Topic C1 — Atomic Structure and the Periodic Table

Page 91 — Atoms

Warm-up

The radius of an atom is approximately **0.1** nanometres.
The radius of the nucleus is around $\mathbf{1 \times 10^{-14}}$ metres.
That's about **1/10 000** of the radius of an atom.
An atom doesn't have an overall **charge** as it has equal numbers of **protons/electrons** and **electrons/protons**.

1.1 nucleus ***[1 mark]***
1.2 –1 ***[1 mark]***
1.3 neutron: 0 charge ***[1 mark]***
proton: +1 charge ***[1 mark]***
2.1 mass number = 39 ***[1 mark]***
2.2 atomic number = 19 ***[1 mark]***
2.3 protons = 19 ***[1 mark]***
neutrons = mass number – atomic number
= 39 – 19 = **20** ***[1 mark]***
electrons = 19 ***[1 mark]***

Page 92 — Elements

1.1 Atoms are the smallest part of an element that can exist ***[1 mark]***.
1.2 They have the same number of protons / 17 protons ***[1 mark]*** but a different number of neutrons / $^{35}_{17}Cl$ has 2 less neutrons than $^{37}_{17}Cl$ ***[1 mark]***.
2.1

Isotope	No. of Protons	No. of Neutrons	No. of Electrons
^{32}S	16	16	16
^{33}S	16	17	16
^{34}S	16	18	16
^{36}S	16	20	16

[3 marks — 1 mark for each correct column]

2.2 Relative atomic mass = [(94.99 × 32) + (0.75 × 33) + (4.25 × 34) + (0.01 × 36)] ÷ (94.99 + 0.75 + 4.25 + 0.01)
= 3209.29 ÷ 100 = 32.0929 = **32.1** ***[2 marks for correct answer, otherwise one mark for using correct equation]***
2.3 X and Z are isotopes ***[1 mark]***. They have the same atomic number / same number of protons ***[1 mark]*** but different mass numbers / number of neutrons ***[1 mark]***.

Page 93 — Compounds

1.1 It contains two elements chemically combined ***[1 mark]***.
1.2 4 ***[1 mark]***
A molecule of ammonia contains 1 nitrogen atom and 3 hydrogen atoms making a total of 4 atoms altogether.
2.1 sodium chloride ***[1 mark]***
2.2 Any one of: **B.** NaCl / **C.** C_2H_4 / **E.** H_2O ***[1 mark]***
It contains two or more elements chemically combined (in fixed proportions) ***[1 mark]***.
2.3 6 ***[1 mark]***
C_2H_4 contains 2 carbon atoms and 4 hydrogen atoms.
2.4 Yes, a new compound has been made as the atoms in C_2H_6 are in different proportions to the atoms in C or F / there are a different number of hydrogen atoms in the molecule ***[1 mark]***.

Page 94 — Chemical Equations

Warm-up

1 True
2 False
3 True
4 True

1.1 sodium + chlorine → sodium chloride ***[1 mark]***
1.2 $2Na + Cl_2 \rightarrow 2NaCl$ ***[1 mark]***
2.1 $4NH_3 + \mathbf{5}O_2 \rightarrow 4NO + \mathbf{6}H_2O$ /
$2NH_3 + \mathbf{2.5}O_2 \rightarrow 2NO + 3H_2O$ ***[1 mark]***
2.2 E.g. there are 7 oxygen atoms on the left hand side of the equation and only 6 on the right hand side ***[1 mark]***.

Page 95 — Mixtures and Chromatography

1.1 Mixture ***[1 mark]***. Air consists of two or more elements or compounds ***[1 mark]*** that aren't chemically combined together ***[1 mark]***.
1.2 No ***[1 mark]***, as argon is an element in a mixture. Chemical properties are not affected by being in a mixture ***[1 mark]***.
2 How to grade your answer:
Level 0: Nothing written worthy of credit ***[No marks]***.
Level 1: Some explanation or description given but little detail and key information missing ***[1–2 marks]***.
Level 2: Clear description of method and some explanation of results but some detail missing ***[3–4 marks]***.
Level 3: A clear and detailed description of method and a full explanation of results ***[5–6 marks]***.
Here are some points your answer may include:
<u>Setting up the experiment</u>
Draw a line in pencil near the bottom of a piece of chromatography paper.
Place a small sample of each ink on the pencil line.
Pour a shallow layer of water / solvent into a beaker.
Place the chromatography paper in the container.
The water should be below the pencil line and the ink spots.
Place a lid on the container and wait for the solvent to rise to near the top of the paper.
Remove the paper from the container when the solvent has risen close to the top of the paper.
<u>Explanation of results</u>
A shows one spot, so only contains one dye.
B shows two spots that have separated, so contains two dyes.
C shows three spots that have separated, so contains three dyes.
B and C are mixtures as they contain more than one element or compound not chemically combined together.
B and C contain at least one of the same dyes

Page 96 — More Separation Techniques

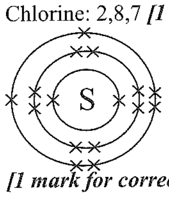
1.1 Add water to the mixture to dissolve the potassium chloride ***[1 mark]***. Filter the mixture. The chalk will stay on the filter paper, ***[1 mark]*** the dissolved potassium chloride will pass through ***[1 mark]***.

1.2 E.g. evaporate the potassium chloride solution to a much smaller volume and then leave it to cool *[1 mark]*.
2.1 Add the mixture to methylbenzene. The sulfur will dissolve (the iron will not dissolve) *[1 mark]*. Filter the solution to obtain the insoluble iron *[1 mark]*. Evaporate the methylbenzene to obtain crystals of sulfur *[1 mark]*.
2.2 No, the student is incorrect *[1 mark]*. The iron and sulfur are chemically combined in iron(II) sulfide / iron(II) sulfide is a compound *[1 mark]* so chemical methods would be needed to separate them out *[1 mark]*.

Page 97 — Distillation
1 Simple distillation *[1 mark]*
2.1 Place a stopper / stopper with a thermometer in the top of the distillation flask *[1 mark]*.
2.2 The solution is heated/boiled and the octane evaporates first as it has a lower boiling point than the impurity *[1 mark]*. There is cold water flowing through the (Liebig) condenser *[1 mark]*. This condenses the gaseous octane back into a liquid which is then collected *[1 mark]*.
2.3 The octane has a boiling point greater than 100 °C / greater than the boiling point of water *[1 mark]*. So it would not evaporate *[1 mark]*.

Pages 98-99 — The History of The Atom
Warm-up
New experimental evidence can disprove models — **True**
Scientific models can be based on existing theories and new experimental evidence — **True**
Older scientific theories must be ignored when new ones are adopted — **False**
1.1 Tiny solid spheres that can't be divided *[1 mark]*.
1.2 Plum pudding model — A positively charged 'ball' with negatively charged electrons in it *[1 mark]*.
Bohr's model — Electrons in fixed orbits surrounding a small positively charged nucleus *[1 mark]*.
Rutherford's nuclear model — A small positively charged nucleus surrounded by a 'cloud' of negative electrons *[1 mark]*.
1.3 neutron *[1 mark]*
2.1 Most of the atom is "empty" space *[1 mark]*.
2.2 Niels Bohr *[1 mark]*
3.1 Atoms are neutral / have no overall charge *[1 mark]*. Therefore there must have been positive charge to balance the negative charge of the electrons *[1 mark]*.
3.2 How to grade your answer:
Level 0: Nothing written worthy of credit *[No marks]*.
Level 1: A brief description of either the nuclear or the 'plum pudding' model is given *[1 to 2 marks]*.
Level 2: A description of both the nuclear model and the plum pudding model is given and some comparisons made *[3 to 4 marks]*.
Level 3: A full comparison of the models is given and similarities and differences are clearly explained *[5 to 6 marks]*.
Here are some points your answer may include:
Similarities
They both have areas of positive charge.
They both have electrons.
They are both neutral overall.
Differences
Positive charge isn't divided into protons in plum pudding model.
Plum pudding model does not have a nucleus but has a 'ball' of positive charge instead.
Plum pudding model does not have neutrons or protons, it only has electrons surrounded by a positive charge.
Plum pudding model does not have shells of electrons (surrounding nucleus), the electrons are arranged randomly within a sphere of positive charge.
Modern nuclear model has most of the mass concentrated in the nucleus but the plum pudding model has the mass spread evenly throughout the entire atom.

Page 100 — Electronic Structure
1.1 2,8,8,2 *[1 mark]*
1.2 The electrons in an atom occupy the lowest energy levels/innermost shell first *[1 mark]*. The innermost shell/lowest energy level can hold 2 electrons *[1 mark]*.
2.1 Chlorine: 2,8,7 *[1 mark]*
2.2



[1 mark for correct number of electrons, 1 mark for correct arrangement]
You don't have to have the electrons paired up on the diagram. As long as there is the same number of electrons on the same shells you get the marks.
2.3 Phosphorus/P *[1 mark]*

Page 101 — Development of The Periodic Table
1.1 He left gaps so that elements with similar properties were in the same group / for elements that had not yet been discovered *[1 mark]*.
1.2 **D**. Between 2.4 and 7.2 g/cm³ *[1 mark]*. **E**. EkO_2 *[1 mark]* **F**. $EkCl_4$ *[1 mark]* **G**. Very slow *[1 mark]*.
2.1 Protons (neutrons and electrons) had not been discovered / atomic numbers weren't known *[1 mark]*.
2.2 Ar and K / Te and I *[1 mark]*.
2.3 Isotopes of an element have different numbers of neutrons/different atomic masses *[1 mark]*, but the same chemical properties *[1 mark]*.

Page 102 — The Modern Periodic Table
1.1 By atomic number / proton number *[1 mark]*.
1.2 Similar properties occur at regular intervals / there are repeating patterns in the properties of the elements *[1 mark]*.
1.3 They have the same number of outer shell electrons *[1 mark]*.
2.1 Group 2 *[1 mark]*. The atom has 2 outer shell electrons. *[1 mark]*.
2.2 Period 3 *[1 mark]*. The atom has 3 shells of electrons *[1 mark]*.
2.3 Magnesium/Mg *[1 mark]*
2.4 Choose one from: beryllium / calcium / strontium / barium / radium *[1 mark]*

Page 103 — Metals and Non-Metals
1.1 A^{2+}: metal X^{2-}: non-metal *[1 mark if both correct.]*
1.2 Any three from, e.g.: dull / brittle / poor conductor of electricity / low density / lower melting point/boiling point than metals *[1 mark for each]*.
2.1 Metals: Towards the left and bottom.
Non-metals: Towards the right and top *[1 mark]*.
2.2 Elements that react to form positive ions are metals *[1 mark]*.
2.3 Any one from: e.g. good electrical conductor / good thermal conductor / strong / high boiling point / high melting point / malleable *[1 mark]*.
2.4 Both are metals that lose their (2 or 3) outer shell electrons *[1 mark]* to form positive ions *[1 mark]*.

Page 104 — Group 1 Elements
1.1 **Y** *[1 mark]*. As element **Y** has a higher melting point, it must be higher up the group than **X** *[1 mark]*.
The higher up the group an element is, the lower its atomic number.
1.2 $2X_{(s)} + 2H_2O_{(l)} \rightarrow 2XOH_{(aq)} + H_{2(g)}$
[1 mark for correct reactants and products and 1 mark for balanced equation. Half the ratio is acceptable]
1.3 Anything between 8-14 *[1 mark]*.
2.1

	Boiling Point / °C	Radius of atom / pm
Rb	687.8	248
Cs	670.8	265
Fr	**Accept lower than 670.8**	**Accept greater than 265**

[1 mark for each correct answer]

2.2 Francium would be more reactive than caesium *[1 mark]*. As you go further down the group the outer electron is further away from the nucleus *[1 mark]*, so the attraction between the nucleus and the electron decreases and the electron is more easily lost *[1 mark]*.

2.3 Formula: Fr_3P *[1 mark]*
Equation: $12Fr + P_4 \rightarrow 4Fr_3P$ ***[1 mark for correct reactants and products, 1 mark for correctly balancing the equation]***

Pages 105-106 — Group 7 Elements

Warm-up

Fluorine
Chlorine
Bromine
Iodine

1.1 They are non-metals that exist as molecules of two atoms *[1 mark]*.

1.2 Chlorine is more reactive than bromine *[1 mark]*. This is because chlorine's outer shell is closer to the nucleus *[1 mark]* so it's easier for chlorine to gain an electron when it reacts *[1 mark]*.

Because of the increasing distance between the nucleus and the outer shell, reactivity decreases down the group. Bromine is further down the group than chlorine, it's outer shell is further away from the nucleus and therefore it's less reactive than chlorine.

1.3 P *[1 mark]*

2.1 $2Fe + 3Br_2 \rightarrow 2FeBr_3$ ***[1 mark for Br_2 and 1 mark for balanced equation. Half the ratio is acceptable]***

2.2 –1 *[1 mark]*

All halide ions form ions with a –1 charge.

3.1 chlorine + potassium bromide → **potassium chloride** + **bromine** *[1 mark]*

3.2 The solution will turn orange *[1 mark]*.

3.3 displacement *[1 mark]*

3.4 No *[1 mark]*, as chlorine is less reactive than fluorine *[1 mark]*.

4.1 The halogens have seven electrons in their outer shell *[1 mark]*. As you go further down the group additional shells are added so the outer electron is further away from the nucleus *[1 mark]*.

4.2 Astatine will react more slowly than fluorine *[1 mark]* since reactivity decreases down the group *[1 mark]*. Both astatine and fluorine have 7 outer shell electrons so react in a similar way *[1 mark]*. So astatine will react with hydrogen to form hydrogen astatide/HAt *[1 mark]*. $H_2 + At_2 \rightarrow 2HAt$ *[1 mark]*

Page 107 — Group 0 Elements

1.1 Rn Boiling Point: Above –108 °C *[1 mark]*, Xe Density: Between 0.0037 and 0.0097 *[1 mark]*, Ar Atomic Radius: Less than 109 pm *[1 mark]*.

1.2 Krypton is unreactive *[1 mark]*. It has a stable electron arrangement / full outer shell / 8 electrons in its outer shell *[1 mark]*.

1.3 Helium only has 2 electrons in its outer shell. The rest of the noble gases have 8 *[1 mark]*.

2.1 Noble gases are unreactive / they have stable electron arrangements / full outer shells / 8 electrons in their outer shell *[1 mark]*.

2.2 Iodine is much less reactive than fluorine *[1 mark]*.

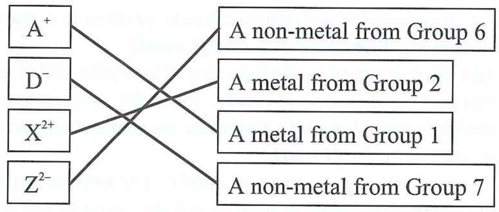
2.3 Neon solidified at –249 °C and xenon at –112 °C *[1 mark]*
Boiling points increase down the group *[1 mark]* and xenon is further down the group than neon so will have the higher boiling point *[1 mark]*.

Topic C2 — Bonding, Structure and Properties of Matter

Page 108 — Formation of Ions

1.1 Metal atoms usually lose electrons to become positive ions *[1 mark]*.

1.2



[2 marks if all four correct, otherwise 1 mark if two correct]

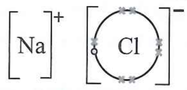
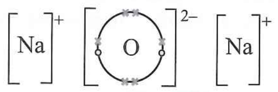
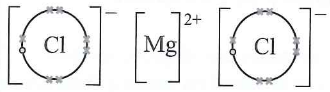
2.1 2– *[1 mark]*

2.2 2,8,8 *[1 mark]*. Sulfur gains two electrons *[1 mark]* to achieve a noble gas electronic structure/a full outer shell *[1 mark]*.

2.3 Argon/Ar *[1 mark]*

Pages 109-110 — Ionic Bonding

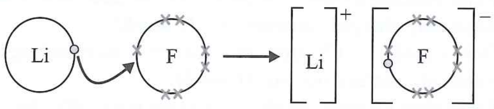
Warm-up:

Dot and cross diagram	Ionic formula
	**NaCl**
	**Na_2O**
	**$MgCl_2$**

1.1 calcium chloride *[1 mark]* and potassium oxide *[1 mark]*

Compounds that contain ionic bonding have to be made up of a metal and a non-metal. All the other options only contain non-metals, so can't be held together by ionic bonds.

1.2

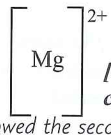


[1 mark for arrow showing electron transfer from Li to F, 1 mark for correct electronic structure of fluoride ion, with seven crosses and one dot, 1 mark for correct charges on the ions.]

1.3 electrostatic attraction / electrostatic force *[1 mark]*

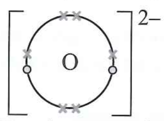
1.4 E.g. the particles in the compound are oppositely charged ions / have opposite charges / the bond is formed by electrons being transferred from one atom to another *[1 mark]*.

2.1



[1 mark for no electrons in outer shell, 1 mark for correct charge]

If you showed the second electron shell of magnesium containing eight electrons as dots, you also get the mark.



[1 mark for eight electrons in the outer shell, with two dots and six crosses, 1 mark for correct charge]

2.2 E.g. the magnesium atom transfers two electrons to the oxygen atom *[1 mark]*. A magnesium ion with a 2+ charge forms *[1 mark]*, and an oxide ion with a 2– charge forms *[1 mark]*. The oppositely charged ions are attracted to each other by electrostatic attraction *[1 mark]*.

3.1 Element X: Group 7 *[1 mark]*
Reason: Any one of, e.g. it has formed an ion by gaining 1 electron / it forms 1– ions / the uncharged element would have seven electrons in its outer shell *[1 mark]*.
Element Z: Group 2 *[1 mark]*
Reason: Any one of, e.g. it has formed an ion by losing 2 electrons / it forms 2+ ions / the uncharged element would have two electrons in its outer shell *[1 mark]*.

3.2 How to grade your answer:
Level 0: There is no relevant information *[No marks]*.
Level 1: The discussion is limited and doesn't mention both the uses and limitations of dot and cross diagrams *[1 to 2 marks]*.
Level 2: There is some discussion of dot and cross diagrams, with at least one use and one limitation covered *[3 to 4 marks]*.

Level 3: The discussion is comprehensive in evaluating both the uses and limitations of dot and cross diagrams ***[5 to 6 marks]***.

Here are some points your answer may include:

Dot and cross diagrams show:

Charge of the ions.

The arrangement of electrons in an atom or ion.

Which atoms the electrons in an ion originally come from.

Empirical formula (correct ratio of ions).

Dot and cross diagrams do not:

Show the structure of the compound.

Correctly represent the sizes of ions.

Pages 111-112 — Ionic Compounds

Warm-up:

In an ionic compound, the particles are held together by **strong** forces of attraction. These forces act **in all directions** which results in the particles bonding together to form **giant lattices**.

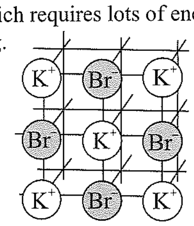
1.1 conduct electricity in the solid state ***[1 mark]***

1.2 giant ionic lattice ***[1 mark]***

2.1 Sodium chloride contains positive sodium ions (Na^+) ***[1 mark]*** and negative chloride ions (Cl^-) ***[1 mark]*** that are arranged in a regular lattice/giant ionic lattice ***[1 mark]***. The oppositely charged ions are held together by electrostatic forces acting in all directions ***[1 mark]***.

2.2 To melt sodium chloride, you have to overcome the very strong electrostatic forces/ionic bonds between the particles ***[1 mark]***, which requires lots of energy ***[1 mark]***.

3.1 E.g.



[1 mark for K^+ ions, 1 mark for Br^- ions, 1 mark for correct structure, with alternating ions]

You'd also get the marks if you labelled all the white circles as Br^- and all the grey circles as K^+.

3.2 Advantage: Any one of, e.g. the diagram shows the 3D arrangement of the ions / it suggests the structure is extended / it shows the regular (repeating) pattern of the ions ***[1 mark]***.
Disadvantage: Any one of, e.g. the diagram doesn't correctly represent the sizes of ions / it shows gaps between the ions ***[1 mark]***.

3.3 KBr ***[1 mark]***

Remember that the overall charge of the ionic compound must be neutral. So you can work out the empirical formula by seeing that you only need one bromide ion to balance the charge on a potassium ion.

3.4 Boiling point: Potassium bromide has a giant structure with strong ionic bonds ***[1 mark]***. In order to boil, these bonds need to be broken, which takes a lot of energy ***[1 mark]***.
Electrical conductivity of solid: The ions are in fixed positions in the lattice ***[1 mark]*** and so are not able to move and carry a charge through the solid ***[1 mark]***.
Electrical conductivity of solution: In solution, the ions are free to move ***[1 mark]*** and can carry a charge from place to place ***[1 mark]***.

Pages 113-114 — Covalent Bonding

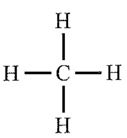
1.1 They share a pair of electrons ***[1 mark]***.

1.2 Non-metals ***[1 mark]***

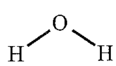
1.3 BH_3 ***[1 mark]***

Find the molecular formula by counting up how many atoms of each element there are in the diagram.

2



[1 mark]



[1 mark]

O=O ***[1 mark]***

Each line represents one covalent bond. Oxygen has a double bond, so you need to draw two lines between the oxygen atoms to show this.

3.1 E.g. it contains only non-metals ***[1 mark]*** and Figure 1 shows shared electrons ***[1 mark]***.

3.2 Any two from, e.g. they don't show how the atoms are arranged in space / they don't show the relative sizes of the atoms ***[2 marks — 1 mark for each correct answer]***.

3.3 One electron from hydrogen and one from carbon form a shared pair ***[1 mark]*** that are attracted to the nuclei of the carbon and hydrogen atoms ***[1 mark]*** by electrostatic attraction ***[1 mark]***.

4.1 Displayed formula: e.g. it shows how all the atoms in a molecule are connected in a simple way ***[1 mark]***, but it doesn't show the 3D structure of the molecule / it doesn't show which atom the electrons in the bond originally come from ***[1 mark]***.
Dot and cross diagram: e.g. it shows where the electrons in each covalent bond originally came from ***[1 mark]*** but it doesn't show the 3D structure of the molecule / they can become very complicated if the molecule is large ***[1 mark]***.
3D model: e.g. it shows how all the atoms are arranged in space in relation to each other / it shows the correct bond angles in the molecule ***[1 mark]*** but it quickly becomes complicated for large molecules / you can't tell which atom in the bonds the electrons originally came from ***[1 mark]***.

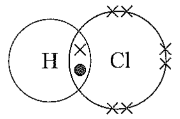
4.2 The displayed formula ***[1 mark]*** would be the best as it is easy to see how the atoms in a large molecule are connected without the diagram becoming too complicated ***[1 mark]***.

Pages 115-116 — Simple Molecular Substances

1.1 The bonds between the atoms are strong ***[1 mark]***, but the forces between the molecules are weak ***[1 mark]***.

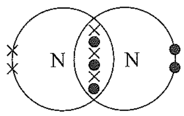
1.2 The weak forces between the molecules / the intermolecular forces ***[1 mark]***.

2.1



[1 mark for correct number of electrons, 1 mark for one shared pair]

2.2



[1 mark for correct number of electrons, 1 mark for three shared pairs]

2.3 E.g. N_2 has a triple covalent bond, whilst HCl has a single covalent bond ***[1 mark]***.

3.1 Simple molecular substances have weak forces between molecules ***[1 mark]*** so not much energy is needed to overcome them/they normally have low melting points ***[1 mark]***.

3.2 Iodine won't conduct electricity ***[1 mark]*** because the I_2 molecules aren't charged / the electrons aren't free to move so can't carry a charge ***[1 mark]***.

4.1 When methane boils, the forces between the molecules are overcome ***[1 mark]*** and it turns from a liquid into a gas ***[1 mark]***. Methane is a smaller molecule then butane ***[1 mark]*** so the forces between the molecules are weaker ***[1 mark]*** and less energy is needed to overcome them ***[1 mark]***.

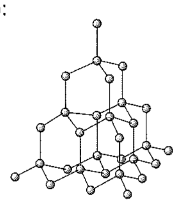
4.2 Carbon needs four more electrons to get a full outer shell, and does this by forming four covalent bonds ***[1 mark]***. Hydrogen only needs one more electron to complete its outer shell, so can only form one covalent bond ***[1 mark]***.

Remember that the outer electron shell in hydrogen only needs two electrons to be filled, not eight like other electron shells.

4.3 Four ***[1 mark]***. Silicon has four outer electrons so needs four more to get a full outer shell / silicon has the same number of outer shell electrons as carbon so will form the same number of bonds ***[1 mark]***.

Page 117 — Polymers and Giant Covalent Substances

Warm-up:



1.1 Ammonia ***[1 mark]***

Ammonia has a simple covalent structure — it forms small molecules.

1.2 The covalent bonds are very strong *[1 mark]*, so a lot of energy is needed to break them *[1 mark]*.

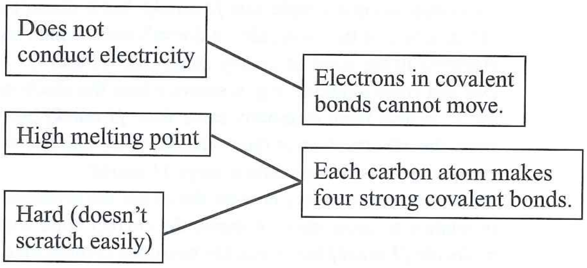
2.1 $(C_2H_4)_n$ *[1 mark]*

2.2 Solid *[1 mark]*. The molecule is very large and so the intermolecular forces are strong *[1 mark]* and need lots of energy to be broken *[1 mark]*.

2.3 covalent bonds *[1 mark]*

Page 118 — Allotropes of Carbon

1.1



[2 marks if all three correct, otherwise 1 mark if one correct]

1.2 A: graphene *[1 mark]*
B: buckminster fullerene *[1 mark]*
C: carbon nanotube / fullerene *[1 mark]*

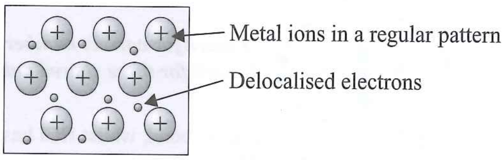
1.3 Any one of, e.g. to strengthen materials / to deliver drugs into the body / as a catalyst / as a lubricant / in electronics *[1 mark]*

2.1 Graphite is made up of sheets of carbon atoms arranged in hexagons *[1 mark]*, with weak forces between the sheets *[1 mark]*. Each carbon atom forms three covalent bonds *[1 mark]*, and has one delocalised electron *[1 mark]*.

2.2 Graphite has delocalised electrons *[1 mark]* which are free to move through the substance and carry an electric charge *[1 mark]*.

Page 119 — Metallic Bonding

1.1 E.g.



[1 mark for regular arrangement of metal ions, 1 mark for delocalised electron, 1 mark for correct labels]

1.2 There is a strong electrostatic attraction *[1 mark]* between the delocalised electrons and the positive metal ions *[1 mark]*.

1.3 High *[1 mark]* because the bonding is strong so requires lots of energy to break *[1 mark]*.

1.4 Good *[1 mark]* because the electrons are free to move throughout the structure and carry an electrical charge *[1 mark]*.

2.1 Metallic structures have layers of atoms *[1 mark]* that are able to slide over one another *[1 mark]*.

2.2 Atoms of different elements are different sizes *[1 mark]*. Adding atoms of a different size to a pure metal distorts the layers *[1 mark]* making it harder for them to slide over one another *[1 mark]*.

Page 120 — States of Matter

1.1 solid, liquid, gas *[1 mark]*

1.2 $NaCl_{(s)}$: solid *[1 mark]*
$O_{2(g)}$: gas *[1 mark]*
$Hg_{(l)}$: liquid *[1 mark]*

2.1 solid spheres *[1 mark]*

2.2 liquid *[1 mark]*

2.3 Any two from: melting / boiling / condensing / freezing *[1 mark for each]*

2.4 Any two from: e.g. the model says nothing about forces between particles / particles aren't really spheres / particles are mostly empty space, not solid *[1 mark for each]*.

Page 121 — Changing State

1.1 melting *[1 mark]*

1.2 boiling point *[1 mark]*

1.3 The bonds are strong *[1 mark]*.

2.1 sodium chloride *[1 mark]*

At 900 °C, water would be a gas and copper would be a solid.

2.2 Sodium chloride *[1 mark]* and water *[1 mark]*.

At 1500 °C, copper would be a liquid.

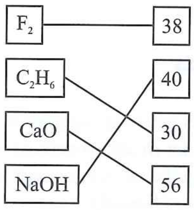
2.3 Boiling sodium chloride *[1 mark]*.

2.4 No *[1 mark]*. When copper boils, the metallic bonds are broken *[1 mark]*, but when water boils only the intermolecular forces are broken *[1 mark]*, so you can't tell anything about the strength of the covalent bonds *[1 mark]*.

Topic C3 — Quantitative Chemistry

Page 122 — Relative Formula Mass

1



[2 marks if all four correct, otherwise 1 mark if two correct]

2.1 $M_r(MgO) = 24 + 16 = 40$ *[1 mark]*

percentage by mass of magnesium $= \frac{A_r(Mg)}{M_r(MgO)} \times 100$

$= \frac{24}{40} \times 100 = \mathbf{60\%}$ *[1 mark]*

2.2 Mass of magnesium ions $= 200 \times \frac{15}{100} = \mathbf{30\ g}$ *[1 mark]*

2.3 Mass of magnesium oxide containing 30 g of magnesium ions $= 30 \div \frac{60}{100} = \mathbf{50\ g}$ *[1 mark]*

If you used the percentage mass of magnesium ions as 40% and the mass of magnesium ions in the mixture as 20 g, your answer will also be 50 g.

Page 123 — The Mole

Warm-up:

6.02×10^{23}

1.1 M_r of carbon dioxide $= 12 + (16 \times 2) = \mathbf{44}$ *[1 mark]*

1.2 Moles of carbon dioxide $= 110 \div 44 = \mathbf{2.5\ mol}$ *[1 mark]*

1.3 1 mole of carbon dioxide would weigh more *[1 mark]*. It has a higher relative formula mass *[1 mark]*.

2.1 2 mol sulfur $= 2 \times 32\ g = \mathbf{64\ g}$ *[1 mark]*

2.2 M_r of iron sulfide $= 56 + 32 = 88$
Moles of iron sulfide $= 44 \div 88 = \mathbf{0.50\ mol}$ ***[2 marks for correct answer, otherwise 1 mark for correct working]***

2.3 The number of atoms in 3 moles of sulfur is greater than the number of molecules in 2 moles of iron sulfide *[1 mark]*. There's the same number of atoms in 1 mole of sulfur as there are molecules in 1 mole of iron sulfide so in 3 moles of sulfur there will be more atoms than there are molecules in 2 moles of iron sulfide *[1 mark]*.

Pages 124-125 — Conservation of Mass

1.1 $2Mg + O_2 \rightarrow 2MgO$ *[1 mark]*

1.2 Mass of oxygen = 20 g of MgO – 12 g of Mg = **8 g** ***[2 marks for correct answer, otherwise 1 mark for correct working]***

2.1 The mass of reactants equals the mass of products in a chemical reaction *[1 mark]*. Atoms are not made or destroyed during a chemical reaction *[1 mark]*. So, there must be the same number of each type of atom in the products as in the reactants *[1 mark]*.

2.2 The mass of the powder would increase *[1 mark]*. Oxygen gas was not included as part of the original measurement *[1 mark]*. Particles of oxygen are added to the zinc to form zinc oxide powder *[1 mark]*.

3.1 The measurement is correct *[1 mark]*. Carbon dioxide (a gas) is produced and released into the atmosphere *[1 mark]*. So, the student only measured the mass of the solid product, not both products *[1 mark]*.

3.2 M_r of sodium oxide $= 106 - 44 = \mathbf{62}$ *[1 mark]*

3.3 Moles of $Na_2CO_3 = 53 \div 106 = 0.50$
For every mole of Na_2CO_3 that reacts, 1 mole of CO_2 is produced. Only 0.50 moles of Na_2CO_3 react so 0.50 moles of CO_2 are produced.
Mass of carbon dioxide $= 0.50 \times 44 = \mathbf{22\ g}$ ***[3 marks for correct answer, otherwise 1 mark for 0.50 moles of Na_2CO_3 and 1 mark for a 1:1 molar ratio]***

To work out a molar ratio, you need to use the balanced symbol equation for the reaction. The numbers in front of the chemical formulas show the number of moles of a substance that react or are produced in the reaction. In this question, for every 1 mole Na_2CO_3 heated, 1 mole of carbon dioxide is produced — a 1:1 molar ratio.

3.4 Mass of sodium oxide = 53 g – 22 g = **31 g** ***[1 mark]***

Pages 126-127 — The Mole and Equations

Warm-up:

3

1 $H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$ ***[1 mark]***

2.1 Moles of sodium = 9.2 ÷ 23 = **0.4 mol** ***[1 mark]***

2.2 M_r of water = (1 × 2) + 16 = 18
Moles of water = 7.2 g ÷ 18 = **0.4 mol** ***[2 marks for correct answer, otherwise 1 mark for correct working]***

2.3 Divide the number of moles of each substance by the lowest of these number of moles (0.2 mol) to give the molar ratios.
Na = 0.4 ÷ 0.2 = 2 mol
H_2O = 0.4 ÷ 0.2 = 2 mol
NaOH = 0.4 ÷ 0.2 = 2 mol
H_2 = 0.2 ÷ 0.2 = 1 mol
$2Na + 2H_2O \rightarrow 2NaOH + H_2$ ***[3 marks for correct answer, otherwise 1 mark for correct method and 1 mark for at least 2 correct numbers in the equation]***

3.1 Moles of methane = 8 g ÷ 16 = 0.5 mol
Moles of oxygen = 32 g ÷ 32 = 1 mol
Moles of carbon dioxide = 22 g ÷ 44 = 0.5 mol
Moles of water = 18 g ÷ 18 = 1 mol ***[1 mark]***
Divide by the lowest of these numbers which is 0.5:
Methane = 0.5 ÷ 0.5 = 1 mol
Oxygen = 1 ÷ 0.5 = 2 mol
Carbon dioxide = 0.5 ÷ 0.5 = 1 mol
Water = 1 ÷ 0.5 = 2 mol ***[1 mark]***
$CH_4 + \mathbf{2}O_2 \rightarrow CO_2 + \mathbf{2}H_2O$ ***[1 mark]***

3.2 Moles of oxygen = 48 g ÷ 32 = 1.5 mol
Molar ratio of oxygen : carbon dioxide = 2:1
Moles of carbon dioxide = 1.5 mol ÷ 2 = **0.75 mol** ***[3 marks for correct answer, otherwise 1 mark for 1.5 mol of oxygen and 1 mark for molar ratio of 2:1]***

3.3 Molar ratio of $CH_4 : H_2O$ = 1:2
4 mol of methane will produce **8 mol** of water ***[1 mark]***.

3.4 Mass of water = 18 × 8 = **144 g** ***[1 mark]***

If you got the equation wrong in 3.1 but used all the right working in parts 3.2, 3.3 and 3.4, you still get the marks, even if you got a different answer to the one here.

Page 128 — Limiting Reactants

1.1 To make sure that all the hydrochloric acid was used up in the reaction ***[1 mark]***.

1.2 The limiting reactant is completely used up during a reaction ***[1 mark]*** and so its quantity limits the amount of product that can be formed ***[1 mark]***.

2.1 Molar ratio of copper oxide : copper sulfate = 1:1
Therefore, 0.50 mol of copper sulfate is produced.
M_r of copper sulfate = 63.5 + 32 + (16 × 4) = 159.5
Mass of copper sulfate = 0.50 × 159.5 = **80 g** ***[3 marks for correct answer, otherwise 1 mark for 0.50 moles of copper sulfate and 1 mark for M_r of 159.5]***

2.2 The amount of product formed is directly proportional to the amount of limiting reactant ***[1 mark]***. So doubling the quantity of the sulfuric acid will double the mass of the copper sulfate ***[1 mark]***.

2.3 If only 0.4 mol of copper oxide is present, there will not be enough molecules to react with all the sulfuric acid ***[1 mark]***. The copper oxide will be the limiting reactant ***[1 mark]*** and only 0.4 mol of product will be formed ***[1 mark]***.

Page 129 — Concentrations of Solutions

1.1 Conc. of calcium chloride = 28 g ÷ 0.4 dm^3 = **70 g/dm³** ***[1 mark for correct answer and 1 mark for correct units]***

1.2 The concentration of a solution is the amount of a substance in a given volume of a solution ***[1 mark]***.

2.1 Volume in dm^3 = 500 ÷ 1000 = 0.50 dm^3 ***[1 mark]***.
Concentration = 40.0 ÷ 0.500 = **80** g/dm³ ***[1 mark]***.

2.2 Mass = 60.0 × 0.500 = **30** g ***[1 mark]***.

2.3 Mean = (18.2 + 18.1 + 18.4 + 18.5) ÷ 4 = **18.3 g/dm³** ***[1 mark]***

2.4 Range = 18.5 – 18.1 = 0.4
Uncertainty = range ÷ 2 = 0.4 ÷ 2 = **± 0.2 g/dm³** ***[2 marks for correct answer, otherwise 1 mark for calculating range]***

Topic C4 — Chemical Changes

Page 130 — Acids and Bases

Warm-up

Universal indicator will turn **red** in strongly acidic solutions and **purple** in strongly alkaline solutions. In a **neutral** solution, Universal indicator will be green. A pH probe attached to a pH meter is **more** accurate than Universal indicator as it displays a numerical value for pH.

1.1 beer ***[1 mark]***

1.2 blue / blue-green ***[1 mark]***

1.3 H^+ ***[1 mark]***

1.4 0 ***[1 mark]*** – 14 ***[1 mark]***

2.1 acid + alkali → salt + water ***[1 mark]***

2.2 $H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(l)}$ ***[1 mark]***

You still get the marks if you didn't include state symbols.

Page 131 — Strong Acids and Weak Acids

1.1 A strong acid completely ionises/dissociates in solution ***[1 mark]***. A weak acid only partly ionises in solution ***[1 mark]***.

1.2 Nitric acid would have a lower pH than ethanoic acid ***[1 mark]*** because it is a stronger acid/more dissociated/ionised ***[1 mark]***, so the concentration of H^+ would be greater ***[1 mark]***.

You would also get the marks for using the reverse argument — ethanoic acid would have a higher pH because it is a weaker acid so the concentration of H^+ ions is lower.

1.3 3 ***[1 mark]***

As the concentration of H^+ ions in solution decreases by a factor of 10, the pH rises by 1.

1.4 Adding water to the beaker ***[1 mark]***.
Adding ethanoic acid to the beaker at the same concentration as the citric acid ***[1 mark]***.
Changing the citric acid to carbonic acid of the same concentration ***[1 mark]***.

Pages 132-133 — Reactions of Acids

1.1 Neutralisation ***[1 mark]***

1.2 Fizzing — Carbon dioxide is produced ***[1 mark]***

2.1 sulfuric acid + lithium hydroxide → lithium sulfate + water ***[1 mark]***

2.2 $H_2SO_4 + 2LiOH \rightarrow \mathbf{Li_2SO_4} + 2H_2O$ ***[1 mark for correct formula of Li_2SO_4, 1 mark for correct balancing]***

2.3 Both reactions produce lithium sulfate and water ***[1 mark]***. The reaction between sulfuric acid and lithium carbonate also produces carbon dioxide ***[1 mark[***.

3.1 Add zinc oxide to hydrochloric acid until the reaction stops / the excess metal oxide sinks to the bottom ***[1 mark]***. Filter the excess solid from the solution using a filter funnel ***[1 mark]***. Heat the zinc chloride solution to evaporate some of the water and then leave to cool ***[1 mark]***. Filter and dry the crystals that form ***[1 mark]***.

3.2 E.g. zinc carbonate ***[1 mark]***.

Any other insoluble zinc base or zinc metal also gets a mark.

4 How to grade your answer:
Level 0: Nothing written worth of credit ***[No marks]***.
Level 1: Some suitable tests are named but it is not clear how the results would enable the solutions to be identified. The chemistry of the tests is not clearly described ***[1 to 2 marks]***.
Level 2: Tests that enable at least one solution to be identified are clearly described, or tests that would enable all solutions to be identified are named but not clearly described ***[3 to 4 marks]***.
Level 3: At least two tests are described together with the expected outcomes. It is clear how these tests would be used to distinguish between all three solutions. The chemistry of the tests is correctly described ***[5 to 6 marks]***.

Here are some points your answer may include:
Test the pH of each solution.
The neutral solution/the solution that turns Universal indicator green is the salt.
Add a couple of drops of Universal indicator to the solutions followed by some dilute acid.
The solution containing sodium carbonate will fizz as it reacts with the acid to release carbon dioxide gas as shown by the equation: acid + sodium carbonate → sodium salt + water + carbon dioxide
The solution containing sodium hydroxide will react with acid changing the Universal indicator solution from blue/purple to green, but there won't be any fizzing as no gas is released as shown by the reaction:
acid + sodium hydroxide → sodium salt + water
The solution containing the sodium salt won't react with acid.

Pages 134-135 — The Reactivity Series

1.1 magnesium + hydrochloric acid → magnesium chloride + hydrogen *[1 mark]*
1.2 Positive magnesium ions *[1 mark]*
1.3 It forms positive ions less easily / it's lower down in the reactivity series *[1 mark]*.
1.4 Any one of: e.g. potassium / sodium / lithium / calcium *[1 mark]*.
2.1 metal + water → metal hydroxide + hydrogen *[1 mark]*
2.2 $Ca_{(s)} + 2H_2O_{(l)} \rightarrow Ca(OH)_{2(aq)} + H_{2(g)}$ *[1 mark for each correct product]*
2.3 Any one from: e.g. lithium / sodium / potassium *[1 mark]* As it is higher in the reactivity series than calcium / loses electrons more easily than calcium / forms positive ions more easily *[1 mark]*.
2.4 potassium, sodium, zinc *[1 mark]*
3.1 When a metal reacts with an acid, the metal forms positive ions *[1 mark]*. The results show that lithium reacts more vigorously with acid than magnesium does *[1 mark]*, so lithium forms positive ions more easily *[1 mark]*.
3.2 A very vigorous fizzing/more vigorous than lithium *[1 mark]*, sodium disappears *[1 mark]*.
3.3 lithium, calcium, copper *[1 mark]*
3.4 It is not possible to tell the difference between magnesium and zinc from these results since both have same reaction with dilute acid *[1 mark]*. E.g. to find which is more reactive, you could find the effect of adding zinc to water *[1 mark]*.

Page 136 — Separating Metals from Metal Oxides

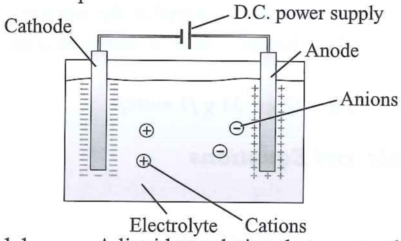
1.1 E.g. gold *[1 mark]*
1.2 Many metals can react with other elements/oxygen to form compounds/oxides *[1 mark]*.
1.3 Reduction is the loss of oxygen *[1 mark]*.
1.4 Magnesium is more reactive than carbon *[1 mark]*.
2.1 $2Fe_2O_3 + 3C \rightarrow 4Fe + 3CO_2$
[1 mark for correct equation, 1 mark for correct balancing]
2.2 Carbon has been oxidised *[1 mark]* as it has gained oxygen during this reaction *[1 mark]*.
2.3 E.g. extracting magnesium would have high energy costs to provide the high temperature and reduced pressure needed *[1 mark]*, but iron extraction doesn't need to be continuously heated *[1 mark]*.

Page 137 — Redox Reactions

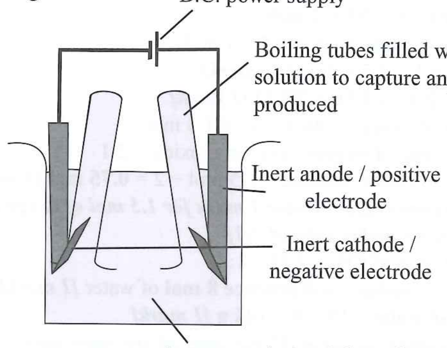
1.1 Reduction is the gain of electrons *[1 mark]*.
1.2 zinc chloride + sodium → zinc + sodium chloride *[1 mark]*
1.3 Hydrogen gains electrons *[1 mark]*.
1.4 Chlorine is neither oxidised nor reduced *[1 mark]*.
2.1 $Mg_{(s)} + Fe^{2+}_{(aq)} \rightarrow Mg^{2+}_{(aq)} + Fe_{(s)}$ *[1 mark]*
You still get the marks if you didn't include state symbols.
2.2 No reaction would occur *[1 mark]*. Copper is less reactive than iron so doesn't displace it *[1 mark]*.

Pages 138-140 — Electrolysis

Warm-up



1.1 A liquid or solution that can conduct electricity *[1 mark]*.
1.2 lead bromide → lead + bromine *[1 mark]*
1.3 Lead ions have a positive charge *[1 mark]*. This means they are attracted to the negative cathode *[1 mark]*.
1.4 Br^- *[1 mark]*
1.5 oxidation *[1 mark]*
1.6 So the ions can move to the electrodes *[1 mark]*.
2.1 molten aluminium *[1 mark]*
2.2 To lower the melting point of the electrolyte *[1 mark]*.
2.3 Carbon in the electrodes reacts with oxygen to form carbon dioxide *[1 mark]*, so they degrade over time *[1 mark]*.
3.1 Iron ions, chloride ions, hydrogen ions and hydroxide ions *[1 mark for iron ions and chloride ions, 1 mark for hydrogen ions and hydroxide ions]*.
3.2 At the cathode: hydrogen is discharged.
At the anode: chlorine is discharged *[1 mark]*.
3.3 oxygen *[1 mark]*
3.4 Iron can be extracted via reduction with carbon *[1 mark]*, which is less expensive than electrolysis *[1 mark]*.
4.1 E.g.



[1 mark for power supply, 1 mark for electrodes in solution, 1 mark for boiling tubes over the electrodes, 1 mark for labels]

4.2

Solution	Product at cathode	Product at anode
$CuCl_2$	Cu	Cl_2
KBr	H_2	Br_2
H_2SO_4	H_2	O_2 and H_2O

[1 mark for each correct answer]

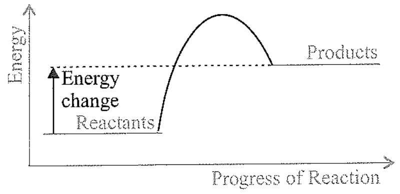
4.3 Potassium is more reactive than hydrogen *[1 mark]* so hydrogen is discharged *[1 mark]*. There are no halide ions *[1 mark]* so oxygen and water are discharged *[1 mark]*.
4.4 Cathode: $2H^+ + 2e^- \rightarrow H_2$ *[1 mark]*
Anode: $4OH^- \rightarrow O_2 + 2H_2O + 4e^-$
/ $4OH^- - 4e^- \rightarrow O_2 + 2H_2O$ *[1 mark]*

Topic C5 — Energy Changes

Pages 141-142 — Exothermic and Endothermic Reactions

1 In an endothermic reaction, energy is transferred from the surroundings so the temperature of the surroundings goes down *[1 mark]*.
2.1 endothermic *[1 mark]*

2.2



[1 mark for correct curve, 1 mark for energy change]

The curve has to go above the energy of the products and then fall back down. If you didn't do this, you don't get the mark.

2.3 From the surroundings ***[1 mark]***.

2.4 It stays the same ***[1 mark]***.

2.5 E.g. a sports injury pack ***[1 mark]***.

3.1 The activation energy is the minimum amount of energy that reactants must have when they collide with each other in order to react ***[1 mark]***. It's shown by the difference between the energy of the reactants and the maximum energy reached by the curve on the reaction profile ***[1 mark]***.

3.2 Reaction A is the most suitable reaction ***[1 mark]***.
Reaction C is endothermic, so would not give out heat, and couldn't be used to warm your hands ***[1 mark]***.
Reaction A has a lower activation energy than Reaction B / gives out more energy than Reaction B ***[1 mark]***.

4.1 Any three from: e.g. thermometer / polystyrene cup (and lid) / mass balance / measuring cylinder / beaker filled with cotton wool / stopwatch ***[1 mark for each]***.

4.2 How to grade your answer:
Level 0: There is no relevant information ***[No marks]***.
Level 1: The method is vague, and misses out important details about how the investigation could be carried out ***[1 to 2 marks]***.
Level 2: The method is clear, but misses out a few key details about how the investigation would be carried out or how the variables could be controlled ***[3 to 4 marks]***.
Level 3: There is a clear and detailed method that includes ways to reduce energy transfer to the surroundings, and specifies variables that should be controlled throughout the investigation ***[5 to 6 marks]***.
Here are some points your answer may include:
Measure out an exact volume of the acid solution into the polystyrene cup.
Record the initial temperature of the acid solution.
Add one metal powder and stir the mixture.
Place a lid on the polystyrene cup to reduce the amount of energy transferred to the surroundings.
Take the temperature of the mixture every 30 seconds and record the highest temperature.
Repeat the experiment for each different metal.
Use the same volume and concentration of acid each time you repeat the experiment.
Make sure the acid starts at the same temperature each time you repeat the experiment.
Use the same number of moles and the same surface area of metal each time you repeat the experiment.

Page 143 — Bond Energies

1.1 Energy to break the bonds = (4 × C–H) + Cl–Cl
= (4 × 413) + 243 = 1652 + 243 = 1895 kJ/mol
Energy produced when bonds form = (3 × C–H) + C–Cl + H–Cl
= (3 × 413) + 346 + 432 = 1239 + 346 + 432
= 2017 kJ/mol
Energy change of reaction = Energy to break bonds – Energy produced when bonds form
= 1895 – 2017 = **–122 kJ/mol** ***[3 marks for correct answer, otherwise 1 mark for 1895 kJ/mol, 1 mark for 2017 kJ/mol, 1 mark for subtracting energy produced when bonds form from energy needed to break bonds]***

Three of the C–H bonds are unchanged in this reaction. So you could also calculate this by working out just the energy needed to break the C–H and the Cl–Cl bond, and subtracting the energy that's released when the new C–Cl and H–Cl bonds form.

1.2 The reaction is exothermic ***[1 mark]*** because the energy released when the bonds of the products form is greater than the energy needed to break the bonds of the reactants ***[1 mark]***.

2 Total energy needed to break the bonds in the reactants
= H–H + F–F = 436 + 158 = 594 kJ/mol
Energy change of reaction = Energy needed to break bonds – Energy released when bonds form
So, energy released when bonds form = Energy needed to break bonds – Energy change of reaction
= 594 – (–542) = 1136 kJ/mol
Energy released when bonds form = 2 × H–F bond energy
So, H–F bond energy = 1136 ÷ 2 = **568 kJ/mol**
[3 marks for correct answer, otherwise 1 mark for finding the energy needed to break the bonds, 1 mark for finding the energy released by forming bonds.]

Topic C6 — The Rate and Extent of Chemical Change

Pages 144-146 — Rates of Reaction

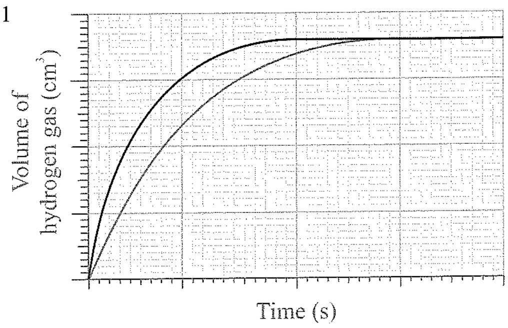
1.1 Using a larger volume of the solution, but keeping the concentration the same ***[1 mark]***.

1.2 activation energy ***[1 mark]***

1.3 A catalyst decreases the activation energy ***[1 mark]***.

2 Produced most product: C ***[1 mark]***
Finished first: B ***[1 mark]***
Started at the slowest rate: A ***[1 mark]***

3.1



[1 mark for curve with steeper gradient at the start of the reaction, 1 mark for curve reaching the final volume earlier, 1 mark for final volume being the same as for the other curve]

3.2 The frequency of the collisions ***[1 mark]*** and the energy of the colliding particles ***[1 mark]***.

3.3 There are more particles in a given volume/the particles are closer together ***[1 mark]***, so the collisions between particles are more frequent ***[1 mark]***.

3.4 The rate would increase ***[1 mark]***.

3.5 Smaller pieces have a higher surface area to volume ratio ***[1 mark]***. So for the same volume of solid, the particles around it will have more area to work on and collisions will be more frequent ***[1 mark]***.

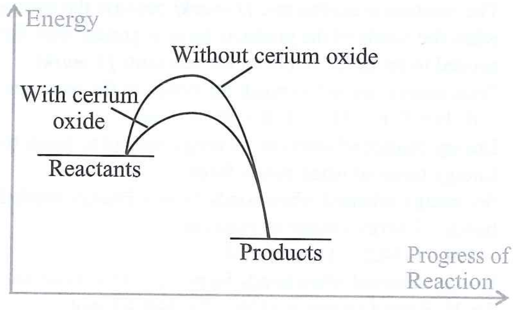
3.6 E.g. changing the temperature / adding a catalyst ***[1 mark]***.

4.1 E.g. increasing the volume of the reaction vessel would decrease the pressure of the reacting gases ***[1 mark]***. So the particles would be more spread out and would collide less frequently ***[1 mark]***, so the reaction rate would decrease ***[1 mark]***.
Increasing the temperature would cause the particles to move faster, so the frequency of collisions would increase ***[1 mark]*** and the reaction rate would increase ***[1 mark]***.

4.2 It's a catalyst ***[1 mark]***.

4.3 The reaction equation won't change ***[1 mark]***. Cerium oxide isn't used up in the reaction, so doesn't appear in the reaction equation ***[1 mark]***.

4.4



[1 mark for correct relative energies of products and reactants, 1 mark for start and end energies being the same for reactions with and without cerium oxide, 1 mark for reaction with cerium oxide rising to a lower energy than reaction without cerium oxide]

Pages 147-149 — Measuring Rates of Reaction

Warm-up

The rate of a reaction can be measured by dividing the amount of **reactants** used up or the amount of **products** formed by the **time**. To find the rate at a particular time from a graph with a curved line of best fit, you have to find the **gradient** of the **tangent** at that time.

1 mass *[1 mark]*, volume of gas *[1 mark]*

2.1 time taken for the solution to go cloudy *[1 mark]*

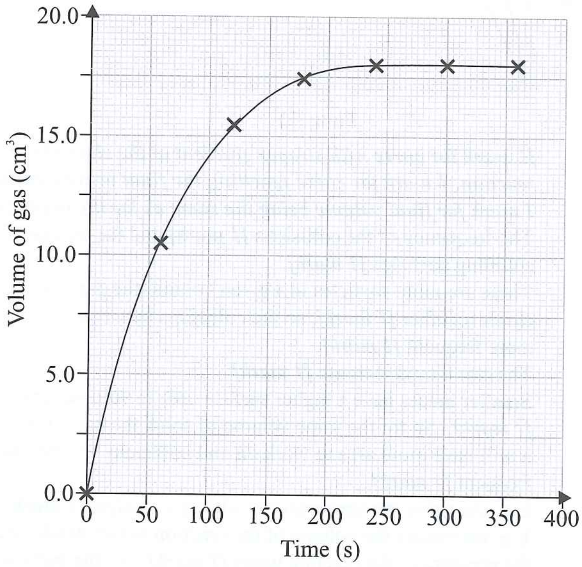
2.2 temperature *[1 mark]*

2.3 Any one from: e.g. the concentration of the reactants / the volume of the reactants / the depth of the reaction mixture *[1 mark]*.

2.4 It would be more accurate to measure the volume of gas produced *[1 mark]* as this method less subjective *[1 mark]*.

3.1 E.g. a gas syringe / a measuring cylinder inverted in a bowl of water *[1 mark]*.

3.2



[2 marks for all points plotted correctly, or 1 mark for at least 5 points plotted correctly, 1 mark for line of best fit.]

3.3 Any value between 210-240 s *[1 mark]*

When no more gas is produced, the reaction has stopped.

3.4 E.g. Mean rate of reaction = $\frac{\text{amount of product formed}}{\text{time for reaction to stop}}$

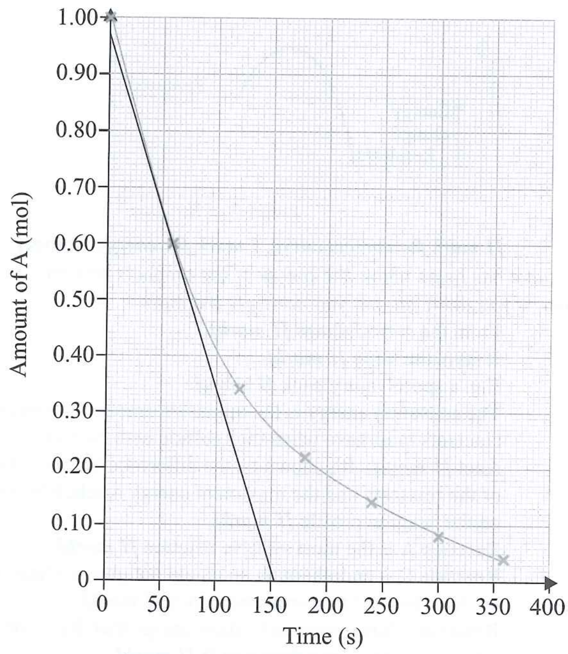
$= \frac{18.0}{240} = \mathbf{0.075\ cm^3/s}$

[2 marks for correct answer between 0.075-0.086 cm³/s, otherwise 1 mark for correct equation]

If you got the wrong answer in 3.3, but used it correctly here as the change in y, you still get all the marks.

3.5 E.g. repeat the experiment using the same method *[1 mark]* and check that the results are similar *[1 mark]*.

4.1

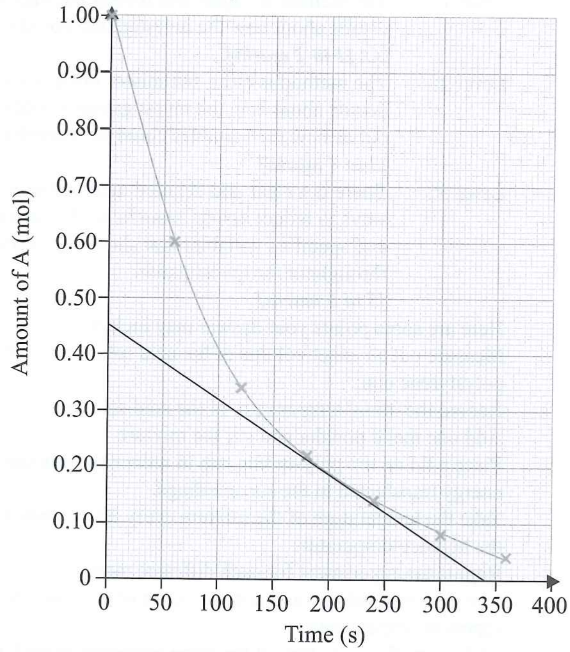


Gradient = $\frac{\text{change in } y}{\text{change in } x} = \frac{0.97}{153} = \mathbf{0.0063\ mol/s}$

(allow between 0.0053 mol/s and 0.0073 mol/s)

[4 marks for correct answer, otherwise 1 mark for correctly drawn tangent to curve at 50 s, 1 mark for answer to 2 s.f., 1 mark for correct units]

4.2



Gradient = $\frac{\text{change in } y}{\text{change in } x} = \frac{0.45}{340} = \mathbf{0.0013\ mol/s}$

(allow between 0.0008 mol/s and 0.0018 mol/s)

[4 marks for correct answer, otherwise 1 mark for correctly drawn tangent to curve at 200 s, 1 mark for answer to 2 s.f., 1 mark for correct units]

4.3 The rate decreases *[1 mark]*. This is because, as the amount of reactant A falls, so does its concentration and so the frequency of collisions between the reactant particles decreases *[1 mark]*.

Page 150 — Reversible Reactions

1.1 That the reaction is reversible / can go both ways *[1 mark]*.

1.2 At equilibrium, the rate of the forward reaction is equal to the rate of the backwards reaction *[1 mark]*.

2.1 It will be exothermic *[1 mark]*. The same amount of energy will be released in the reverse reaction as is taken in by the forward reaction *[1 mark]*.

2.2 The system has reached equilibrium *[1 mark]*. This mixture contains both blue copper(II) ions and the yellow copper compound, so the colours mix to form green *[1 mark]*.

2.3 E.g. by changing the temperature / by changing the concentration of one of the reactants *[2 marks — 1 mark for each correct answer]*.

Pages 151-152 — Le Chatelier's Principle

Warm-up

more reactants
more reactants
more products

1.1 If you change the conditions of a reversible reaction at equilibrium, the system will try to counteract that change *[1 mark]*.

1.2 E.g. the temperature / the concentration of the reactants *[2 marks — 1 mark for each correct answer]*

2.1 At higher temperatures there will be more ICl and less ICl_3 / the equilibrium will shift to the left *[1 mark]*. This is because the reverse reaction is endothermic so opposes the increase in temperature *[1 mark]*.

2.2 There would be more ICl_3 and less ICl *[1 mark]* because the increase in pressure *[1 mark]* causes the equilibrium position to move to the side with the fewest molecules of gas *[1 mark]*.

3.1 At higher temperature there's more product (brown NO_2) in the equilibrium mixture *[1 mark]*. This suggests that the equilibrium has moved to the right/forward direction *[1 mark]*, so the forward reaction is endothermic *[1 mark]*.

From Le Chatelier's principle, you know that increasing the temperature will favour the endothermic reaction as the equilibrium tries to oppose the change. So the forward reaction must be endothermic, as there's more NO_2 in the equilibrium mixture at higher temperatures.

3.2 The mixture would go a darker brown *[1 mark]*, as the decrease in pressure causes the equilibrium to move to the side with the most molecules of gas *[1 mark]*, meaning more NO_2 is formed *[1 mark]*.

4 Observation 1: Increasing amounts of red $FeSCN^{2+}$ are formed, so the solution becomes a darker red *[1 mark]*. When equilibrium is reached, the amount of each substance stops changing, and so does the colour *[1 mark]*.
Observation 2: The concentration of Fe^{3+} initially increases, so the solution becomes more orangey *[1 mark]*. The equilibrium then shifts to make more $FeSCN^{2+}$, so the solution becomes darker red in colour *[1 mark]*.
Observation 3: The concentration of $FeSCN^{2+}$ initially increases, so the solution becomes darker red *[1 mark]*.
The equilibrium then shifts to produce more reactants, so the solution becomes more orangey *[1 mark]*.

Topic C7 — Organic Chemistry

Pages 153-154 — Hydrocarbons

Warm-up

Hydrocarbon	Not a hydrocarbon
propane ethene C_2H_6 C_2H_4	butanoic acid CH_3CH_2Cl hydrochloric acid

1.1 A compound that is formed from hydrogen and carbon atoms only *[1 mark]*.

1.2 butane, propane, ethane, methane *[1 mark]*

1.3 C_nH_{2n+2} *[1 mark]*

1.4 hydrocarbon + oxygen → **carbon dioxide** + **water** *[1 mark]*

1.5 oxidised *[1 mark]*

2.1 **B** *[1 mark]*

2.2 **B**, **D**, and **E** *[1 mark]*. They have the general formula C_nH_{2n+2} *[1 mark]*.

2.3 **E** *[1 mark]*. Boiling point increases with increasing molecular size/number of carbons *[1 mark]*.

3.1 Diesel will be more viscous than petrol *[1 mark]*. The higher boiling point of diesel means it contains larger molecules/ molecules with longer chains *[1 mark]*.

3.2 Petrol *[1 mark]*. The lower boiling point of petrol means it contains smaller molecules/molecules with shorter chains *[1 mark]*.

3.3 $C_{20}H_{42}$ *[1 mark]*

3.4 $2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$ *[1 mark for correct formulas of products, 1 mark for balancing]*

Any correct balance of the equation is correct, e.g. $C_8H_{18} + 12\frac{1}{2}O_2 \rightarrow 8CO_2 + 9H_2O$.

Page 155 — Fractional Distillation

1.1 The remains of ancient organisms/plankton *[1 mark]*.

1.2 A resource which is being used quicker than it is being replaced so will run out eventually *[1 mark]*.

1.3 alkanes *[1 mark]*

2.1 boiling point *[1 mark]*

2.2 The fractionating column is hot at the bottom and cool at the top *[1 mark]*. So longer hydrocarbons, which have higher boiling points, will condense and be drained off near the bottom *[1 mark]*. Meanwhile, shorter hydrocarbons, with lower boiling points, will condense and be drained off further up the column *[1 mark]*.

2.3 They contain similar numbers of carbon atoms / they have a similar chain length *[1 mark]*.

Pages 156-157 — Uses and Cracking of Crude Oil

1.1 Any two from: e.g. solvents / lubricants / polymers / detergents *[2 marks — 1 mark for each correct answer]*

1.2 cracking *[1 mark]*

1.3 E.g. shorter chain hydrocarbons are more useful/can be used for more applications *[1 mark]*.

2.1 thermal decomposition / endothermic *[1 mark]*

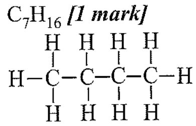
2.2 Hydrocarbons are vaporised / heated to form gases *[1 mark]*. The vapours are then passed over a hot catalyst / the vapours are mixed with steam and heated to very high temperatures *[1 mark]*.

2.3 E.g. $C_{10}H_{22} \rightarrow C_7H_{16} + C_3H_6$ *[1 mark]*

Cracking equations must always be balanced and have a shorter alkane and an alkene on the right-hand side.

3.1 C_7H_{16} *[1 mark]*

3.2



[1 mark for correct number of carbons, 1 mark for correct displayed formula]

3.3 E.g. to produce polymers / as a starting material for other chemicals *[1 mark]*.

4 How to grade your answer:

Level 0: Nothing written worth of credit *[No marks]*.

Level 1: Basic outline of how some fractions are processed but lacking detail. Some mention of the uses of cracking products *[1 to 2 marks]*.

Level 2: Reason for cracking explained and some detail given about the process. The uses of cracking products are covered in detail *[3 to 4 marks]*.

Level 3: Reasons for cracking and the process of cracking are explained in detail, including an accurate balanced symbol or word equation. Examples given of the uses of the products of cracking *[5 to 6 marks]*.

Here are some points your answer may include:

Reasons for cracking

There is a higher demand for short chain hydrocarbons as these make good fuels.
Long chain hydrocarbons are less useful than short chain hydrocarbons, so there is less demand for them.
Cracking helps the supply of short chain hydrocarbons to meet the demand.

Cracking process

The long chain hydrocarbons are heated and vaporised.
The vapours are passed over a hot catalyst / mixed with steam and heated to a high temperature so that they thermally decompose.
Any relevant word equation: e.g. decane → octane + ethene
Any relevant balanced equation:
e.g. $C_{12}H_{26} \rightarrow C_8H_{18} + 2C_2H_4$

Uses of cracking products
The products of cracking are useful as fuels.
Alkenes are used as a starting material when making lots of other compounds and can be used to make polymers.

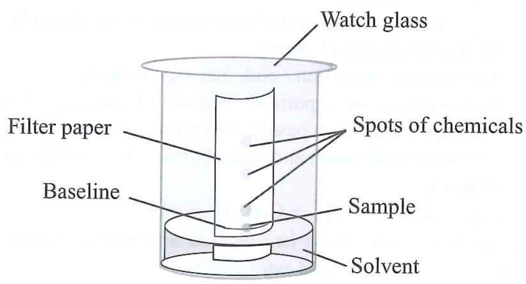
Topic C8 — Chemical Analysis

Page 158 — Purity and Formulations

1.1 A single element or compound not mixed with any other substance ***[1 mark]***.
1.2 Sample **A** ***[1 mark]***. The purer the substance, the smaller the range of the melting point / purer substances melt at higher temperatures than impure substances ***[1 mark]***.
1.3 Sample **A** ***[1 mark]***.
2.1 It is a mixture that has been designed to have a precise purpose ***[1 mark]***. Each of the components is present in a measured quantity ***[1 mark]*** and contributes to the properties of the formulation ***[1 mark]***.
2.2 By making sure each component in the mixture is always present in exactly the same quantity ***[1 mark]***.
2.3 Any one from: e.g. medicines / cleaning products / fuels / cosmetics / fertilisers / metal alloys ***[1 mark]***.

Pages 159-160 — Paper Chromatography

Warm-up



1.1 **E**: $R_f = \frac{\text{distance travelled by substance}}{\text{distance travelled by solvent}} = \frac{3.6}{9.5} = \mathbf{0.38}$
[2 marks for correct answer, otherwise 1 mark for using correct equation to calculate R_f]
F: $R_f = \frac{\text{distance travelled by substance}}{\text{distance travelled by solvent}} = \frac{8.0}{9.5} = \mathbf{0.84}$
[2 marks for correct answer, otherwise 1 mark for using correct equation to calculate R_f]
1.2 E.g. they're distributed differently between the mobile phase and the stationary phase ***[1 mark]***.
1.3 They're all pure substances ***[1 mark]***.
1.4 **D** and **E** ***[1 mark]***.
2.1 E.g. to stop any solvent evaporating ***[1 mark]***.
2.2 **A** spends more time in the mobile phase compared to the stationary phase than **B** does ***[1 mark]***.
2.3 **B** and **C** ***[1 mark]***.
2.4 The student is incorrect ***[1 mark]***. Substances have different R_f values in different solvents as the attraction between the substance and solvent changes ***[1 mark]***.
2.5 It suggest that there are at least 3 substances in **W** ***[1 mark]***.
2.6 There were only two spots in the chromatogram shown because two of the substances in **W** are similarly distributed between the mobile phase/water and stationary phase / they had similar R_f values ***[1 mark]***.

Page 161 — Tests for Gases

1.1 litmus paper ***[1 mark]***.
1.2 chlorine/Cl_2 ***[1 mark]***
2.1 E.g. the gas could be toxic/an irritant ***[1 mark]***
2.2 Bubble the gas through limewater ***[1 mark]***. If the gas is carbon dioxide, the limewater will turn cloudy ***[1 mark]***.
2.3 The gas was not hydrogen ***[1 mark]***.
2.4 oxygen ***[1 mark]***

Topic C9 — Chemistry of the Atmosphere

Pages 162-163 — The Evolution of the Atmosphere

Warm-up
1 False
2 True
3 True
4 False
1.1 One-fifth oxygen and four-fifths nitrogen ***[1 mark]***.
1.2 Any two from: e.g. carbon dioxide / water vapour / named noble gas ***[2 marks — 1 mark for each correct answer]***
1.3 By algae and plants photosynthesising ***[1 mark]***.
1.4 By volcanic activity ***[1 mark]***.
1.5 200 million years ***[1 mark]***
2.1 E.g. photosynthesis by plants and algae / carbon dioxide dissolved in the oceans ***[1 mark]***.
2.2 From matter that is buried and compressed over millions of years ***[1 mark]***.
2.3 Coal: from thick plant deposits ***[1 mark]***.
Limestone: from calcium carbonate deposits from the shells and skeletons of marine organisms ***[1 mark]***.
3.1 E.g. the long timescale means there's a lack of evidence ***[1 mark]***.
3.2 $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$ ***[1 mark]***
3.3 Oxygen is produced by photosynthesis ***[1 mark]*** and there are no plants or algae / there isn't any photosynthesis ***[1 mark]*** on Mars.
3.4 The fact that the red beds formed about 2 billion years ago suggests that before this time there wasn't enough oxygen in the air for iron oxide to form / from this time there was enough oxygen in the air for iron oxide to form ***[1 mark]***.

Pages 164-165 — Greenhouse Gases and Climate Change

1.1 Nitrogen ***[1 mark]***
1.2 They help to keep Earth warm ***[1 mark]***.
1.3 Any two from: e.g. deforestation / burning fossil fuels / agriculture / producing waste ***[2 marks — 1 mark for each correct answer]***
2.1 Greenhouse gases absorb long-wave (thermal) radiation ***[1 mark]*** reflected from Earth's surface ***[1 mark]***. They then reradiate this thermal radiation in all directions, including back towards Earth, helping to warm the atmosphere ***[1 mark]***.
2.2 E.g. flooding ***[1 mark]*** and coastal erosion ***[1 mark]***.
2.3 Any one from: e.g. changes in rainfall patterns / the ability of certain regions to produce food might be affected / the frequency/severity of storms might increase / the distribution of wild species might change ***[1 mark]***.
3 How to grade your answer:
Level 0: There is no relevant information ***[No marks]***.
Level 1: Unstructured and no logic. The trends in the variables are described but reasons are not given ***[1 to 2 marks]***.
Level 2: Some structure and logic but lacking clarity. The trends in the variables are described and there is some explanation of how the increase in carbon dioxide may have come about and how this might be linked to temperature ***[3 to 4 marks]***.
Level 3: Clear, logical answer. The trends in the variables are described and there is a clear explanation of how the increase in carbon dioxide may have come about and how this may be linked to temperature ***[5 to 6 marks]***.
Here are some points your answer may include:
The graph shows an increase in carbon dioxide levels in the atmosphere between 1960 and 2015.
The increase in carbon dioxide levels is likely to be due to human activities which release carbon dioxide into the atmosphere. These activities include increased burning of fossil fuels, increased deforestation and increased waste production.
The graph shows that the increase in carbon dioxide appears to correlate with an increase in global temperatures.
The increase in global temperatures is likely to be due to the increase in carbon dioxide in the atmosphere, as carbon dioxide is a greenhouse gas so helps to keep Earth warm.

4.1 The global warming potential for methane is significantly greater than for carbon dioxide *[1 mark]*.

4.2 It has a very high global warming potential compared to other gases *[1 mark]* and stays in the atmosphere for a long time *[1 mark]*.

Page 166 — Carbon Footprints

1.1 A measure of the amount of carbon dioxide and other greenhouse gases *[1 mark]* released over the full life cycle of something *[1 mark]*.

1.2 Any two from: e.g. using renewable or nuclear energy sources / using more energy efficient appliances *[2 marks — 1 mark for each correct answer]*.

1.3 E.g. lack of education / reluctance to change their lifestyle / cost of changing lifestyle *[1 mark]*.

2.1 Any two from, e.g: specialist equipment is needed to capture the carbon dioxide / it's expensive to capture and store the carbon dioxide / it could be difficult to find suitable places to store the carbon dioxide *[2 marks — 1 mark for each correct answer]*.

2.2 E.g. governments could tax companies based on the amount of greenhouse gases they emit *[1 mark]*. They could also put a cap on the emissions produced by a company *[1 mark]*. Governments might be reluctant to impose these methods if they think it will affect economic growth / could impact on people's well-being *[1 mark]*, especially if other countries aren't using these methods either / the country is still developing *[1 mark]*.

Page 167 — Air Pollution

1.1 Coal can contain sulfur impurities *[1 mark]*

1.2 Acid rain: sulfur dioxide / nitrogen oxides/nitrogen monoxide/ nitrogen dioxide/dinitrogen monoxide *[1 mark]*
Global dimming: e.g. (carbon) particulates *[1 mark]*

1.3 Any two from: e.g. damage to plants / buildings / statues / corrodes metals *[2 marks — 1 mark for each correct answer]*.

2.1 The reaction of nitrogen and oxygen from the air *[1 mark]* at the high temperatures produced by combustion *[1 mark]*.

2.2 Nitrogen oxides cause respiratory problems *[1 mark]* and contribute to acid rain *[1 mark]*.

2.3 E.g. they can cause respiratory problems *[1 mark]*.

2.4 Carbon monoxide *[1 mark]*. It is colourless and odourless *[1 mark]*.

Topic C10 — Using Resources

Page 168 — Finite and Renewable Resources

1.1 Coal *[1 mark]*. It does not form fast enough to be considered replaceable *[1 mark]*.

1.2 A resource that reforms at a similar rate to, or faster, than humans can use it *[1 mark]*.

2.1 E.g. the development of fertilisers has meant higher yields of crops *[1 mark]*.

2.2 Any one from: e.g. synthetic rubber has replaced natural rubber / poly(ester) has replaced cotton in clothes / bricks are used instead of timber in construction *[1 mark]*.

3 Any one advantage from: e.g. allows useful products to be made / provides jobs / brings money into the area *[1 mark]*.
Any one disadvantage: e.g. uses large amounts of energy / scars the landscape / produces lots of waste / destroys habitats *[1 mark]*.

Pages 169-170 — Reuse and Recycling

1.1 An approach to development that takes account of the needs of present society *[1 mark]* while not damaging the lives of future generations *[1 mark]*.

1.2 E.g. chemists can develop and adapt processes that use less resources/do less damage to the environment *[1 mark]*. For example, chemists have developed catalysts that reduce the amount of energy required for industrial processes *[1 mark]*.

2.1 The raw materials for the jute bag are more sustainable *[1 mark]* as plant fibres are a renewable resource, whilst crude oil is a finite resource *[1 mark]*.

2.2 The production of the poly(ethene) bag is more sustainable *[1 mark]* as it needs less energy to be produced from its raw materials than the jute bag *[1 mark]*.

2.3 The jute bag can be reused and the poly(ethene) bag can be recycled, improving both their sustainability *[1 mark]*. However, the jute bag is more sustainable if the bags are disposed of in landfill *[1 mark]*, as it is biodegradeable, whilst the poly(ethene) bag isn't *[1 mark]*.

3.1 Any two from: e.g. often uses less energy / conserves the amount of raw materials on Earth / cuts down on waste sent to landfill *[2 marks — 1 mark for each correct answer]*.

3.2 Any one from: e.g. glass / metal *[1 mark]*
E.g. glass is crushed and melted down to form other glass products/other purpose / metal is melted and cast into the shape of a new product *[1 mark]*.

3.3 reusing *[1 mark]*

4.1 Plants are grown on soil containing copper compounds *[1 mark]*, so as they grow, copper builds up in their leaves *[1 mark]*. The plants are burned *[1 mark]*. The resulting ash contains the copper compounds *[1 mark]*.

4.2 By electrolysis of a solution containing the copper compounds *[1 mark]* or by displacement using scrap iron *[1 mark]*.

4.3 Copper is a finite resource *[1 mark]* and will eventually run out *[1 mark]*. Recycling copper makes it more sustainable *[1 mark]*.

Page 171 — Life Cycle Assessments

Warm-up
Getting the Raw Materials — Coal being mined from the ground.
Manufacturing and Packaging — Books being made from wood pulp.
Using the Product — A car using fuel while driving.
Product Disposal — Plastic bags going on to landfill.

1.1 Any two from: e.g. if a product is disposed of in landfill sites, it will take up space / may pollute land/water / energy is used to transport waste to landfill / pollution can be caused by incineration *[2 marks — 1 mark for each correct answer]*.

1.2 Any one from: e.g. energy / water / some natural resources / certain types of waste *[1 mark]*

1.3 They can be subjective / they are difficult to measure *[1 mark]*.

1.4 No *[1 mark]*. Some elements of the LCA are not objective/ require the assessors to make value judgements/cannot be quantified reliably *[1 mark]*, therefore different people are likely to make a different judgement/estimate *[1 mark]*.

1.5 Selective LCAs could be written so they only show elements that support a company's claims / they could be biased *[1 mark]* in order to give them positive advertising *[1 mark]*.

Pages 172-173 — Potable Water

Warm-up
1 False
2 True
3 False

1.1 pure water *[1 mark]*

1.2 e.g. from the ground / lakes / rivers *[1 mark]*.

1.3 passing water through filter beds — solid waste *[1 mark]*
sterilisation — microbes *[1 mark]*

1.4 E.g. chlorine, ozone, ultraviolet light *[3 marks — 1 mark for each correct answer]*.

2.1 **A**: Bunsen burner *[1 mark]*
B: round bottom flask *[1 mark]*
C: thermometer *[1 mark]*
D: condenser *[1 mark]*

2.2 Pour the salt water into the flask and secure it on top of a tripod *[1 mark]*. Connect the condenser to a supply of cold water *[1 mark]* that goes in at the bottom and out at the top *[1 mark]*. Heat the flask and allow the water to boil *[1 mark]*. Collect the water running out of the condenser in a beaker *[1 mark]*.

2.3 Reverse osmosis / a method which uses membranes *[1 mark]*

2.4 Desalination requires a lot of energy compared to the filtration and sterilisation of fresh water *[1 mark]*. Since the UK has a plentiful supply of fresh water there is no need to use desalination processes *[1 mark]*.

Page 174 — Waste Water Treatment

1.1 organic matter, harmful microbes *[2 marks — 1 mark for each correct answer]*

1.2 It may contain harmful chemicals which need to be removed *[1 mark]*.

2.1 To remove grit ***[1 mark]*** and large bits of material/twigs/plastic bags ***[1 mark]***.

2.2 Substance A: sludge ***[1 mark]***
Substance B: effluent ***[1 mark]***

2.3 anaerobic digestion ***[1 mark]***

2.1 Energy can be created.
Energy can be destroyed.
[1 mark for both correct answers, otherwise no marks if more than two boxes have been ticked]

2.2 Useful energy store: e.g. kinetic energy store (of razor) ***[1 mark]***
Wasted energy store: e.g. thermal energy store