Contents

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Printed by Elanders Ltd, Newcastle upon Tyne.
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Topic 1 — Atomic Structure and the Periodic Table

Page 1 — 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 2 — 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 3 — 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 4 — 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 5 — 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:

Setting up the experiment

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.

Explanation of results

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 6 — 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 7 — 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 aspirin 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 aspirin back into a liquid which is then collected *[1 mark]*.

2.3 The aspirin 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 8-9 — 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.

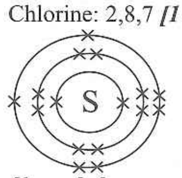
Page 10 — Electronic Structure

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 11 — 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/cm^3 *[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 12 — 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 13 — Metals and Non-Metals

1.1 Metals: Towards the left and bottom.
Non-metals: Towards the right and top *[1 mark]*.
1.2 Elements that react to form positive ions are metals *[1 mark]*.
1.3 Any one from: e.g. good electrical conductor / good thermal conductor / strong / high boiling point / high melting point / malleable *[1 mark]*.
1.4 Both are metals that lose their (2 or 3) outer shell electrons *[1 mark]* to form positive ions *[1 mark]*.
2.1 Iron is a metal and therefore strong / good at conducting heat/electricity / has a high boiling/melting point *[1 mark for each property up to a maximum of 2 marks]*. Sulfur is a non-metal and therefore is more brittle / has a lower density / doesn't conduct electricity / dull looking *[1 mark for each property up to a maximum of 2 marks]*.
2.2 E.g. they can form more than one ion *[1 mark]*, they make good catalysts *[1 mark]*.
2.3 Any two from: e.g. cobalt / copper / manganese / nickel / chromium / vanadium *[1 mark for each correct answer]*

Any two transition metals (apart from iron) will get you the marks.

Page 14 — 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 15-16 — 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]*

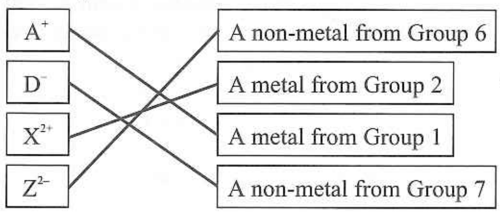
Page 17 — Group 0 Elements

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 2 — Bonding, Structure and Properties of Matter

Page 18 — Formation of Ions

1.1 Metal atoms usually lose electrons to become positive ions *[1 mark]*.
1.2

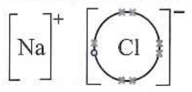
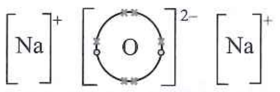
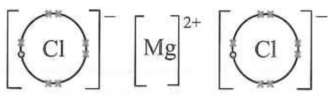


[2 marks if all four correct, otherwise 1 mark if two correct]

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 19-20 — Ionic Bonding

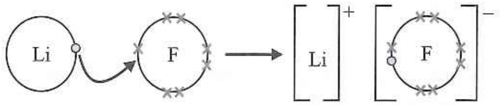
Warm-up

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

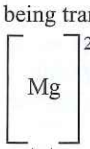


[1 mark for arrow showing electron transfer from Li to F, 1 mark for correct electronic structure of fluoride ion, with seven crosses and one dot, 1 mark for correct charges on the ions.]

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

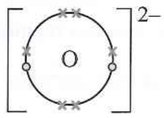
1.4 E.g. the particles in the compound are oppositely charged ions / have opposite charges / the bond is formed by electrons being transferred from one atom to another ***[1 mark]***.

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 21-22 — 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**.

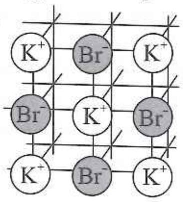
1.1 conduct electricity in the solid state ***[1 mark]***

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 23-24 — Covalent Bonding

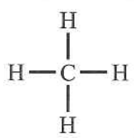
1.1 They share a pair of electrons ***[1 mark]***.

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]***.

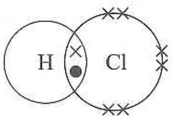
4.2 The displayed formula ***[1 mark]*** would be the best as it is easy to see how the atoms in a large molecule are connected without the diagram becoming too complicated ***[1 mark]***.

Pages 25-26 — Simple Molecular Substances

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

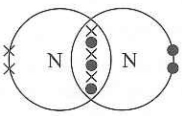
1.2 The weak forces between the molecules / the intermolecular forces ***[1 mark]***.

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]***.

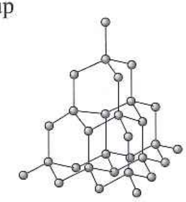
4.2 Carbon needs four more electrons to get a full outer shell, and does this by forming four covalent bonds ***[1 mark]***. Hydrogen only needs one more electron to complete its outer shell, so can only form one covalent bond ***[1 mark]***.

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 27 — 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]***.

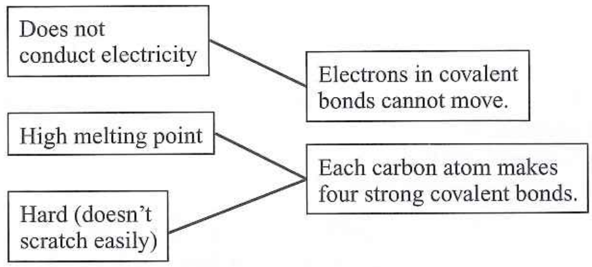
2.1 $(C_2H_4)_n$ ***[1 mark]***

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 28 — Allotropes of Carbon

1.1



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

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

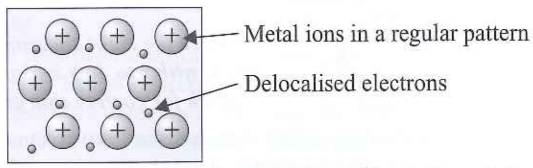
1.3 Any one of, e.g. to strengthen materials / to deliver drugs into the body / as a catalyst / as a lubricant / in electronics ***[1 mark]***

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 current ***[1 mark]***.

Page 29 — 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 30 — 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]***

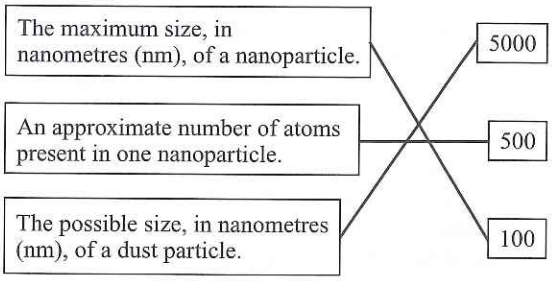
2.4 Any two from: e.g. the model says nothing about forces between particles / particles aren't really spheres / particles are mostly empty space, not solid ***[1 mark for each]***.

Page 31 — 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]*.

Pages 32-33 — Nanoparticles

Warm-up
1 True
2 False
3 True
4 True
5 False
1



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

2.1 10 nm × 10 nm × 10 nm = **1000 nm^3** *[1 mark]*
2.2 Area of one side = 10 nm × 10 nm = 100 nm^2
A cube has six sides, so total surface area = 6 × 100 nm^2
= **600 nm^2** ***[2 marks for correct answer, otherwise 1 mark for the area of one side]***
2.3 Surface area to volume ratio = 600 nm^2 ÷ 1000 nm^3
= **0.6 nm^{-1}** *[1 mark]*
2.4 Volume = 1 nm × 1 nm × 1 nm = 1 nm^3
Surface area of one side = 1 nm × 1 nm = 1 nm^2
Total surface area of cube = 6 × 1 nm^2 = 6 nm^2
Surface area to volume ratio = 6 nm^2 ÷ 1 nm^3 = **6 nm^{-1}**
[4 marks for correct answer, otherwise 1 mark for correct volume, 1 mark for correct surface area of one side, 1 mark for correct total surface area]
E.g. decreasing the side length by a factor of 10 increases the surface area to volume ratio by a factor of 10 *[1 mark]*.
3.1 Surface area to volume ratio = 0.12 ÷ 10 = **0.012 nm^{-1}** *[1 mark]*
The side length has increased by a factor of ten, so the surface area to volume ratio will decrease by a factor of 10.
3.2 Material Y *[1 mark]*, because the particles have a lower surface area to volume ratio *[1 mark]*.

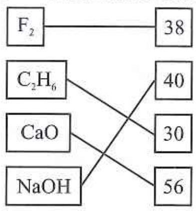
Page 34 — Uses of Nanoparticles

1.1 E.g. suncreams containing nanoparticles give better skin coverage *[1 mark]* and are better at absorbing UV rays *[1 mark]*.
1.2 E.g. the nanoparticles in suncreams may affect people's health *[1 mark]*, and when they're washed away they could damage the environment *[1 mark]*.
2.1 Material: carbon nanotubes *[1 mark]*
Reason: e.g. the carbon nanotubes trap the drug molecules inside, and release them when they're at the right place in the body *[1 mark]*.
2.2 Material: silver *[1 mark]*
Reason: e.g. silver nanoparticles are antibacterial, so will help to kill any bacteria that are in the water *[1 mark]*.
2.3 Material: carbon nanotubes *[1 mark]*
Reason: e.g. carbon nanotubes are strong, so will strengthen the sports equipment, but they are also light, so won't add much weight to the equipment *[1 mark]*.

Topic 3 — Quantitative Chemistry

Page 35 — 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 = $\frac{A_r(\text{Mg})}{M_r(\text{MgO})} \times 100$
= $\frac{24}{40} \times 100$ = **60%** *[1 mark]*
2.2 Mass of magnesium ions = 200 × $\frac{15}{100}$ = **30 g** *[1 mark]*
2.3 Mass of magnesium oxide containing 30 g of magnesium ions = 30 ÷ $\frac{60}{100}$ = **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 36 — The Mole

Warm-up:
6.02×10^{23}
1.1 M_r of carbon dioxide = 12 + (16 × 2) = **44** *[1 mark]*
1.2 Moles of carbon dioxide = 110 ÷ 44 = **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 × 32 g = **64 g** *[1 mark]*
2.2 M_r of iron sulfide = 56 + 32 = 88
Moles of iron sulfide = 44 ÷ 88 = **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 37-38 — 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 reactants *[1 mark]*.
3.2 M_r of sodium oxide = 106 – 44 = **62** *[1 mark]*
3.3 Moles of Na_2CO_3 = 53 ÷ 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 × 44 = **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 39-40 — 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
$\mathbf{2Na + 2H_2O \rightarrow 2NaOH + H_2}$ ***[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 41 — 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 yield 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]***.

Pages 42-43 — Gases and 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 Mass of CO_2 = (36 ÷ 24) × 44 = **66 g**
[2 marks for correct answer, otherwise 1 mark for using the correct equation to calculate mass]

2.2 1 mole of any gas at room temperature and pressure has a volume of 24 dm^3 ***[1 mark]***. So, 1 mole of CO_2 and 1 mole of O_2 will have the same volume ***[1 mark]***.

3.1 M_r of O_2 = 2 × 16 = 32
Volume of oxygen = (16 g ÷ 32) × 24 = **12 dm³**
[3 marks for correct answer, otherwise 1 mark for M_r of oxygen, 1 mark for using the correct equation to calculate volume]

3.2 Molar ratio of oxygen : carbon dioxide = 2:1
Volume of carbon dioxide = 12 ÷ 2 = **6 dm³** ***[2 marks for correct answer, otherwise 1 mark for 2:1 molar ratio]***

4.1 Volume of oxygen = 48 ÷ 2 = **24 dm³** ***[1 mark]***

As the molar ratio of carbon monoxide to oxygen is 2:1, there must be half the volume of oxygen as there is carbon monoxide.

4.2 Volume of carbon monoxide: (28 ÷ 28) × 24 = 24 dm^3
Carbon monoxide to oxygen molar ratio = 2:1 so volume of oxygen = 24 ÷ 2 = **12 dm³** ***[4 marks for correct answer, otherwise 1 mark for using the formula volume = mass ÷ M_r × 24, 1 mark for correct volume of carbon monoxide and 1 mark for 2:1 molar ratio]***

4.3 24 dm^3 ***[1 mark]***

The molar ratio of carbon monoxide to carbon dioxide is 2:2, therefore there is the same volume of carbon dioxide as there is carbon monoxide.

5.1 Moles of Na_2CO_3 = 0.50 mol/dm³ × 0.50 dm³ = **0.25 mol** ***[1 mark]***

5.2 M_r of Na_2CO_3 = (23 × 2) + 12 + (16 × 3) = 106
Mass of 0.25 mol of Na_2CO_3 = 0.25 × 106 = **26.5 g** ***[2 marks for correct answer, otherwise 1 mark for correct working]***

Pages 44-45 — Concentration Calculations

1.1 M_r of HCl = 1 + 35.5 = 36.5
Concentration of HCl = 18.25 ÷ 36.5 = **0.500 mol/dm³**
[3 marks for correct answer, otherwise 1 mark for M_r of HCl, 1 mark for correct equation to convert the units of concentration]

1.2 Volume of HCl = 25.0 cm³ ÷ 1000 = 0.0250 dm³
Moles of HCl = 0.500 mol/dm³ × 0.0250 dm³ = **0.0125 mol**
[3 marks for correct answer, otherwise 1 mark for concentration of HCl in dm³ and 1 mark for correct equation to calculate moles]

1.3 Moles of NaOH = **0.0125 mol** ***[1 mark]***

The molar ratio of hydrochloric acid to sodium hydroxide is 1:1, so there must be the same number of moles of sodium hydroxide as there are hydrochloric acid.

1.4 Volume of NaOH = 50.0 cm³ ÷ 1000 = 0.0500 dm³
Concentration of NaOH = 0.0125 mol ÷ 0.0500 dm³
= **0.250 mol/dm³**
[3 marks for correct answer, otherwise 1 mark for volume of NaOH in dm³ and 1 mark for correct equation to calculate concentration]

1.5 M_r of NaOH = 23 + 16 + 1 = 40
Concentration of NaOH = 0.250 mol × 40 = **10 g/dm³**
[3 marks for correct answer, otherwise 1 mark for M_r of NaOH and 1 mark for correct equation to convert the units of concentration]

2.1 $Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$
[1 mark for correct symbols, 1 mark for correct balancing]

2.2 Mean volume of HCl = (12.50 + 12.55 + 12.45) ÷ 3
= **12.50 cm³**
[2 marks for correct answer, otherwise 1 mark for correct equation to calculate the mean]

2.3 Volume of HCl = 12.50 cm³ ÷ 1000 = 0.01250 dm³
Volume of Na_2CO_3 = 25.0 cm³ ÷ 1000 = 0.0250 dm³
Moles of HCl = 0.0125 dm³ × 1.00 mol/dm³ = 0.0125 mol
Molar ratio of HCl : Na_2CO_3 = 2:1

Moles of Na_2CO_3 = 0.01250 mol ÷ 2 = 0.006250 mol
Concentration of Na_2CO_3 = 0.006250 mol ÷ 0.0250 dm^3
= **0.250 mol/dm^3**
[6 marks for correct answer, otherwise 1 mark for volumes of HCl and Na_2CO_3 in dm^3, 1 mark for correct equation to calculate moles, 1 mark for moles of HCl, 1 mark for moles of Na_2CO_3 and 1 mark for correct equation to calculate concentration]

If answer to question 2.2 is incorrect, but your working is correct here, you still get all the marks, even if you got a different answer.

Page 46 — Atom Economy

1.1 Any two from: e.g. less waste / more sustainable / more profitable ***[2 marks — 1 mark for each correct answer]***.
1.2 M_r of ethanol = (12 × 2) + (1 × 6) + 16 = **46** ***[1 mark]***
1.3 M_r of ethene = (12 × 2) + (1 × 4) = **28** ***[1 mark]***
1.4 Atom economy = (28 ÷ 46) × 100 = **61%**
[2 marks for correct answer, otherwise 1 mark for correct equation for atom economy]
2 Atom economy of reaction using magnesium:
M_r of reactants = A_r(Mg) + (2 × M_r(HCl))
= 24 + (2 × 36.5) = 97
Atom economy = (2 ÷ 97) × 100 = **2%** ***[2 marks for correct answer, otherwise 1 mark for M_r of reactants]***
Atom economy of reaction using zinc:
M_r of reactants = A_r(Zn) + (2 × M_r(HCl))
= 65 + (2 × 36.5) = 138
Atom economy = (2 ÷ 138) × 100 = **1%** ***[2 marks for correct answer, otherwise 1 mark for M_r of reactants]***
More economical reaction: the magnesium reaction ***[1 mark]***

Page 47 — Percentage Yield

1.1 Percentage yield = (1.8 g ÷ 2.4 g) × 100 = **75%**
[2 marks for correct answer, otherwise 1 mark for correct method]
1.2 Any one from: e.g. some of the magnesium may not yet have reacted / some product may have been left behind in the crucible ***[1 mark]***.
2.1 Mass of N_2 in g = 14 × 1000 = 14 000 g
Number of moles of N_2 = 14 000 ÷ (2 × 14) = 500 mol
500 mol of N_2 react to produce 2 × 500 = 1000 mol of NH_3.
M_r of NH_3 = 14 + (3 × 1) = 17
Theoretical yield = moles × M_r = 1000 × 17 = 17 000 g
= **17 kg**
[4 marks for correct answer, otherwise 1 mark for correct number of moles of N_2, 1 mark for correct number of moles of NH_3 and 1 mark for M_r of NH_3]
2.2 Percentage yield = (4.5 kg ÷ 17 kg) × 100 = **26%**
[2 marks for correct answer, otherwise 1 mark for correct method]
2.3 Any two from: e.g. the reaction is reversible so may not have gone to completion / products may have been lost during the reaction / there may have been side reactions ***[1 mark for each correct answer]***.
2.4 Any two from: e.g. to reduce waste / increase sustainability / to reduce cost ***[2 marks — 1 mark for each correct answer]***.

Topic 4 — Chemical Changes

Page 48 — Acids and Bases

Warm-up

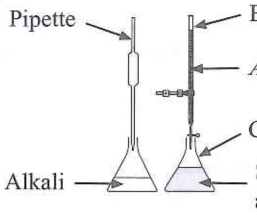
Universal indicator will turn **red** in strongly acidic solutions and **purple** in strongly alkaline solutions. In a **neutral** solution, Universal indicator will be green. A pH probe attached to a pH meter is **more** accurate than Universal indicator as it displays a numerical value for pH.

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 49 — Titrations

Warm-up



1.1 Universal indicator is the most suitable indicator for use in titrations ***[1 mark]***.
1.2 A burette allows an acid/alkali to be added to a solution drop-by-drop ***[1 mark]*** which helps determine the end-point more accurately ***[1 mark]***.
1.3 The titration should be repeated several times to achieve several consistent readings ***[1 mark]***. The mean reading should be used to calculate the concentration ***[1 mark]***.

Page 50 — 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 51-52 — 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 + **2**LiOH → **Li_2SO_4** + **2**H_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 worthy 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 53-54 — 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 55 — Separating Metals from Metal Oxides

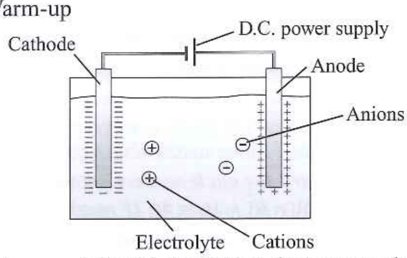
1.1 E.g. gold ***[1 mark]***
1.2 Many metals can react with other elements/oxygen to form compounds/oxides ***[1 mark]***.
1.3 Reduction is the loss of oxygen ***[1 mark]***.
1.4 Magnesium is more reactive than carbon ***[1 mark]***.
2.1 $2Fe_2O_3 + 3C \rightarrow 4Fe + 3CO_2$
[1 mark for correct equation, 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 56 — Redox Reactions

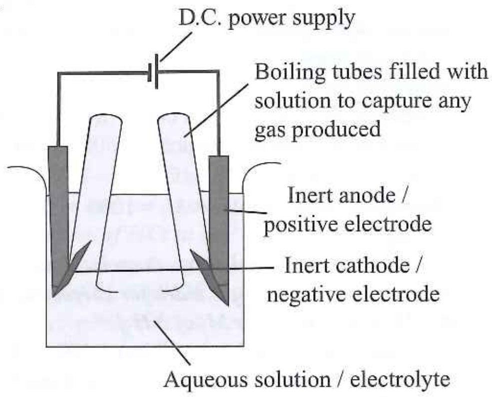
1.1 Reduction is the gain of electrons ***[1 mark]***.
1.2 zinc chloride + sodium → zinc + sodium chloride ***[1 mark]***
1.3 Hydrogen gains electrons ***[1 mark]***.
1.4 Chlorine is neither oxidised nor reduced ***[1 mark]***.
2.1 $Mg_{(s)} + Fe^{2+}_{(aq)} \rightarrow Mg^{2+}_{(aq)} + Fe_{(s)}$ ***[1 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 57-59 — 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 cathode
$CuCl_2$	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]

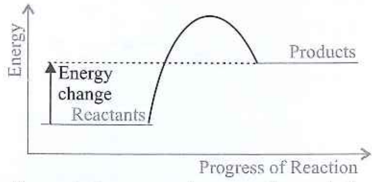
Topic 5 — Energy Changes

Pages 60-61 — 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 62 — 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.

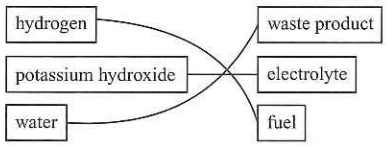
1.2 The reaction is exothermic ***[1 mark]*** because the energy released when the bonds of the products form is greater than the energy needed to break the bonds of the reactants ***[1 mark]***.

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.]

Page 63-64 — Cells, Batteries and Fuel Cells

Warm-up
1 False
2 False
3 True

1



[2 marks for three correct lines, 1 mark for one correct line]

2.1 Cell B ***[1 mark]*** as if the two metals are the same then no voltage will be produced / the two metals must be different in order for a voltage to be produced ***[1 mark]***.

2.2 The set-up is a battery ***[1 mark]***. The voltage will increase to be twice the voltage of Cell B by itself ***[1 mark]***.

2.3 The reactants/chemicals in the cells get used up ***[1 mark]***, so a voltage is no longer produced ***[1 mark]***.

2.4 It can be reversed by connecting the cell to an external electric current ***[1 mark]***.

3.1 Reaction equation: $H_2 \rightarrow 2H^+ + 2e^-$ ***[1 mark]***
Type of reaction: oxidation ***[1 mark]***

3.2 water ***[1 mark]***

3.3 Any one of: e.g. hydrogen fuel cells are less polluting to dispose of than rechargeable batteries / there's a limit to how many times a rechargeable battery can be recharged, but this isn't a problem for hydrogen fuel cells / fuel cells store more energy than rechargeable batteries ***[1 mark]***.

4.1 C, A, D, B ***[2 marks, or 1 mark if 2 correct]***
The greater the voltage of the cell, the more reactive the metal ***[1 mark]***. Metal C produces the greatest voltage, so is the most reactive, followed by A, then D, and finally B which produces the lowest voltage ***[1 mark]***.

4.2 E.g. the electrolyte ***[1 mark]***.

Topic 6 — The Rate and Extent of Chemical Change

Pages 65-67 — Rates of Reaction

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