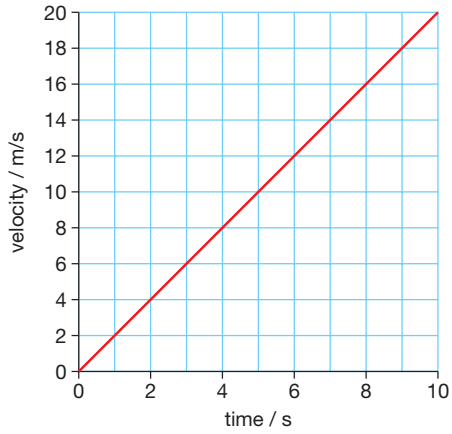
b Speed is a scalar quantity – it is distance travelled divided by time without regard to direction. Velocity is a vector quantity – it is speed in a specified direction.

10 ▶ 4 m/s²

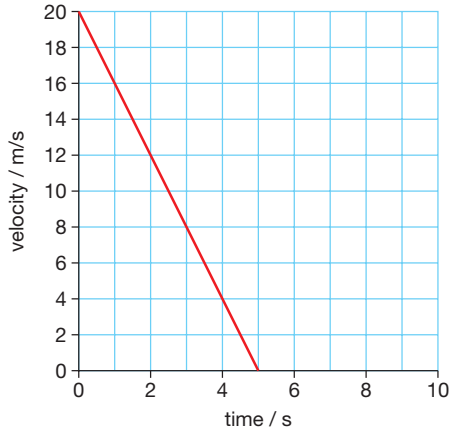
11 ▶ **a**



b



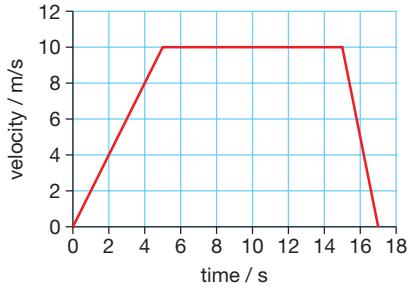
c



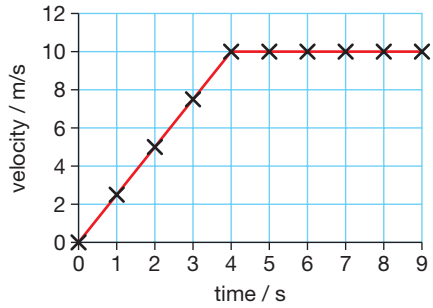
12 ▶ **a** 3 m/s **b** 15 m/s **c** 75 m/s

13 ▶ **a** B **b** A **c** D **d** C

14 ▶



15 ▶ a



b 2.5 m/s²

c i 20 m **ii** 50 m

d average speed = $\frac{\text{total distance travelled}}{\text{time taken}}$

$= \frac{70\,\text{m}}{9\,\text{s}}$

$= 7.78\,\text{m/s}$

16 ▶ The total distance travelled increases with the square of the time from the start, 0.5 m after 1 s, 2.0 m after 2 s, 4.5 m after 3 s, etc. Calculating the average velocity over each 1 s time interval (between the drips) and then plotting a graph of average velocity against time allows the acceleration to be calculated from the gradient of the graph. The acceleration is 1 m/s².

17 ▶ a v = final velocity; u = initial velocity; a = acceleration; s = displacement

b 32 m

CHAPTER 2

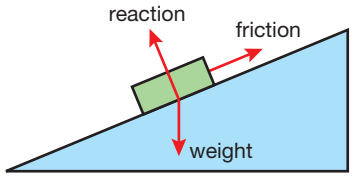
1 ▶ a gravity **b** friction

c normal reaction or contact force

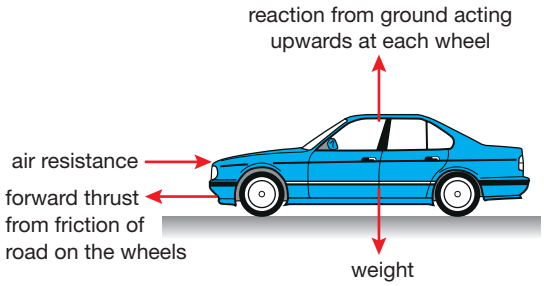
2 ▶ friction and air resistance (or viscous drag)

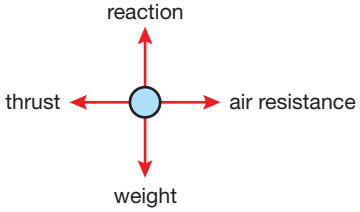
3 ▶ a 1200 N **b** 1250 N **c** 50 N **d** red

4 ▶



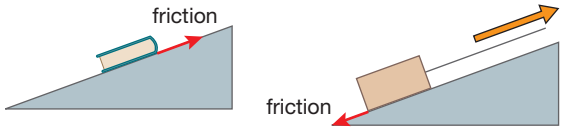
5 ▶



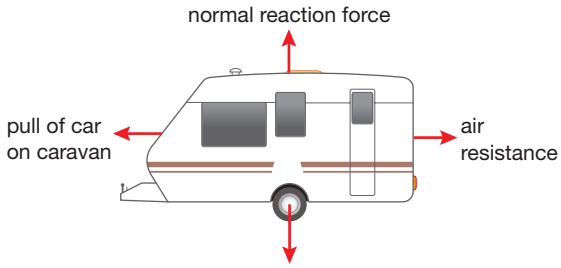


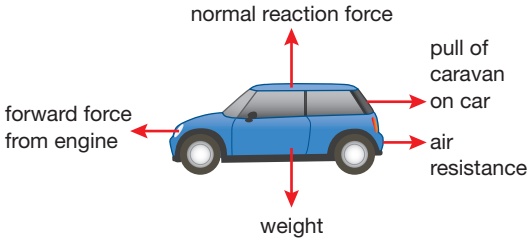
6 ▶ Any two sensible examples, for example: Without friction, objects would not be able to start moving from a stationary position, or stop moving when in motion. It would not be possible to build things because it would be difficult to pick up the building materials, and structures rely on friction to remain intact. Walking would be impossible without friction acting between your feet and the ground. Climbing a rope would be impossible without friction acting between your hands and the rope.

7 ▶



8 ▶

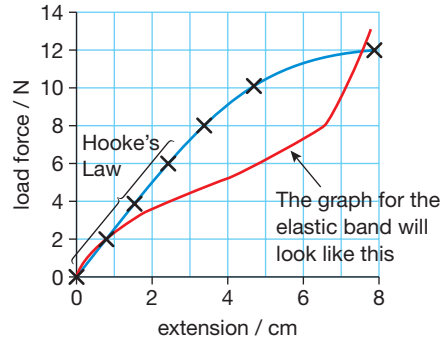




9 ▶ a

Load force on spring / newtons	Length of spring / cm	Extension of spring / cm
0	5.0	0.0
2	5.8	0.8
4	6.5	1.5
6	7.4	2.4
8	8.3	3.3
10	9.7	4.7
12	12.9	7.9

b c d



CHAPTER 3

1 ▶ A force that is not balanced by a force in the opposite direction. An accelerating car has an unbalanced force when the forwards force from the engine is bigger than the backwards force from air resistance.

2 ▶ From the equation *force* = *mass* × *acceleration* ($F = ma$) we can see that if F, the thrust force of the rocket engines, is constant and m, the mass of the rocket, decreases then the acceleration must increase.

3 ▶ a $F = ma$, where mass = 0.5 kg and acceleration = 4 m/s^2

So F = 0.5 kg × 4 m/s^2 = 2 N

b $m = \frac{F}{a}$, where force = 200 N and acceleration = 0.8 m/s^2

So $m = \frac{200\,\text{N}}{0.8\,\text{m/s}^2} = 250\,\text{kg}$

c Use $a = \frac{F}{m}$, where force = 250 N and mass = 25 kg

So $a = \frac{250\,\text{N}}{25\,\text{kg}} = 10\,\text{m/s}^2$

4 ▶ a Thinking distance is the distance a car travels after the driver has seen a hazard but *before* the driver applies the brakes; during this period the car is not decelerating.

b The braking distance is the distance travelled by the car *after* the driver has started braking and the car is decelerating to rest.

c The overall stopping distance is the sum of the thinking distance and the braking distance.

5 ▶ The braking distance of a car depends on the speed at which the car is travelling and the braking force that can be applied without the car skidding (as skidding means the car is out of control). The maximum braking force will be limited by factors that affect the friction between the car tyres and the road surface – for example, the condition of the tyres and the road surface. If the road surface is wet, icy or oily, friction will be reduced. The braking distance is greater if the speed of the car is higher or the maximum safe braking force is reduced.

6 ▶ a 0.75 s (the period during which the velocity of the car is constant at 24 m/s)

b 18 m (given by the area under the velocity–time graph during the first 0.75 s)

c 2.5 s (the period during which the velocity of the car is decreasing to zero)

d 48 m (the sum of the thinking distance and the braking distance – the total area under the graph)

7 ▶ a Use *weight* = *mass* × *gravity*

mass of apple in kg = 0.1 kg

strength of gravity on the Earth is approximately 10 N/kg

weight of apple on the Earth = 0.1 kg × 10 N/kg = 1 N

b Use *weight* = *mass* × *gravity*

mass of apple in kg = 0.1 kg

strength of gravity on the Moon is approximately 1.6 N/kg

weight of apple on the Moon = 0.1 kg × 1.6 N/kg = 0.16 N

8 ▶ The factors affecting the drag force on a high-speed train are:

- the speed of the train
- the shape of the train
- the direction of any wind that may be blowing
- (harder) the viscosity of the air that the train is travelling through; this will depend on temperature, humidity, etc.

9 ▶ See page 522 for a description of a suitable experiment.

10 ▶ At **A**: velocity is zero at start, so air resistance is zero and the unbalanced force is **downwards** (and is due to gravity or the weight of the parachutist).

At **B**: as the velocity of the parachutist increases, so does the size of the upward air resistance force – so the **unbalanced downwards force is smaller**.

At **C**: the velocity of the parachutist has increased to the point where the upward air resistance force is exactly the same as the downward force of gravity on the parachutist – the **unbalanced force is zero** and the parachutist has reached terminal velocity.

At **D**: the parachutist has opened her parachute. This greatly increases the upward air resistance force so the **unbalanced force** on the parachutist is now **upwards**. The parachutist's velocity decreases.

At **E**: as the parachutist slows down, the upward air resistance force due to the parachute decreases. This means that the **unbalanced upward force is smaller** (so the rate of deceleration of the parachutist decreases).

At **F**: the parachutist has slowed to a velocity at which the upward acting air resistance is once again equal to the downward acting force of gravity. The **unbalanced force is again zero.** (But note that the effect of opening the parachute is to make the new terminal velocity lower.)

END OF UNIT 1 QUESTIONS

1 ▶ a B (1) **b** D (1) **c** A (1) **d** C (1)

2 ▶ a B (1)

b i Displacement is distance travelled in a specified direction. Distance is how far you have travelled, not taking into account any changes in your direction of travel. (2)

ii 1 m vertically above the ground (1)

c i The ball falls with an acceleration downwards, a = 10 m/s^2 (1)

The downward displacement of the ball on reaching the ground, s = 3 m (1)

The ball had an initial velocity, u = 0 m/s (1)

So $v^2 = u^2 + 2as$ gives $v^2 = 0^2 + 2 \times 10\,\text{m/s}^2 \times 3\text{m}$ (1)

$v = \sqrt{60}\,\text{m}^2/\text{s}^2 = 7.75\,\text{m/s}$ (1)

You need to find the answer to **iii** first!

iii Time for the tennis ball to reach the ground, $t = \frac{v-u}{a}$ (1)

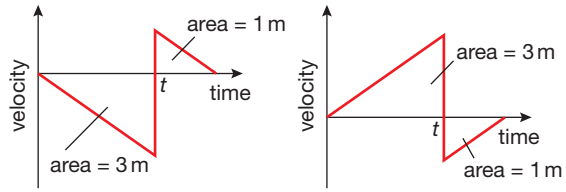
$t = \frac{7.75\,\text{m/s}}{10\,\text{m/s}^2} = 0.775\,\text{s}$ (1)

ii Average speed = $\frac{\text{distance travelled}}{\text{time taken}}$ (1)

Average speed = $\frac{3\text{ m}}{0.775\text{ s}}$ = 3.87 m/s (1)

d From the area beneath the graph line (1)

e



gradient of both line segments = 10 m/s^2

2 marks for shape showing acceleration and abrupt change in direction, 1 mark for value of *t* as calculated in **c iii**, 1 mark for labelling area of larger triangle 3 m, 1 mark for labelling area of smaller triangle 1 m, and 1 mark for stating that the gradient of both line segments is the acceleration due to gravity, taken as 10 m/s^2.

The left-hand sketch graph assumes that up is positive for velocity; the right-hand sketch graph assumes that down is positive for velocity. Either is correct.

3 ▶ a i The load force on the wire (from the number of weights) (1)

ii The extension of the wire (1)

iii Temperature / type of wire / diameter of wire / initial length of wire under test (1)

b Using $F = mg$ (1)

c *1 mark for each point in italics and 1 mark for any other from this list (max 5 marks):*

Note type of wire

Monitor temperature during experiment

Measure diameter of wire under test with micrometer

Measure the extension produced by a range of increasing load forces

Measure the extension produced by the same load forces as the wire is unloaded

Plot a graph of extension against load force

Draw the best fit line through the plotted points

If best fit line is a straight line through the origin of the axes then wire obeys Hooke's law

d Use a longer length of wire (1). (This will increase the extension produced by each load, improving the accuracy of the measurements.)

Add weights one by one and note the extension produced by each increase in load; then remove the weights one by one and note the extension at each value of load during unloading (1).

If the extension is elastic: the extension at each value of load should be the same during loading and unloading (1) / the wire should return to its original length when the load is reduced to the starting value (1).

UNIT 2 ANSWERS

CHAPTER 4

1 ▶ a 3 W **b** 50 V **c** 0.26 A

d 100 W × 18 000 s = 1 800 000 J (1800 kJ)

2 ▶ a The kettle is designed for a voltage of 230 V. At this voltage, 1.5 kJ of electrical energy is transferred into heat energy each second.

b $I = \frac{P}{V} = \frac{1500\text{ W}}{230\text{ V}}$ = 6.52 A. The fuse should be rated at around 7 A or above. The next common rating above this is 13 A, so a 13 A fuse is needed.

c Electrical energy is being transferred at a rate of 100 J/s in the 100 W bulb but only at 60 J/s in the 60 W bulb.

3 ▶ a It can be reset. It does not need to be replaced every time it breaks the circuit.

b So no electrical energy can enter the appliance. If the switch was in the neutral wire, electricity could enter the appliance and possibly cause a shock if the appliance was faulty.

c The outer casing is made from an insulator, e.g. plastic.

4 ▶ The power ratings of most appliances are shown on the appliance itself.

CHAPTER 5

1 ▶ a Electrons

b There are many free charge carriers (free electrons) in metals, but very few in a plastic.

c i 3 C **ii** 1800 C **iii** 10 800 C

2 ▶ a i Charge can travel all the way around a complete circuit. An incomplete circuit has gaps, so charge cannot travel all the way around it.

ii In a series circuit, there is only one path for the current to follow. In a parallel circuit, there is more than one path for the current to follow.

b S1 open: bulbs, A, B and C will go out.

S2 open: bulbs A, B and C will go out.

S3 open: bulbs D, E, F, G and H will go out.

S4 open: bulbs D and E will go out.

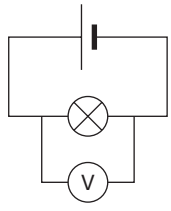
S5 open: bulbs F, G and H will go out.

S6 open: bulbs G and H will go out.

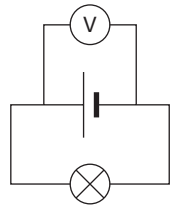
c All the bulbs will glow with equal brightness.

d It is a series circuit; therefore the current through all bulbs is the same.

3 ▶ a i



ii



b As each coulomb of charge passes through the 1.5 V cell, it receives 1.5 J of electrical energy.

4 ▶ a In the positions shown, the bulb will glow. If S1 is moved to B, the circuit is incomplete and the bulb will be turned off. If S2 is then moved to D, the circuit is again complete and the bulb will glow. If S2 is moved to D while S1 is still in position A, the circuit is incomplete and the bulb will be turned off.

b Turning lighting on and off from the top and bottom of a staircase.

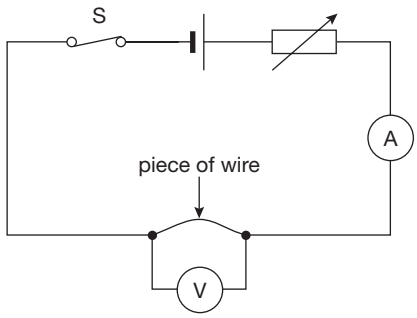
5 ▶ In parallel. If the lights are wired in series, the current through the string of lights will be too small to make them glow, and if the circuit is broken at any point (e.g. by a faulty bulb), all the bulbs will go off.

6 ▶ If all parts of the cooker are connected in series, turning one part on will turn on all the other parts as well.

CHAPTER 6

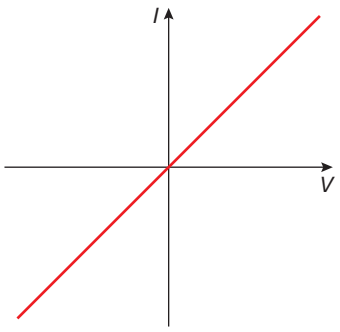
1 ▶ a The current that flows through a conductor is directly proportional to the potential difference (or voltage) across its ends, provided its temperature remains constant.

b

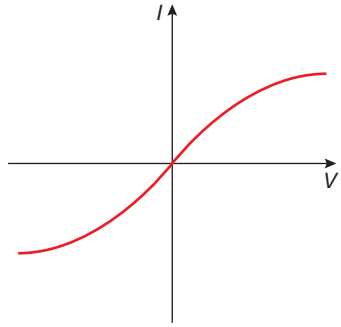


c Close the switch and record the readings on the ammeter and voltmeter. Use the variable resistor to change the resistance and take new readings. Repeat this at least six times. A graph of *I* against *V* should show a straight line passing through the origin, confirming Ohm's law.

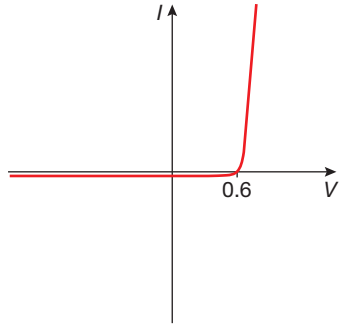
d i A straight line graph passing through the origin, indicating a constant resistance.



ii As the current increases, the filament gets hotter and its resistance increases.



iii The resistance in one direction is very high, i.e. the diode will not conduct. The resistance in the opposite direction is much smaller, i.e. the diode will conduct.

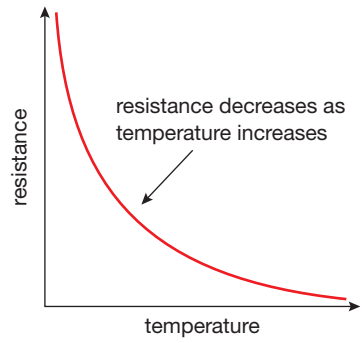


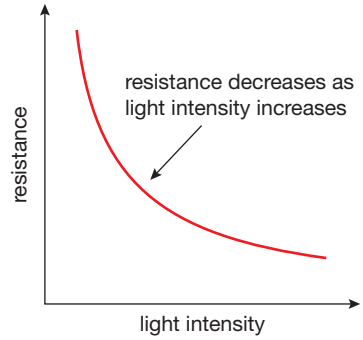
2 ▶ a 4 Ω **b** 0.24 A **c** 30 V

3 ▶ a i Resistance decreases as temperature increases / resistance increases as temperature decreases.

ii Resistance decreases as light intensity increases.

iii





b Thermistors can be used in temperature-sensitive circuits such as fire alarms and thermostats. LDRs can be used in light-sensitive circuits such as automatic lighting controls.

END OF UNIT 2 QUESTIONS

1 ▶ **a** B (1) **b** D (1) **c** A (1) **d** B (1)

2 ▶ electrons (1); coulomb (1); energy (1); resistance (1); lower (1)

3 ▶ **a** Y is an ammeter (1); Z is a voltmeter (1)

b variable resistor (1)

c It can be used to change the current. (1)

d 2.5 A (1)

e 4.0 V (1)

f $R = \frac{4.0\,\text{V}}{2.0\,\text{A}}$ (1)

$= 2.0\,\Omega$ (1)

g It increases. (1)

4 ▶ **a** $I = \frac{V}{R}$ (1)

$= \frac{12\,\text{V}}{10\,\Omega} = 1.2\,\text{A}$ (1)

b $Q = I \times t$ (1)

$= 1.2\,\text{A} \times 5\,\text{s} = 6\,\text{C}$ (1)

c $E = V \times I \times t$ (1)

$= 12\,\text{V} \times 1.2\,\text{A} \times 60\,\text{s} = 864\,\text{J}$ (1)

5 ▶ **a** $I = \frac{P}{V}$ (1)

$= \frac{2300\,\text{W}}{230\,\text{V}}$ (1)

$= 8.7\,\text{A}$ (1)

b 13 A (1)

c A double-insulated appliance has an outer casing made of plastic or some other insulating material. (1)

Even if there is a fault inside the appliance, making a live wire touch the casing, the user will not get a shock. (1)

d $R = \frac{V}{I} = \frac{230\,\text{V}}{8.7\,\text{A}} = 26.4\Omega$ (1)

6 ▶ **a** Two insulating materials are rubbed together (1), which transfers some electrons from one material to the other (1). The material that gains electrons has a negative charge (1) and the material that loses electrons has a positive charge (1).

b i Any static charge that has built up on the aircraft in flight (1) can be discharged through the earthing wire (1) instead of causing a spark which could ignite fuel vapour (1).

ii A wire is attached from the aircraft to a point on the tanker. (1)

c Electrostatic painting attracts paint to the object being painted (1) so less paint is wasted (1) and therefore less paint is needed (1).

d An inkjet printer uses the fact that opposite charges attract (1) and similar charges repel (1) to direct drops of ink to the correct places on the paper (1).

7 ▶ **a** Any four uses, such as cooking, heating water for washing, heating the house, drying hair, etc. (1 mark per use)

b A fault in an appliance could lead to a live wire touching the casing ($\frac{1}{2}$); in this situation, the presence of an earth wire conducts the current to earth and blows the fuse ($\frac{1}{2}$). This prevents someone touching the casing getting a shock ($\frac{1}{2}$). A double-insulated hairdryer has an insulating case, so the person cannot get a shock even if the fuse has not blown ($\frac{1}{2}$).

8 ▶ **a** 10 V (2) **b** 2 V (2) **c** 12 V (1)

UNIT 3 ANSWERS

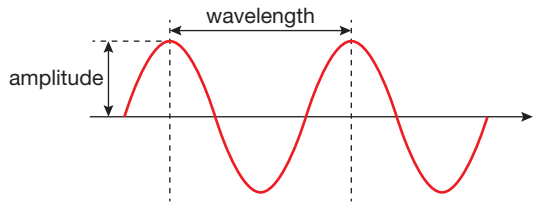
CHAPTER 7

1 ▶ **a** The vibrations of a transverse wave are **across** the direction in which the wave is moving. The vibrations of a longitudinal wave are **along** the direction in which the wave is moving.

b Transverse waves: light (or any other electromagnetic wave) or surface water waves

Longitudinal waves: sound waves

c



2 ▶ **a** 0.4 s **b** 2.5 Hz

3 ▶ **a** $f = \frac{v}{\lambda} = \frac{1500\,\text{m/s}}{1.5\,\text{m}} = 1000\,\text{Hz}$

b $T = \frac{1}{f} = 0.001\,\text{s}$

4 ▶ **a** The wavefronts are squashed closer together as the car approaches.

b It would be higher.

c It would be lower than when the car is stationary.

5 ▶ Rays of light from the fish have been refracted at the surface of the water so the hunter does not see the real position of the fish.

CHAPTER 8

1 ▶ **a** They all: transfer energy; are transverse waves; travel at the same speed through a vacuum; can be reflected, refracted and diffracted.

b Light, microwaves and radio waves

c Microwaves and infra-red waves

d Gamma rays

e Infra-red

f Microwaves

2 ▶ **a** Water molecules within the food absorb the microwaves and become hot, so the food cooks throughout, not just from the outside as in the case of a normal oven.

b X-rays pass easily through soft body tissue but cannot travel through bones. Therefore bones leave 'shadows' on X-ray photographs, which show the shape of the bone and can show if bones have been broken.

c The Earth's ozone layer absorbs large quantities of the Sun's UV radiation. If this layer is damaged, more UV light will reach the surface of the Earth. UV light is harmful to human eyes and can cause skin cancer.

d Exposure to gamma radiation kills the micro-organisms that cause food to decay.

3 ▶ a i Wear lead lined clothes, stand behind a lead screen

ii Wear clothing, use sunblock

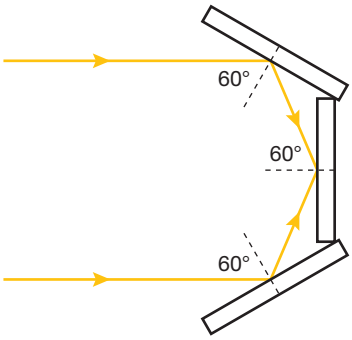
b X-rays: overexposure can cause cancer
Ultraviolet: overexposure can be harmful to human eyes and can cause skin damage such as sunburn and/or blistering

4 ▶

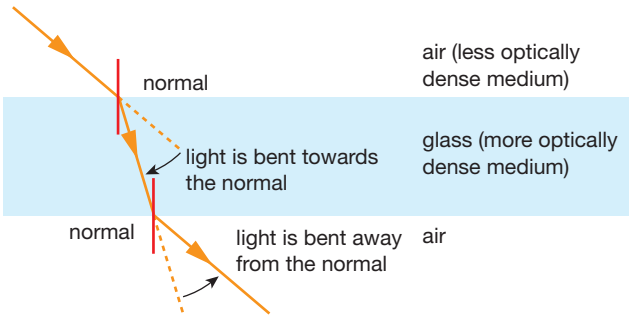
Type of radiation	Possible harm	Precautions
x-rays	cancer	lead screening
microwaves	cancer	metal screening
infra-red	skin burns	avoid over-exposure
ultraviolet	cancer/skin damage	glasses, sunblock

CHAPTER 9

1 ▶ Your diagram could look something like this:

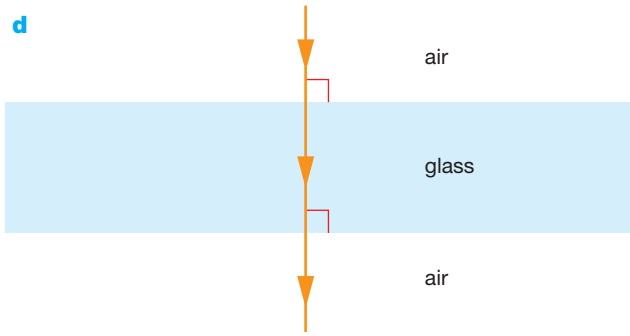


2 ▶ a and **b**



c As the ray of light enters the glass block, it slows down and is refracted towards the normal. As the ray leaves the glass block, its speed increases and it is refracted away from the normal.

d



3 ▶ a $n = \frac{\sin i}{\sin r} = \frac{\sin 55°}{\sin 31°} = 1.59$

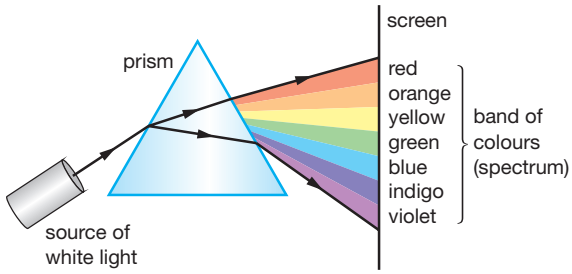
b $\sin r = \frac{\sin i}{n} = \frac{\sin 45°}{1.59} = 0.445$

$r = 26.4°$

c $\sin c = \frac{1}{n} = \frac{1}{1.59} = 0.629$

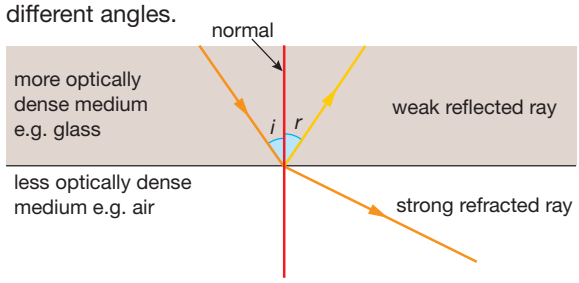
$c = 39°$

4 ▶ a

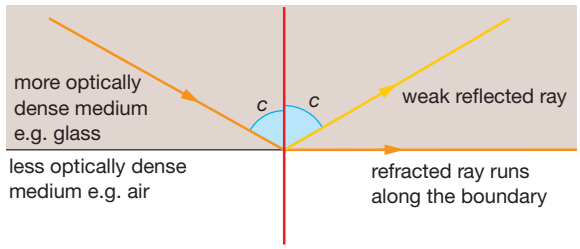


b White light is composed of a mixture of colours. Because each colour travels at a different speed through the prism, the different colours are refracted through different angles.

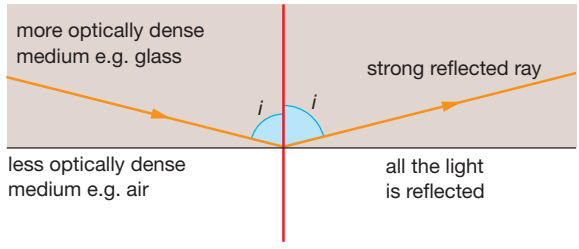
5 ▶ a



b

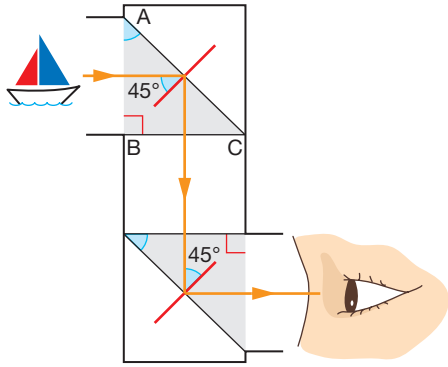


c



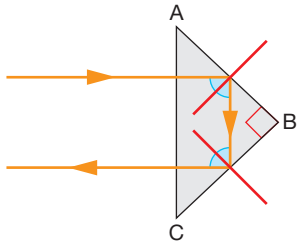
6 ▶ a If a ray of light travelling from glass or water to air strikes the boundary between the two at an angle greater than the critical angle, the ray is reflected by the boundary and is not refracted. This phenomenon is called total internal reflection.

b



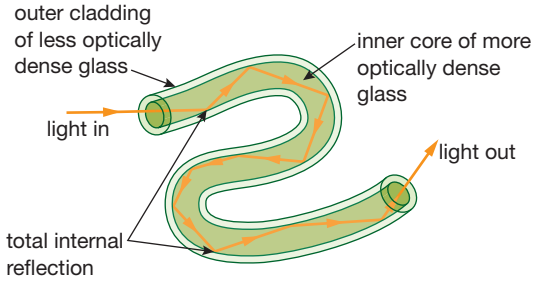
c The final image created by a prismatic periscope is likely to be sharper and brighter than that produced by a periscope which uses mirrors.

d



Bicycle reflectors and binoculars use prisms to turn light through 180°.

7 ▶ a



As the fibres are very narrow, light entering the inner core always strikes the boundary of the two glasses at an angle that is greater than the critical angle. This means that all the light is reflected (total internal reflection).

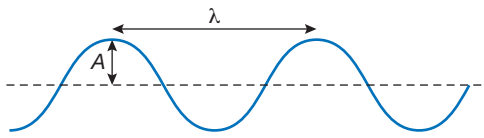
b Optical fibres are used in the construction of endoscopes. Bundles of optical fibres carry light into and out of a patient's body. Images of the inside of the body can be created from the reflected light.

c Telecommunications

END OF UNIT 3 QUESTIONS

1 ▶ a B (1) **b** D (1) **c** A (1)

2 ▶ a



b i $f = \frac{v}{\lambda}$ (1)

$= \frac{20\,\text{m/s}}{2.5\,\text{s}}$ (1)

$= 8\,\text{Hz}$ (1)

ii $T = \frac{1}{f}$

$= \frac{1}{8\,\text{Hz}}$

$= 0.125\,\text{s}$ (1)

3 ▶ a A less dense glass, i.e. a glass with a lower refractive index. (1)

b A more dense glass, i.e. a glass with a higher refractive index. (1)

c The light strikes the boundary at an angle greater than the critical angle (1) so total internal reflection takes place (1).

d Optical fibres are used in endoscopes. These allow doctors / surgeons to see inside the body, and make keyhole surgery possible. (1)

4 ▶ a i The vibrations of a longitudinal wave are along the direction in which the wave is travelling (1). The vibrations of a transverse wave are across the direction in which the wave is travelling. (1)

ii Sound waves are longitudinal waves. (1) Light waves and surface water waves are transverse waves. (1)

b To improve the accuracy of the experiment. (1)

c

Experiment	Time in seconds	Speed of sound in m/s
1	2.95	339
2	3.00	333
3	2.90	345
4	3.20	313
5	2.95	339

(1 mark for each row of table completed)

Average speed of sound from experiment = 334 m/s (1)

d No. The effect of any wind is cancelled out as the sound travels in one direction as it approaches the building, and in the opposite direction as it returns.

5 ▶ a Radio waves, microwaves, infra-red waves, visible spectrum, ultraviolet waves, X-rays, gamma rays. (2 marks for all correct; lose 1 mark for each wave in the wrong position (no negative marks))

b All these waves transfer energy (1), are transverse waves (1), travel at the speed of light in a vacuum (1), can be reflected, refracted and diffracted (1).

c Radio waves – communication (1); microwaves – communication / cooking (1); infra-red waves – cooker / heater / remote control / night vision (1); visible light – seeing / communication (1); ultraviolet waves – fluorescent tubes / tanning lamps (1); X-rays – X-radiography (1); gamma rays – sterilising food or equipment / radiotherapy (1)

d Gamma rays (1), X-rays (1) and ultraviolet waves (1)

e Radio waves (1), microwaves (1) and visible light (1)

6 ▶ a i $n = \frac{\sin i}{\sin r} = \frac{\sin 38}{\sin 24} = 1.51$ (4)

ii $n = \frac{1}{\sin c}$, $c = 41.3$ (2)

b $n = \frac{1}{\sin c} = \frac{1}{\sin 42} = 1.49$ (3)

UNIT 4 ANSWERS

CHAPTER 10

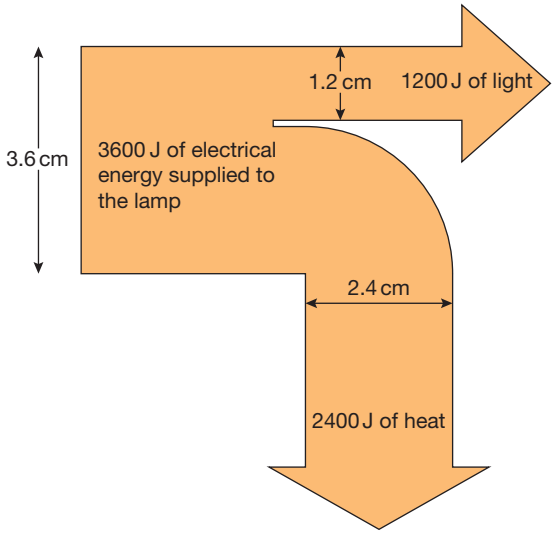
1 ▶ a Stored chemical energy in the battery → electrical energy in the circuit → heat and light in the lamp filament

b Stored chemical energy in the paraffin wax → heat and light as the candle burns

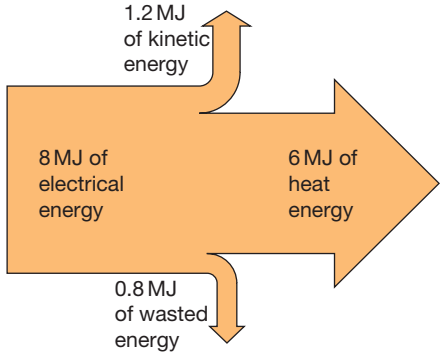
c Kinetic energy of moving hands → heat energy

d Stored energy in the stretched elastic of the trampoline → kinetic energy of the trampolinist moving upwards → gravitational potential energy as the trampolinist slows to a halt at the top of the bounce

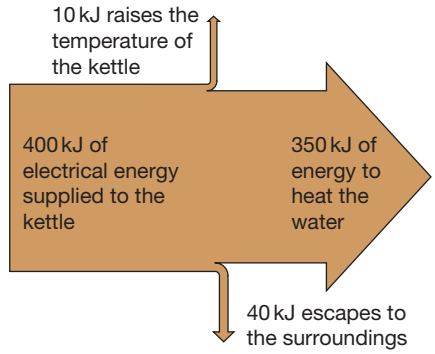
2 ▶ a



b



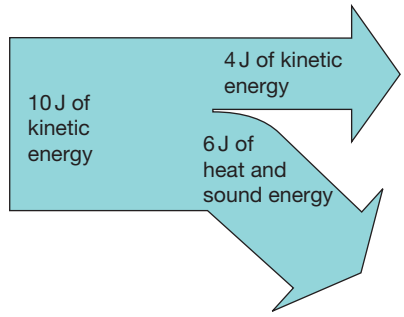
3 ▶ a



b Efficiency $= \frac{350}{400} = 0.875$

4 ▶ a 6 J of energy is converted to heat in the ball and the ground and to sound.

b



CHAPTER 11

1 ▶ a Some of the heat energy in the tea is transferred to the spoon. Also, the metal spoon is a good conductor of heat, so it increases the area from which the heat of the tea can be lost.

b The plastic lid traps a layer of air above the tea. Air is a poor conductor of heat. The layer of trapped air also greatly reduces heat loss from the surface of the hot tea by preventing convection currents in the air above the cup. It also reduces the amount of heat lost through evaporation.

2 ▶ a Copper is a very good conductor of heat. This is an advantage, because it allows the water in the kettle to heat up quickly, as the energy from the stove is easily transferred through the copper to the water within the kettle. However, it could also be considered to be a disadvantage, as the heat transfer from the water inside the kettle to the outer surface of the kettle is also rapid.

b A shiny surface reduces heat loss by thermal radiation. A kettle allowed to go black would radiate more heat from its surface than a shiny, clean one.

3 ▶ Although paper is a poor thermal conductor, it is thin, so heat can transfer through it quite rapidly. This heat energy is then rapidly conducted away from the paper by the brass section, because brass is a very good thermal conductor. Wood is a poor thermal conductor, so heat is transferred away from the paper much more slowly. As a result, the temperature of the paper rises enough for it to start to scorch.

4 ▶ Both benches will be in thermal equilibrium with the surroundings; that is, they will both be at the same temperature as their surroundings and, therefore, each other. Thus the metal bench is not actually colder than the wooden one *to start with*. However, the metal bench conducts heat much more readily than the wooden bench. Heat from the body is quickly conducted away from the body by the metal bench, and the region beneath the person's body remains close to the air temperature. Heat travels much more slowly through wood, so the region under the person sitting on the wooden bench *does* warm up. As its temperature gets close to the person's body temperature, the rate at which heat is transferred from the body into the bench is reduced and the bench does not feel as cold.

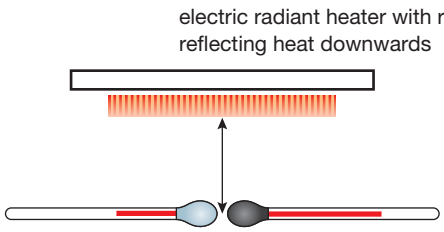
5 ▶ a Water is a relatively poor thermal conductor. As it is a fluid (capable of flowing or moving around), the main mechanism of heat transfer is convection. Convection means that heated water, which expands and becomes less dense, is displaced upward by colder and therefore denser water. If the heating element was positioned near the top of the kettle, only the top layer of water would be heated, because the colder denser water would be *below* the element and would not be directly heated by contact with the heating element.

b At the top. Air cooled by the element will become more dense and will sink down the freezer. If the cooling element was placed at the bottom, only the bottom layer of air would become cold.

6 ▶ The slots at the top allow air that has been heated by the computer circuitry – and thus become less dense – to be pushed upwards by colder, denser air drawn in through the slots in the base of the computer case. This convection current means that a steady stream of cooler air is drawn across the electronic circuitry, helping to keep it cool. Convection does not take place so effectively if the ventilation slots are in the sides of the case at the same level, so fans are necessary to maintain a sufficient circulation of cool air across the circuitry.

7 ▶ The fire heats the air in the right-hand shaft in the diagram. This air expands and becomes less dense, and is therefore pushed upwards by colder, denser air drawn down the other shafts in the mine. This ensures there is a steady circulation of fresh (colder, denser) air drawn down the shaft on the left of the diagram.

8 ▶ a



The apparatus above will show if heat is absorbed more readily by thermometer B (with a black bulb) than by thermometer A (with a shiny bulb).

b Measure the initial temperatures on each thermometer and then take readings at 30 s intervals.

c The thermometers should be identical apart from the bulbs and should be placed at the same distance from the heater. The apparatus should be screened from draughts and other sources of heat. The experiment should be repeated.

d Placing the thermometers below the heat source means that heat cannot be transferred from the source to the thermometers by convection. Air is a very poor thermal conductor so little heat will be transferred by conduction. If the temperature shown on thermometer B rises more quickly than the temperature shown on thermometer A we can therefore conclude that the blackened bulb of thermometer B is a better absorber of thermal radiation than the shiny bulb of thermometer A.

CHAPTER 12

1 ▶ a A wide range of answers possible, e.g. rubbing hands to warm them.

b Heat water to produce steam, which is then used to rotate a turbine. The turbine can then raise a weight.

2 ▶ a joule

b The joule is the amount of work done when a force of 1 N is applied through a distance of 1 m in the direction of the force.

c For each, use: work done = force × distance

i $W = 6 \times 1\,\text{N} \times 0.8\,\text{m} = 4.8\,\text{J}$

ii $W = 100\,000\,\text{N} \times 200\,\text{m} = 20\,\text{MJ}$

iii $W = (60\,\text{kg} \times 10\,\text{N/kg}) \times 2.8\,\text{m} = 1680\,\text{J}$

iv $W = (350\,\text{kg} \times 10\,\text{N/kg}) \times 45\,\text{m} = 157.5\,\text{kJ}$

3 ▶ Use gravitational potential energy = mgh

GPE = 200 000 000 kg × 10 N/kg × 800 m = 160 000 MJ

4 ▶ a Use the formula $\text{KE} = \frac{1}{2}mv^2$ where m is the mass of the moving object in kg and v is its velocity in m/s to give the KE in joules.

b i $\text{KE} = \frac{1}{2} \times 80\,\text{kg} \times (9\,\text{m/s})^2 = 3240\,\text{J}$

ii $\text{KE} = \frac{1}{2} \times 0.0002\,\text{kg} \times (50\,\text{m/s})^2 = 0.25\,\text{J}$

iii $\text{KE} = \frac{1}{2} \times 0.06\,\text{kg} \times (24\,\text{m/s})^2 = 17.28\,\text{J}$

5 ▶ At the top of the stone's flight, all of its initial KE is converted to GPE, so 48 J = mgh, where $m = 0.04\,\text{kg}$ and $g = 10\,\text{N/kg}$. Hence: $h = \dfrac{48\,\text{J}}{0.04\,\text{kg} \times 10\,\text{N/kg}} = 120\,\text{m}$

6 ▶ The initial GPE that the coin has is completely converted to KE when it reaches the ground, so $mgh = \frac{1}{2}mv^2$.

As mass, m, is common to both sides of the equation, it cancels to give $gh = \frac{1}{2}v^2$.

Rearranging, we can calculate the velocity $v = \sqrt{(2gh)}$, so $v = \sqrt{(2 \times 10\,\text{N/kg} \times 80\,\text{m})} = 40\,\text{m/s}$.

Assumption: air resistance has little effect.

7 ▶ Power is the rate of doing work (or the rate of converting energy) and can be calculated using:

$$\text{power} = \frac{\text{work done in J}}{\text{time taken in s}}$$

The unit of power is the watt.

8 ▶ a Weight = mass × gravitational field strength, so the person weighs 400 N

b Total height = height of one step × number of steps = 4 m

c Work done = force × distance = 1600 J

d Power = $\frac{\text{work done}}{\text{time taken}}$ so the person's power output is 133 W

9 ▶ a i 144 km/h × 1000 = 144 000 m/h

ii $\frac{144\,000\text{ m/h}}{3600} = 40\text{ m/s}$

b KE = $\frac{1}{2}$ × 500 kg × (40 m/s)^2 = 400 000 J

c Assuming no energy is converted to other forms than movement (impossible in reality), the average power developed by the engine is: $\frac{400\,000\text{ J}}{5\text{ s}} = 80\,000\text{ W}$

END OF UNIT 4 QUESTIONS

1 ▶ a D (1) **b** C (1) **c** B (1) **d** A (1) **e** D (1)

2 ▶ a Work done = force × distance (1)
= 800 N × 30 m (1)
= 24 000 J (1)

b Power = $\frac{\text{energy transferred}}{\text{time taken}}$
= $\frac{24\,000\text{ J}}{16\text{ s}}$ (1)
= 1500 W (1)

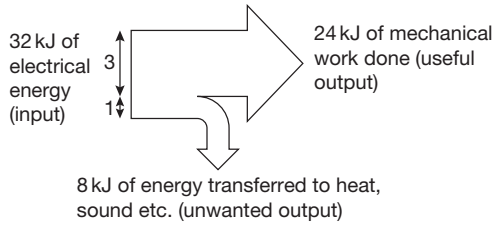
c i This means that only 75% of the electrical power supplied to the motor is transferred usefully in raising the load. (2)

ii Efficiency = $\frac{\text{useful power transferred}}{\text{total electrical power supplied}}$ (1)

Total electrical power supplied = $\frac{\text{useful power transferred}}{75/100}$ (1)

Total electrical power supplied = 2000 W = 2 kW (1)

d



(3)

3 ▶ a B (1)

b Once the rocket has left the launcher, it loses speed as KE is transferred to GPE. (1)

At the top of the flight, the rocket comes to a stop: KE is zero, GPE is maximum. (1)

The rocket then falls and gains speed as GPE is transferred to KE. (1)

It hits the ground with max KE, which is then transferred to heat, sound etc. (1)

4 ▶ a Any 3 from the following (1 mark each, maximum 3 marks)

Make the mass of ice in each experiment the same (1)

Ensure the initial temperature of the ice is the same in each experiment (1)

Ensure the initial temperature of the water in each tube is the same (1)

Make sure the source of heat is the same in each experiment (1)

Make sure the room temperature is the same during each experiment (1)

b i A C B (1) because heating directly beneath the ice, as in B, will mean that more energy is transferred to the ice directly (1). In C, the water in the tube will also need to heat up (1) and in A the water must be heated up and heat must transfer down through the water, which will take longer than in C. (1)

ii In B, the ice melts quickly because it is almost in direct contact with the heat source (conduction takes place through the glass wall and a thin layer of water).

In A and C, heat must be transferred through roughly the same length of water, but convection currents will transfer heat from the bottom of the tube in C, as the directly heated water becomes less dense and is pushed to the top of the tube by colder denser water.

This causes heat to be transferred to the top of the tube quite quickly. (1)

In tube A, convection will not transfer heat from the top of the tube to the bottom so conduction is the principal way in which heat can be transferred between the heated water at the top and the ice at the bottom. (1)

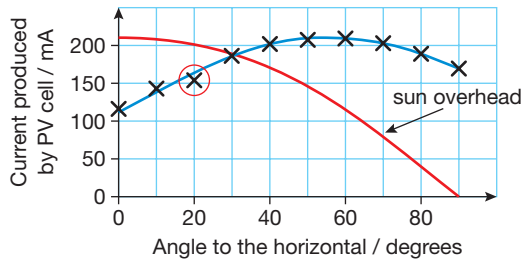
The water at the top can be boiling without the ice at the bottom melting quickly, so we can assume that water is a poor conductor of heat. (1)

5 ▶ a i the current through the load (1)

ii the angle between the plane of the PV cell and the horizontal (1)

iii Any one from: the distance between the lamp and the PV cell (1); the brightness of the lamp (1); the brightness of other lighting in the room (1), etc.

b



All points plotted correctly (2)

Sensible scales (1)

Scales labelled (1)

Smooth best fit line (1)

c i anomalous result ringed in red (1)
ii peak between 50° and 60° (1)
d i By raising the lamp, keeping the stand position where it is (and re-angling the lamp to keep the PV cell in the beam (1)
ii See red graph line:
Peak at 0° (any magnitude, likely to be greater than for original graph) (1)
Curves downwards (1)
To a very low level at 90° (1)

UNIT 5 ANSWERS

CHAPTER 13

1 ▶ a Submerged the crown in water and measured the volume of water displaced

b density = $\frac{\text{mass}}{\text{volume}}$, so mass = density × volume
mass of crown should be 19 000 kg/m^3 × 0.0001 m^3
= 1.9 kg

2 ▶ a The person's weight will be spread out over the area of the ladder, so the pressure on the roof will be less.

b Area of one boot = 0.021 m^2
Pressure = $\frac{\text{force}}{\text{area}} = \frac{850\text{ N}}{0.021\text{ m}^2}$ = 40 476 Pa

c Force = 850 N + 70 N = 920 N
Pressure = $\frac{920\text{ N}}{0.3\text{ m}^2}$ = 3067 Pa

3 ▶ a p = 0.1 m × 1000 kg/m^3 × 10 N/kg = 1000 Pa

b The gas pressure at point C is balancing the atmospheric pressure in the open section of the tube (point A) and the pressure of the 10 cm difference in water level between point A and point B. Therefore, the pressure of the gas at point C is:
100 000 N/m^2 (100 kPa) + 1000 N/m^2 (from part a) = 101 000 N/m^2 (101 kPa).

c Atmospheric pressure will be restored in the right-hand tube, so the water levels in both sides of the manometer will be equalised.

CHAPTER 14

1 ▶ As a substance is cooled, the pressure it exerts becomes smaller as the particles move more slowly. Absolute zero is the temperature at which the particles are not moving / the gas is exerting zero pressure.

2 ▶ a i 273 K **ii** 373 K **iii** 293 K
b i –23 °C **ii** –4 °C **iii** 32 °C

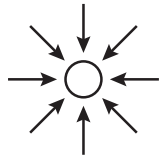
3 ▶ a The piston moves out. The air particles will move faster when they are heated, so there will be more, and harder, collisions with the walls of the container and the piston, increasing the pressure. The increased force on the piston will make it move outwards.

b As the beaker is pushed down, pressure from the water will tend to compress the air trapped in the beaker, so the particles in the air will be closer together.

c As the container is heated, the air particles inside will move faster. The pressure will increase, and may increase enough to force the cork out of the opening.

END OF UNIT 5 QUESTIONS

1 ▶ a B (1) **b** C (1) **c** C (1) **d** C (1) **e** D (1)

2 ▶ a  (2)

b The pressure on the bubble decreases as it rises towards the surface of the cola (1)
so the bubble gets bigger (1)
because pressure × volume is constant (for a fixed mass of gas at constant temperature) (1)

3 ▶ a i The volume of the stone (1)
ii A measuring cylinder (1)
iii Any one from: make sure the stone does not splash water out of the big beaker (1); make sure the measuring cylinder is level (1); measure to the bottom of the liquid meniscus (1); look at the scale straight on (avoid parallax error) (1)

b i density = $\frac{\text{mass}}{\text{volume}}$ (1)
ii The mass must be measured using a digital balance (1)

4 ▶ h = 76 cm; convert to m = 0.76 m (1)
pressure = $h \times \rho \times g$
= 0.76 m × 13 600 kg/m^3 × 10 N/kg (1)
= 103 360 Pa (1)

UNIT 6 ANSWERS

CHAPTER 15

1 ▶ c, e, g

2 ▶ a

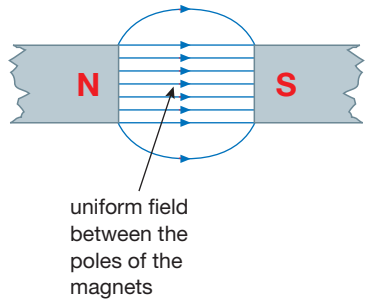
b

Similar poles repel and opposite poles attract.

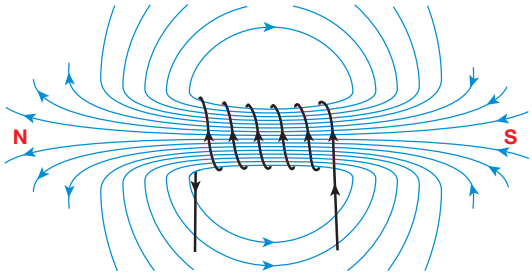
3 ▶ a Shape, strength and direction

b A field which has the same strength everywhere.

c



4 ▶ a



b The magnetic field is strongest where the field lines are closest together and weakest where the field lines are furthest apart.

c The directions of the magnetic field and its poles will also be reversed.

5 ▶ a When current passed through the wire, a magnetic field was created around it.

b From right to left. The magnetic field around the wire is circular, with the wire at its centre. The field is therefore in opposite directions on opposite sides of the wire.

c No. If the current flowing through the wire is reversed, the direction of the magnetic field around the wire will also be reversed.

6 ▶ a Iron loses its magnetism when the current through the coil is turned off, i.e. the electromagnet can be turned off. Steel retains its magnetism after the current / electromagnet has been turned off.

b Increase the current flowing through the coils, increase the number of coils.

CHAPTER 16

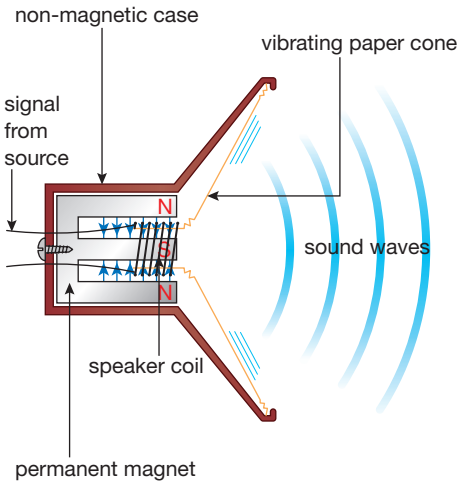
1 ▶ a The wire is pushed upwards.

b The wire is pushed downwards.

c The wire is pushed upwards.

d The wire is pushed with a larger force.

2 ▶ a



b Varying electric currents from the source create magnetic fields (around the speaker coil); the strength and direction of these fields change as the current changes. These changes make the speaker vibrate, creating the sound waves we hear.

3 ▶ a Large deflection on meter

b No deflection on meter

c Smaller deflection on meter than in **a** and in the opposite direction

d Meter deflects in the same direction as in **a**

END OF UNIT 6 QUESTIONS

1 ▶ a C (1) **b** D (1) **c** B (1)

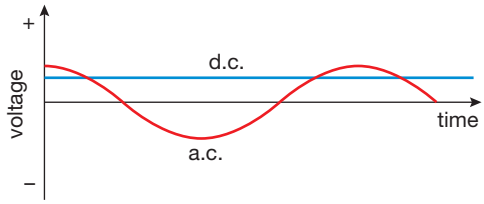
2 ▶ force (1); magnetic (1); loudspeakers (1); motors (1); coil (1); induced (1); dynamos (or generators) (1); generators (or dynamos) (1)

3 ▶ a As the cyclist pedals, a magnet rotates (1). Its magnetic field cuts through a coil (1), inducing current in the coil (1).

b When the cyclist stops pedalling, the magnet is stationary: there is no movement of the magnet and its magnetic field, so no current is produced. (1)

c A generator which produces alternating current. (1)

d Direct current (dc) flows in the same direction all the time. (1) Alternating current (ac) changes direction many times each second (1).



(1)

e The alternating current (1) makes 50 complete cycles each second. (1)

4 ▶ Increase the number of turns on the coil (1) or use a stronger magnet (1). He could pedal faster. (1)

5 ▶ a The permanent magnet will attract the iron armature but then not release it (1), so the hammer will not vibrate up and down (1).

b Iron is a magnetically soft material and therefore loses its magnetism when the current is turned off (1). Steel is a magnetically hard material and therefore retains its magnetism when the current is turned off (1). If the core of the electromaget was made from steel, the hammer would not vibrate up and down as the electromagnet was turned on and off (1).

UNIT 7 ANSWERS

CHAPTER 17

1 ▶

Atomic particle	Relative mass of particle	Relative charge of particle
electron	1	+1
proton	2000	–1
neutron	2000	0

2 ▶ a neutron **b** electron

c proton **d** proton

e electron

3 ▶ **a** The atomic number of an atom is equal to the number of protons in the atomic nucleus. This defines the chemical element. Different chemical elements have different atomic numbers.

b The mass number of an atom is equal to the total number of protons and neutrons in the nucleus.

4 ▶

	$^{3}_{2}$He	$^{13}_{6}$C	$^{23}_{11}$Na
protons	2	6	11
neutrons	1	7	12
electrons	2	6	11

5 ▶ **a** nucleons, protons, neutrons, +2

b electron, proton, neutron

c gamma, short

d electromagnetic

6 ▶ **a** **i** C **ii** B

b $^{1}_{1}\text{p} \rightarrow {}^{1}_{0}\text{p} + {}^{0}_{1}\text{e}$

7 ▶ Alpha radiation is stopped by card; since there is a drop in the detected radiation when a piece of card is placed between the source and the detector, the source must be emitting alpha particles.

Beta radiation is stopped by a thin sheet of aluminium; since there is no change in the detected radiation when an aluminium sheet is used, the source *cannot* be emitting beta particles.

Gamma radiation is stopped by a thick block of lead; since there is a drop in the detected radiation when a lead block is placed between the source and the detector, the source must be emitting gamma radiation.

8 ▶ **a** $^{234}_{90}\text{Th} \rightarrow {}^{234}_{91}\text{Th} + {}^{0}_{-1}\text{e}$

b beta decay

c $^{216}_{84}\text{Po} \rightarrow {}^{212}_{82}\text{Pb} + {}^{4}_{2}\text{He}$

d alpha decay

CHAPTER 18

1 ▶ **a** Background radiation is radiation produced by radioactive material in the Earth and in the Earth's atmosphere. It should be measured and taken into account when measuring the activity of radiation from a particular source.

b Natural background radiation is due to the decay of naturally occurring radioactive isotopes in the Earth that were formed when the Solar System was created. Natural radiation also results from high-energy particles that bombard the Earth. Artificial background radiation comes from man-made sources, rather than from the rocks that make up the Earth.

c Uranium in rocks in the Earth's crust (natural). Radioactive materials that have escaped into the environment from nuclear power stations (artificial). Fallout from atmospheric nuclear weapons testing in the 1950s and 1960s (artificial).

2 ▶ **a** Ionising radiation causes ionisation of a low-pressure gas inside the tube. The ionised gas allows a current to flow between two electrodes, and the current is detected by an electronic circuit.

b A rate meter gives an indication of the number of decays occurring per second.

c A bequerel is a rate of decay of one disintegration per second. 1 kBq is 1000 disintegrations per second.

3 ▶ **a** The half-life of a radioactive sample is the average time taken for half the unstable atoms in the sample to undergo radioactive decay.

b Random means that the decay of an individual atom is unpredictable; we cannot say when any particular atom will undergo decay.

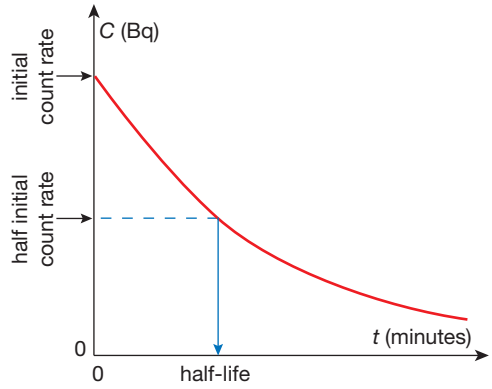
4 ▶ In 1.5 hours the sample has halved in activity three times (240 → 120 → 60 → 30) so three half-life periods have passed. The half-life is 30 minutes.

5 ▶ **a** 70 seconds (1 minute 10 seconds)

b $1\frac{3}{4}$ minutes is three half-lives (3 × 35 seconds), so the volume of water in the burette will have halved again. The burette will be one-eighth full, containing 6.25 ml.

6 ▶ **a** He should measure the background radiation. He should then use a GM tube and rate meter to measure the radioactivity of the sample at regular intervals of, say, 5 minutes for a period of 30–40 minutes.

b The readings of the activity of the sample should be corrected by subtracting the average background radiation count. The corrected readings should then be plotted on a graph of count rate against time. The time taken for the initial activity to fall to half can then be measured from the graph.



CHAPTER 19

1 ▶ **a** It has a short half-life, so its activity drops to a negligible level in a day or two. Beta particles and low energy gamma rays penetrate soft tissue easily, so the progress of the isotope through the body can be monitored easily. The emitted radiation is not strongly ionising, so the risk of tissue damage is acceptably small. (It is also relatively easy to produce.)

b By using a detector such as a GM tube.

2 ▶ β decay. The process involves a change in element – molybdenum to technetium – but with negligible change in mass – the mass number remains the same, 99.

3 ▶ **a** Iodine-131 is taken up by the thyroid gland in the same way as ordinary iodine. An overactive thyroid concentrates more iodine – if the concentration of I-131 is greater than normal, this can be detected by measuring the activity and comparing it with the expected take-up from a normal thyroid gland.

b I-131 is a high-energy beta-emitter. The radiation is sufficiently ionising to destroy cells in the thyroid, reducing its activity.

4 ▶ **a** Radioactive contamination is the accidental transfer of radioactive material onto or into an object or living organism. If safety procedures are ignored, people working with radioactive materials could be contaminated by radioactive materials.

Irradiation is the deliberate exposure to ionising radiation, such as gamma rays or X-rays. The irradiation lasts for a controlled period of time and is then turned off.

b Irradiation is used to sterilise surgical instruments. The instruments are sealed into wrappers and then irradiated with ionising radiation. The radiation passes through the wrapper, destroying any organisms on the instrument; the instrument then remains sterile within its wrapper. The process does not contaminate the instruments with radioactive material.

5 ▶ β radiation is used. It can pass through paper (unlike α particles) but the thicker the paper, the greater the amount of β radiation absorbed.

A β-emitting source is placed above the paper as it emerges from the rollers used to press it to the required thickness. A detector is placed beneath the paper in line with the source. The count rate will decrease if the thickness of the paper passing between the emitter and the detector increases.

To ensure accuracy, the background radiation count should be measured regularly so that the reading from the detector can be corrected. The half-life of the β-emitting source needs to be quite long, so the count rate does not fall significantly over short intervals. The apparatus will need to be recalibrated regularly using paper of known thickness.

Care should be taken to ensure workers cannot come within range of the radiation from the source. The source must be stored in a secure container that is lined with lead to ensure no ionising radiation can escape. The storage area and the part of the paper-making works in which the radiation source is being used should be clearly identified with standard signs. The source must be selected and screened to ensure that it emits only β radiation.

6 ▶ **a** Cosmic radiation causes C-14 to form from nitrogen in the atmosphere.

$${}^{14}_{7}\mathrm{N} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{14}_{6}\mathrm{C} + {}^{1}_{1}\mathrm{p}$$

b Carbon-14 has the same chemical behaviour as the abundant stable isotope C-12. Carbon reacts with oxygen to form carbon dioxide. Through photosynthesis, carbon-14 enters the food chain and therefore all living material.

c Once an organism is dead, no new C-14 is taken in via photosynthesis (plants) or food (animals). The proportion of C-14 in organic material decreases as the C-14 decays.

d The principal assumption is that the rate of production of C-14 through cosmic rays has remained constant over time. In practice this is not so, but it is possible to make adjustments for the variation in C-14 by taking samples from objects of known age.

e The half-life of C-14 is roughly 5600 years. After 10 half-lives have elapsed, the activity remaining in C-14 is too small for accurate measurement.

7 ▶ **a** $\frac{4.5 \times 10^9}{1600} = 2\,812\,500$ half-lives

b Student A is correct – radium formed when the Earth was formed would, by now, have decayed to an immeasurably small amount. Student B is incorrect, as the difference in the initial amount of radium would have to be immense. (As a model of this you can try folding a sheet of paper in half repeatedly – it becomes impossible after seven or eight folds, regardless of how large your starting sheet of paper is.) Student C is correct because radium is continuously being formed by the decay of isotopes of elements with very long half-lives.

8 ▶ **a** Alpha radiation has a very limited range. After alpha particles have travelled only a few centimetres in air, they have lost most of their kinetic energy and thus their ionising power. Alpha particles are stopped completely by quite thin layers of material, even if the material is not very dense.Thus alpha radiation is not particularly dangerous to living cells unless the source is very close to living tissue. If a source is very close to the skin it may, if the exposure is prolonged, cause burns and other tissue damage. The greatest danger is when alpha-emitting material is absorbed into the body. Inside the body, cells do not have the protection of a layer of skin and fat, so they are readily affected by the highly ionising alpha particles. This will result in cell destruction or mutation.

b Radon-220 is an alpha-emitter. It is a dense gas and therefore accumulates in the lower parts of buildings, etc. As it is a gas, it is readily inhaled and thus comes into close contact with internal cells. As described above, this is the most hazardous condition for alpha sources.

CHAPTER 20

1 ▶ **a** The nuclei of its atoms can be split apart by a nucleus.

b i A chain reaction is a reaction that produces further reactions. When a U-235 nucleus splits apart, the neutrons produced can cause further nuclei to split, and so on.

ii If there is only a small amount of U-235, neutrons can escape the material without hitting other U-235 nuclei.

2 ▶ Advantages: virtually inexhaustible supply of energy; does not produce 'greenhouse' gases.

Disadvantages: produces waste that remains extremely dangerous for thousands of years; very high set-up and decommissioning costs.

3 ▶ a Graphite acts as a moderator. It slows down the neutrons produced by the random decay of U-235 and this increases their ability to cause fission when they encounter other atoms of U-235.

b The control rods absorb neutrons. When they are raised out of the reactor, more neutrons are available to cause fission, so more fissions occur and more energy is transferred from nuclear mass into heat.

c The reactor is encased in several metres of concrete and this prevents nearly all radiation from escaping from the reactor vessel. Workers are also required to wear badges and carry electronic devices to monitor the total amount of exposure to radiation they have received over a period of time; these are checked regularly to ensure that workers do not exceed the recommended maximum safe exposure.

4 ▶ Nuclear fission is the splitting of large unstable atoms of isotopes of elements, like uranium, into smaller atoms and other particles, producing large amounts of energy.

Nuclear fusion occurs when atoms of light elements, such as hydrogen, are brought together with enough energy to make them combine to form heavier atoms such as helium.

5 ▶ Fission is a process that occurs naturally in isotopes of some elements. The fission process in a nuclear reactor is carefully controlled and can be shut down when energy is not required. The conditions for nuclear fusion to take place are much more difficult to create. Nuclei of the fusion elements, isotopes of hydrogen, need to be brought together in conditions of high density (lots of nuclei per cubic metre) and extremely high temperatures. These conditions occur in the hearts of stars but creating the conditions for a controlled fusion reaction on Earth is a huge challenge for scientists and engineers.

END OF UNIT 7 QUESTIONS

1 ▶ a D (1) **b** A (1) **c** B (1) **d** B (1) **e** C (1)

2 ▶ a ${}^{1}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H} \rightarrow {}^{2}_{1}\mathrm{H} + {}^{0}_{-1}\mathrm{e}$ (2) **b** ${}^{2}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H} \rightarrow {}^{3}_{2}\mathrm{He}$ (2)

c ${}^{3}_{2}\mathrm{He} + {}^{3}_{2}\mathrm{He} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n} + {}^{1}_{0}\mathrm{n}$ (3)

3 ▶ a E (1) **b** D (1) **c** A (1) **d** C (1) **e** B (1)

4 ▶ a i Nuclear fission is the splitting of large unstable atoms of isotopes of elements, such as uranium, into smaller atoms and other particles producing large amounts of energy. (4)

ii Nuclear fusion occurs when atoms of light elements, such as hydrogen, are brought together with enough energy to make them combine to form heavier atoms, such as helium. (4)

b i A chain reaction occurs when neutrons emitted from a nucleus of a fissile material (such as U-235) collide with further unstable nuclei, causing them to decay and emit further neutrons. If each decay triggers more than one further decay, the reaction will accelerate, causing a huge release of energy in a nuclear explosion. (4)

ii To control a chain reaction and slow down the rate at which decays occur and energy is released, it is necessary to reduce the number of emitted neutrons that could trigger further nuclei to decay. This is done by lowering control rods into the reactor core to absorb neutrons before they can collide with nuclei in the fissile fuel rods. When the control rods are fully lowered into the reactor core, the reaction is shut down and the rate of energy release is very small. (4)

5 ▶ a Nuclear fusion requires plasma made up of deuterium nuclei under high pressure raised to an extremely high temperature. Under these conditions, the nuclei have enough energy to overcome the electrostatic repulsion between them, so they can come into close contact and combine to form heavier nuclei of helium. (3)

b The nuclear fuel for fusion, an isotope of hydrogen, is in abundant supply in water. Uranium – the fuel for nuclear fission – is in limited supply and is dangerous to mine and transport because of its radioactivity. Fusion reactors produce no long-lived nuclear waste. (2)

6 ▶ a A is the atomic mass of the element, equal to the number of nucleons (protons and neutrons) in the nucleus (1). Z is the atomic number, equal to the number of protons in the nucleus (1).

b i D (1) **ii** B (1) **iii** A (1) **iv** C (1)

UNIT 8 ANSWERS

CHAPTER 21

1 ▶ a gravitational forces

b the mass and diameter of the planet

c The orbit of Mercury is much more curved than the orbit of Neptune because the gravitational forces between the Sun and Mercury are much stronger than those between Neptune and the Sun.

d The closer a comet is to the Sun, the faster it travels.

2 ▶ Moons orbit planets. Planets and comets orbit the Sun. The orbits of moons are circular. The orbits of planets are a little elongated (squashed circles or ellipses). The orbits of most comets are very elongated.

3 ▶ a orbital speed $= \frac{2\pi r}{T}$ so

$$T = \frac{2\pi r}{\text{speed}}$$

$$= \frac{2 \times \pi \times (35\,786 + 6400)\,\text{km}}{3.07}$$

$$= 86\,340\,\text{s}$$

b This is 24 hours, so the satellite completes one orbit in the same time as the Earth spins once. If the satellite is over the equator, it is in a geostationary orbit.

4 ▶ a 29.9 km/s (29 886 m/s)

b 12.4 km/s (12 452 m/s)

CHAPTER 22

1 ▶ **a** a galaxy
b attractive gravitational forces pull them together
c the Milky Way
d billions

2 ▶ **a** B class stars have a surface temperature of 33 000 – 10 000 K and a lot of the light they emit is in the blue part of the visible spectrum. K class stars have a surface temperature of 5200 – 3700 K and emit a lot of light in the orange / yellow part of the visible spectrum.
b M class
c F or G class
d 5200 – 7500 K

3 ▶ The apparent brightness of a star is a measure of how bright the star appears when seen from the Earth. The absolute brightness of a star is a measure of how bright the star would appear if it was placed 10 parsecs (32.6 light years) away from the Earth.

4 ▶ Clouds of particle are pulled together so strongly by gravity that nuclear reactions begin: the star is born. Forces of expansion due to the nuclear reactions and forces of contraction due to gravitational forces become balanced. The star is in its stable period. As the nuclear reactions between hydrogen nuclei become rarer, the forces become unbalanced. The star collapses and becomes very hot. New nuclear reactions begin and the star expands greatly until a new balance of forces is established. For stars much more massive than our Sun, the new star is called a red supergiant. At the end of this period, the forces become unbalanced once again and the star collapses. The collapse is so violent that the star becomes unstable and explodes. This is a supernova.

5 ▶ **a** A supernova is an exploding star.
b A supernova occurs when a very massive star (e.g. a red supergiant) reaches the end of this period. It collapses, becomes very unstable and explodes.

END OF UNIT 8 QUESTIONS

1 ▶ **a** B (1) **b** B (1) **c** D (1) **d** B (1)

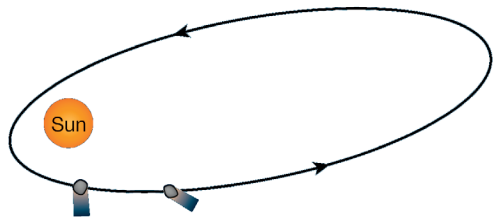
2 ▶ comets (1); orbit (1); closest (1); Mercury (1); Venus (1); strongest (1); curved (1); furthest (1); Uranus (1); Neptune (1); weakest (1); curved (1); circular (1); elliptical (1); satellites (1); moons (1)

3 ▶ **a** $W = 80 \times 9 = 720\,\text{N}$ (3)
b $W = 80 \times 4 = 320\,\text{N}$ (3)
c $W = 80 \times 11 = 880\,\text{N}$ (3)

4 ▶ $V = \frac{2\pi r}{T} = \frac{2 \times \pi \times (250 \times 10^3 + 6400 \times 10^3)}{2 \times 60 \times 60}$
$= 5.8\,\text{km/s}$ (5)

5 ▶ **a** Mercury, Venus and Mars (1)
b 30 years (1)
c 1425 million kilometres (2)
d orbital speed $= \frac{2\pi r}{T}$
T in seconds $= 30 \times 365.25 \times 24 \times 60 \times 60$
$= 946\,728\,000\,\text{s}$
speed $= \frac{2 \times \pi \times 1\,425\,000\,000}{946\,728\,000} = 9.5\ \text{km/s}$ (3)

6 ▶ **a** Your diagram should show an ellipse (1), with the Sun near one end of it (1):



b As a comet gets closer to the Sun, the gravitational forces acting upon it increase (1) and it speeds up (1). As it travels away from the Sun, the Sun's gravity slows it down (1) so its speed is least when it is furthest from the Sun (1).