Answer **all** questions

1. Lithium was discovered in 1817 by the Swedish chemist Arfvedson. Lithium exists naturally as a mixture of isotopes.

(a) Explain the term *isotopes*.

Atoms of the same element with different masses/

Same atomic number, different number of neutrons/

Atoms of the same element with different numbers of neutrons ✓

Response must imply atoms [1]

(b) Which isotope is used as the standard against which relative atomic masses are measured?

carbon-12 ✓

[1]

(c) The mass spectrum below shows the isotopes present in a sample of lithium:

(i) Use this mass spectrum to help you complete the table below for each lithium isotope in the sample.

isotope	percentage composition	number of	
		protons	neutrons
^{6}Li	9 to 6	3	3
^{7}Li	91 to 94	3	4
mark	must add up to 100 ✓	✓	✓

For last 2, mark by column or row

[3]

(ii) Calculate the relative atomic mass of this lithium sample. Your answer should be given to three significant figures.

8 x 6/100 + 92 x 7/100 ✓ = 6.92 ✓ *(91/9 → 6.91; 93/7 → 6.93; 94/6 → 6.94)*

[2]

(d) The species responsible for the peaks in this mass spectrum are lithium ions, produced and separated in a mass spectrometer.

(i) How are the electrons removed from lithium atoms to form lithium ions in a mass spectrometer?

(bombarded) with electrons ✓

[1]

(ii) How does a mass spectrometer separate the ions?

(deflected by) a magnet(ic field) ✓

[1]

(e) The first ionisation energy of lithium is +520 kJ mol^{-1}.

(i) Define the term *first ionisation energy*.

Energy change when each atom in **1 mole** ✓ of **gaseous atoms** ✓

loses an electron ✓ (to form 1 mole of gaseous 1+ ions).

[3]

(ii) The first ionisation energy of sodium is +496 kJ mol^{-1}.

Explain why the first ionisation energy of sodium is less than that of lithium. Your answer should compare the atomic structures of each element.

electron is further from nucleus/ electron in a different shell ✓

electron experiences more shielding ✓

nuclear attraction decreases/distance or shielding outweighs nuclear attraction/ effective nuclear charge is less ✓

[3]

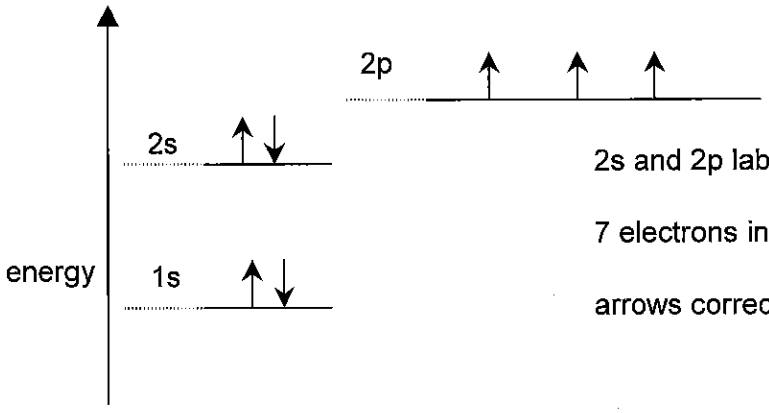
[Total: 15]

2. Electrons are arranged in energy levels. The diagram below is incomplete. It shows two electrons in the 1s level.

(a) Complete the diagram for the 7 electrons in a nitrogen atom by

(i) adding labels for the other sub-shell levels, [1]

(ii) showing how the electrons are arranged. [2]



2s and 2p labels ✓

7 electrons in correct levels ✓

arrows correctly shown ✓

[3]

(b) Magnesium reacts with nitrogen forming magnesium nitride, which is an ionic compound.

(i) Complete the electronic configuration for the 12 electrons in a magnesium atom.

$1s^2 2s^2 2p^6 3s^2$ ✓ [1]

(ii) What is the charge on each ion in magnesium nitride?

magnesium ion 2+ ✓

nitride ion 3– ✓

[2]

(iii) Complete the electronic configuration of each **ion** in magnesium nitride.

magnesium ion $1s^2 2s^2 2p^6$ ✓

nitride ion $1s^2 2s^2 2p^6$ ✓

[2]

(iv) Deduce the formula of magnesium nitride.

Mg_3N_2 ✓

[1]

(c) Magnesium reacts with carbon dioxide forming a mixture of magnesium oxide and carbon.

(i) Write an equation, with state symbols, for this reaction.

$2Mg(s) + CO_2(g) \longrightarrow 2MgO(s) + C(s)$ equation: ✓ state symbols: ✓ [2]

(ii) When water is added to the mixture containing magnesium oxide, some of the magnesium oxide reacts to form a solution of magnesium hydroxide.

$MgO(s) + H_2O(l) \longrightarrow Mg(OH)_2(aq)$

Predict the pH of this solution. 8 – 12 ✓ [1]

[Total: 12]

3. Calcium carbonate is added to an excess of hydrochloric acid.

$CaCO_3(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$

(a) Deduce **two** observations that you would expect to see during this reaction.

observation 1

$CaCO_3$ dissolves/ $CaCO_3$ disappears/ a solution forms ✓

observation 2

fizzing/effervescence/gas evolved/CO_2 evolved ✓

[2]

(b) In this experiment, 0.04 g $CaCO_3$ is added to 25 cm^3 of 0.05 mol dm^{-3} HCl.

(i) Explain what is meant by 0.05 mol dm^{-3} HCl.

0.050 mol/1.825 g HCl (is dissolved) in 1 dm^3 ✓

of solution ✓

[2]

(ii) Calculate how many moles of $CaCO_3$ were used in this experiment.

molar mass of $CaCO_3$ 100 g mol^{-1} ✓

moles of $CaCO_3$ = 0.040/100.1 = 0.00040 ✓ *(calc value: 3.996; accept $CaCO_3$:100)*

[2]

(iii) Calculate how many moles of HCl are required to react with this amount of $CaCO_3$.

moles of HCl that react = 2 x 0.00040 = 0.00080 ✓ *(i.e. ans to (b)(ii) x 2)*

[1]

(iv) Hence show that the HCl is in excess.

moles of HCl used = 0.050 x 25/1000 = 0.00125 ✓ *(accept: 16 cm^3 HCl used)*

[1]

(c) State **one** large-scale use of a named Group 2 compound that is being used to reduce acidity.

NAMED material + example of neutralising for mark. Can be common name:

e.g. Milk of magnesia/MgO for combating acid indigestion

limestone/$CaCO_3$ (or lime/CaO/$Ca(OH)_2$ for combating acidity in fields ✓

Material must be a Group 2 carbonate/oxide/hydroxide [1]

[Total: 9]

4. Water is the most abundant compound on Earth. Much of the chemistry of water is influenced by its polarity and ability to form hydrogen bonds.

(a) Polarity can be explained in terms of electronegativity.

(i) Explain the term *electronegativity*.

attraction (of an atoms) for electrons ✓

in a (covalent) bond ✓

[2]

(ii) Why are water molecules polar?

O and H have different electronegativities / O attracts electrons more than H/

O is very electronegative ✓

[1]

(b) The polarity of water molecules results in the formation of hydrogen bonds.

(i) Draw a diagram to show hydrogen bonding between two molecules of water. Your diagram must include dipoles and lone pairs of electrons.

non-linear H_2O molecule ✓

dipoles in water shown ✓

H-bond between H and an O in another H_2O molecule ✓

Involvement of lone pair on oxygen ✓

Linear H----O–H ✓

(HO_2 can score dipole mark only) [4]

(ii) State the bond angle in a water molecule

bond angle = 104.5 ° ✓ *(accept 104-105 °)*

[1]

(c) State and explain **two** properties of **ice** that are a direct result of hydrogen bonding.

property high(er) melting/boiling point (than expected) ✓

explanation strength of H bonds/H-bonds need to be broken/H-bonds strong ✓

property ice is lighter than water/ max density at 4°C/ice floats ✓

explanation H bonds hold H_2O molecules apart/open lattice in ice/ H-bond is long ✓

(Final mark must imply space within structure;
do NOT accept 'air trapped')

[4]

[Total: 12]

5. Well over 2 000 000 tonnes of sulphuric acid, H_2SO_4, are produced in the U.K. each year. This is used in the manufacture of many important materials such as paints, fertilizers, detergents, plastics, dyestuffs and fibres.

(a) 100 tonnes of sulphur dioxide were reacted with oxygen in stage 2.

Assuming that the reaction was complete, calculate

(i) how many moles of sulphur dioxide were reacted;

M_r: SO_2, 64.1. 1 tonne = 1×10^6 g

moles $SO_2 = 100 \times 10^6/64.1 = 1.56 \times 10^6$ ✓

[1]

(ii) the mass of sulphur trioxide that formed.

M_r: SO_3, 80.1

mass $SO_2 = 1.56 \times 10^6 \times 80.1 = 125 \times 10^6$ g / 125 tonne ✓

[1]

(b) Construct a balanced equation for the formation of sulphuric acid from oleum.

$H_2S_2O_7 + H_2O \longrightarrow 2H_2SO_4$ ✓

[1]

(c) The concentration of the sulphuric acid can be checked by titration. A sample of the sulphuric acid was analysed as follows.

- 10.0 cm^3 of sulphuric acid was diluted with water to make 1.00 dm^3 of solution.
- The diluted sulphuric acid was then titrated with aqueous sodium hydroxide, NaOH.

  $H_2SO_4(aq) + 2NaOH(aq) \longrightarrow Na_2SO_4(aq) + 2H_2O(l)$
- In the titration, 25.0 cm^3 of 0.100 mol dm^{-3} aqueous sodium hydroxide required 20.0 cm^3 of **diluted** sulphuric acid for neutralisation.

(i) Calculate how many moles of NaOH were used.

$0.100 \times 25/1000 = 2.5 \times 10^{-3}$ mol ✓

[1]

(ii) Calculate the concentration, in mol dm^{-3}, of the **diluted** sulphuric acid, H_2SO_4.

moles $H_2SO_4 = 1.25 \times 10^{-3}$ ✓

concentration $H_2SO_4 = 1.25 \times 10^{-3} \times 1000/20 = 0.0625$ mol dm^{-3} ✓

(i.e. Ans to (c)(i) x ½) An answer of 0.125 mol dm^{-3} would score probably 2nd mark- error likely to be molar ratio in equation) [2]

(iii) Calculate the concentration, in mol dm^{-3}, of the original sulphuric acid submitted for analysis.

$100 \times 0.0625 = 6.25$ mol dm^{-3} ✓

(i.e. Ans to (c)(ii) x 100) [1]

[Total: 7]

6. The atomic radii of the elements Li to F and Na to Cl are shown in the table below.

element	Li	Be	B	C	N	O	F
atomic radius/nm	0.134	0.125	0.090	0.077	0.075	0.073	0.071
element	Na	Mg	Al	Si	P	S	Cl
atomic radius/nm	0.154	0.145	0.130	0.118	0.110	0.102	0.099

(a) Using **only** the elements in this table, select

(i) an element with **both** metallic and non-metallic properties,

Si/C/B ✓

[1]

(ii) the element with the largest first ionisation energy

F ✓

[1]

(iii) an element with a giant covalent structure

Si/C/B ✓

[1]

(b) Explain what causes the general **decrease** in atomic radii across each period?

electrons added to same shell /same or similar shielding ✓

increasing nuclear charge/number of protons ✓

electrons experience greater attraction ✓

[3]

(c) Predict and explain whether the size of a sodium **ion** is *larger* or *smaller* than the size of a sodium **atom**.

sodium ion is smaller ✓

shell has been lost ✓

same protons attracting fewer electrons/less electron shielding/

effective nuclear charge greater ✓

(If 'Na ion is larger' and all else is correct then penalise 1st mark only)

[3]

[Total: 9]

7. Chlorine and its compounds have many uses. Chlorine bleach is used to kill bacteria.

(a) Chlorine bleach is made by the reaction of chlorine with aqueous sodium hydroxide.

$Cl_2(g) + NaOH(aq) \longrightarrow NaOCl(aq) + NaCl(aq) + H_2O(l)$

(i) Determine the oxidation number of chlorine in

Cl_2 0 ✓ NaClO +1 ✓ NaCl −1 ✓

[3]

(ii) The actual bleaching agent is the ClO^- ion. In the presence of sunlight, this ion decomposes to release oxygen gas.

Construct an equation for this reaction.

$2ClO^- \longrightarrow 2Cl^- + O_2$ or $2NaClO \longrightarrow 2NaCl + O_2$ ✓

[1]

(b) The sea contains a low concentration of bromide ions. Bromine can be extracted from sea water by first concentrating the sea water and then bubbling chlorine through this solution.

(i) The chlorine oxidises bromide ions to bromine.

Construct a balanced ionic equation for this reaction

$Cl_2 + 2Br^- \longrightarrow Br_2 + 2Cl^-$ ✓

[1]

(ii) Suggest how bromine could be removed from the seawater after the extraction with chlorine.

distill/blow air through/evaporate/use organic solvent ✓

('Evaporate water' is wrong although 'evaporate' is correct: implies Br_2)

'Heat' is wrong

[1]

(c) Phosgene is a compound of chlorine, carbon and oxygen, used to make polyurethanes and dyes.

Phosgene has the percentage composition by mass: Cl, 71.7%; C, 12.1%; O, 16.2%.

(i) Show that the empirical formula of phosgene is Cl_2CO.

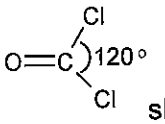
mole ratio: $\frac{71.7}{35.5}$ Cl : $\frac{16.2}{16}$ O : $\frac{12.1}{12}$ C ✓ *i.e. correct use of '35.5', '16' and 12.*

= 2 : 1 : 1 OR 2.02:1.01:2.02 ✓

[2]

(ii) The molecular formula of phosgene is the same as its empirical formula.

Draw a possible structure, including bond angles, for a molecule of phosgene.



shape (*C=O IS required*) ✓ ; bond angle (accept 115 - 125°) ✓

[2]

[Total: 10]

8. *In this question, 2 marks are available for the quality of written communication*

Sodium reacts with chlorine forming sodium chloride.

(a) Describe the bonding in Na, Cl_2 and NaCl. [8]

Na, Cl_2 and *NaCl*: metallic, covalent and ionic bonding respectively ✓.

NaCl: (ionic bonding): electrostatic attraction between ions ✓

correct 'dot-and-cross' diagram ✓

correct charges shown ✓

Cl_2: (covalent bonding): attraction of shared electrons for 2 nuclei ✓

'dot-and-cross' diagram correct ✓

shared pair of electrons ✓

(*'shared' electrons must be described but 'pair' can be within dot-and-cross diagram*)

'dot-and-cross' diagram correct ✓

Na: (metallic bonding): attraction between ions and electrons ✓

delocalised electrons ✓

(*marks could be obtained by suitably annotated diagram*)

Clear, well-organised, using specialist terms

More than half marks likely to score this mark but some writing is essential

Show mark as: Q ✓

[Sub-total: 10 ⟶ 8 max]

(b) Relate the **physical** properties of Cl_2 and NaCl to their structure and bonding. [8]

For Cl_2 and for NaCl, mark **best two properties** only (treat as 3 x 2 'pairs').

choose best two props.

Cl_2:
- poor conductor of electricity ✓ : no mobile electrons or ions ✓
- low m/bt pt: weak intermolecular ✓ van der Waals' forces/simple molecular structure ✓
- soluble in non-polar solvents ✓ : which interact with Cl_2 ✓ ⟶ 4 max

choose best two props.

NaCl:
- conducts only when aq or liquid ✓ when ions are mobile/ ions fixed in lattice ✓
- high m/bt pt ✓ : strong forces between ions/giant ionic lattice ✓
- soluble in polar solvents ✓ : dipoles interact with ions ✓ ⟶ 4 max

Q – legible text with accurate spelling, punctuation and grammar

More than half marks likely to score this mark but do pay attention to SPG

Show mark as: Q ✓

[Sub-total: 9 ⟶ 8 max]

[Total: 16]

1. (a) State what is meant by

(i) an *ionic bond*

(electrostatic) attraction between (oppositely charged) ions ✓

[1]

(ii) a *covalent bond*

shared electrons ✓ shared pair ✓

('both shared electrons' scores both marks)

[2]

(b) Draw 'dot-and-cross' diagrams to show the bonding in sodium chloride and hydrogen chloride. You should show outer electron shells only.

NaCl: correct dot and cross ✓

correct charges ✓

HCl: correct dot and cross ✓

[3]

(c) (i) State what is meant by an *orbital*.

a region in which electrons can be found ✓

(Response must imply the 'where the electrons are found'.
Do NOT accept 'path of electron' or 'electron arrangement')

[1]

(ii) Draw diagrams to show the shape of an s orbital and of a p orbital.

s orbital: circle/ellipse ✓

p orbital: figure of eight/'egg-timer' ✓

[2]

(iii) Complete the table below to show how many electrons **completely** fill each of the following

	number of electrons
a p **orbital**	2 ✓
a d **sub shell**	10 ✓
the third **shell**	18 ✓

[3]

[Total: 12]

2. The table below shows the boiling points of the elements sodium to chlorine in Period 3 of the Periodic Table.

element	Na	Mg	Al	Si	P	S	Cl	
bonding	M	M	M	C	C	C	C	✓
structure	G	G	G	G	S	S	S	✓

(a) **(i)** Complete the *'bonding'* row of the table using

- **M** for *metallic bonding*
- **C** for *covalent bonding*

[1]

(ii) Complete the *'structure'* row of the table using

- **S** for a *simple molecular structure*
- **G** for a *giant structure*

[1]

(b) State what is meant by *metallic bonding*. You should draw a diagram as part of your answer.

positive ions/metal ions/cations ✓

surrounded by free/delocalised/sea of electrons ✓

attraction between the above ✓

(Do NOT accept 'holds electrons', 'glue' or 'cement')

[3]

(c) Explain, in terms of their structure and bonding, why the boiling point of

(i) phosphorus is much **lower** than that of silicon,

Si has stronger forces/P has weaker forces ✓ *(i.e. comparison of forces)*

Si: covalent bonds/giant covalent ✓

P: weak forces between molecules/intermolecular forces/van der Waals ✓

[3 ⟶ 2 max]

(ii) aluminium is much **higher** than that of magnesium.

Al has stronger (metallic) bonding ✓

(If 'stronger covalent forces' then WRONG)

Al has 3 outer electrons, Mg has 2/Al has more (outer) electrons than Mg ✓

Al ions are smaller/ more positive/Al ions have a greater charge density ✓

[3 ⟶ 2 max]

[Total: 9]

3. Hydrogen chloride, HCl, is a colourless gas which dissolves very readily in water forming hydrochloric acid.

(a) At room temperature and pressure, 1.00 dm^3 of water dissolves 432 dm^3 of hydrogen chloride gas.

(i) How many moles of hydrogen chloride dissolve in the water?

432/24 = 18 mol ✓

[1]

(ii) The hydrochloric acid formed has a volume of 1.40 dm^3. What is the concentration, in mol dm^{-3}, of the hydrochloric acid?

18/1.4 = 12.9 mol dm^{-3} ✓ *(Look for 12.86) i.e. ans to (a)(i) / 1.4)*

[1]

(b) In solution, the molecules of hydrogen chloride ionise:

$HCl(aq) \longrightarrow H^+(aq) + Cl^-(aq)$

Describe a simple test to confirm the presence of chloride ions.

Add $AgNO_3(aq)$ ✓

white (precipitate) ✓

Alternative: "electrolysis giving chlorine ✓ which bleaches indicator paper ✓"

[2]

(c) Hydrochloric acid reacts with magnesium oxide, MgO, and magnesium carbonate, $MgCO_3$.

For each reaction, state what you would expect to see and write a balanced equation.

(i) MgO dissolves/disappears ✓

$MgO(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + H_2O(l)$ ✓ (state symbols not required)

[2]

(ii) $MgCO_3$ bubbles/fizzing/CO_2 evolved or formed ✓

$MgCO_3(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + H_2O(l) + CO_2(g)$ ✓

(state symbols not required)

[2]

[Total: 8]

4. Sulphur and sulphur compounds are common in the environment.

(a) A sample of sulphur from a volcano contained 88% by mass of ^{32}S and 12% by mass of ^{34}S.

(i) Complete the table below to show the atomic structure of these isotopes of sulphur.

isotope	number of		
	protons	neutrons	electrons
^{32}S	16	16	16 ✓
^{34}S	16	18	16 ✓

[2]

(ii) Define the term *relative atomic mass.*

average **atomic** mass/weighted mean/average mass

(MUST include reference to atoms or isotopes) ✓

compared with carbon-12 ✓

1/12th of mass of carbon-12/on a scale where carbon-12 is 12 ✓

[3]

(iii) Calculate the relative atomic mass of the volcanic sulphur. Your answer should be given to three significant figures.

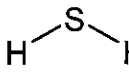
88*32/100 + 12*34/100 ✓

= 32.2 ✓ *(to 3 sig figs: allow full marks for answer. 32.24 (calc) gets 1 mark only)*

[2]

(b) Rotten eggs smell of hydrogen sulphide H_2S, which is a poisonous gas.

Draw a diagram to show the likely shape and bond angle of a hydrogen sulphide molecule. Explain how you have made your choice.



✓ 104 - 105° ✓ *(accept 91-105°)*

Watch for bond angle between S–H and lone pair: this is WRONG)

electron pair repulsion / 4 electron pairs ✓

[3]

(c) Calculate the empirical formula of DMS.

mole ratio: $\frac{38.6}{12}$ C : $\frac{9.7}{1}$ H : $\frac{51.7}{32.1}$ S ✓

i.e. correct use of '12', '1' and 32.1.

= 2 : 6 : 1 / empirical formula = C_2H_6S ✓

(If 16 is used for S, then emp formula ⟶ CH_3S.

OR C: 6 and S: 16, ⟶ C_2H_3S *Worth 1 mark)*

[2]

[Total: 12]

5. The reaction between barium and water is a redox reaction.

$$Ba(s) + 2H_2O(l) \longrightarrow Ba(OH)_2(aq) + H_2(g)$$

(a) Explain, in terms of electrons, what is meant by

(i) oxidation

loss (of electrons) ✓

[1]

(ii) reduction

gain (of electrons) ✓

[1]

(b) Which element has been oxidised in this reaction. Deduce the change in its oxidation state.

Ba ✓

0 to +2 (needs to be completely correct) ✓

[2]

(c) A student reacted 2.74g of barium with water to form 250 cm^3 of aqueous barium hydroxide.

(i) Calculate how many moles of Ba reacted.

2.74/137 / 0.0200 mol ✓

[1]

(ii) Calculate the concentration, in mol dm^{-3}, of $Ba(OH)_2$ was formed.

ans to (c)(i) x 4 mol dm^{-3} ✓ correct answer: 0.0800 mol dm^{-3}

[1]

(iii) Calculate the volume of H_2 that would be produced at room temperature and pressure (r.t.p.). [1 mol of gas molecules occupies 24.0 dm^3 at r.t.p.]

ans to (c)(i) x 24.0 dm^3 ✓ correct answer: 0.480 dm^3 / 480 cm^3

[1]

(iv) The solution of barium hydroxide is alkaline. Identify a compound that could be added to neutralise this solution and write a balanced equation for the reaction that would take place.

any acid ✓

balanced equation to match acid chosen ✓

[2]

(d) The Group 2 elements react more vigorously with water as the group is descended. This can be explained in part by using ionisation energies.

(i) Define the term *first ionisation energy*.

Energy change when **each atom in 1 mole** ✓

of **gaseous atoms** ✓

loses an electron ✓ (to form 1 mole of gaseous 1+ ions).

(or 1 mole of gaseous atoms loses 1 mole of electrons)

[3]

(ii) Explain, in terms of ionisation energies, why the Group 2 elements become more reactive as the group is descended.

ionisation energy decreases ✓

electron is further from nucleus/ electron in a different shell ✓

electron experiences **more** shielding ✓

*(Watch out for **comparison: 'shielding' alone is not enough for mark)***

nuclear attraction decreases/distance or shielding outweighs nuclear attraction/

electron is easier to lose/effective nuclear charge decreases ✓

[4]

[Total: 16]

6. The boiling points of water, hydrogen chloride and argon are shown in Table 7.1 below.

substance	H_2O	HCl	Ar
boiling point /°C	100	–85	–186
number of electrons per molecule	10	18	18

(a) H_2O, HCl and Ar all have van der Waals' forces.

Outline how van der Waals' forces arise between molecules.

oscillating/changing/temporary/transient dipole on one atom ✓

causes an induced/resultant dipole on another molecule/atom ✓

[2]

(b) Liquid H_2O has additional intermolecular forces.

(i) What are these forces?

H_2O: Hydrogen bonds ✓

[1]

(ii) Explain, with the aid of a diagram, how these forces arise between molecules of $H_2O(l)$.

electronegativity/polarity: O **more** electronegative than H

/O is very electronegative ✓

H_2O have polar molecules ✓ *(could be from diagram)*

H bonding: dipoles in water **correctly** shown ✓

H-bond between H and an O in another H_2O molecule ✓

Involvement of lone pair on oxygen ✓

[5]

(c) Liquid HCl also has additional intermolecular forces. What are these forces?

permanent dipole-dipole interactions ✓

[1]

(d) Explain the variation in boiling points shown in Table 7.1.

H-bonds are the strongest ✓

van der Waals' forces/ forces between Ar atoms are the weakest ✓

(i.e. responses should confirm order of strength of 3 types of forces)

[2]

[Total: 11]

7. The bones in an adult human skeleton have a mass of approximately 9 kg. Of this, 1 kg is calcium.

(a) The calcium in bones is present as calcium ions, Ca^{2+}.

Complete the electronic configurations of the following.

a calcium atom: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$ ✓

a calcium ion: $1s^2 2s^2 2p^6 3s^2 3p^6$ ✓

[2]

(b) Calculate the approximate number of calcium ions in an adult human skeleton.

moles of Ca = 1000/40.1 = approx 25 ✓

(IF atomic number is used for Ca (20), then 1st mark is lost but 2nd mark gained)

number of calcium ions = $6 \times 10^{23} \times 25 = 1.5 \times 10^{25}$ ✓

[2]

(c) Explain why calcium atoms are **not** present in a human skeleton?

Ca^{2+} ions more stable than Ca/

Ca atoms react with water/too reactive ✓

[1]

(d) The calcium in bones can be assumed to be present as calcium phosphate. A phosphate ion has the formula PO_4^{3-}.

(i) What is the formula of calcium phosphate?

$Ca_3(PO_4)_2$ ✓

[1]

(ii) Estimate the percentage, by mass, of calcium phosphate in an adult human skeleton.

$Ca_3(PO_4)_2$ has a molar mass of $(40.1 \times 3) + (31 + 16 \times 4)2 = 310.3$ g mol^{-1} ✓

mass of $Ca_3(PO_4)_2$ in bone = 310.3/120.3 = 2.58 kg ✓

% of $Ca_3(PO_4)_2$ in bone = $(2.58/9) \times 100 = 29\%$ ✓ (28.6%)

(i.e. 1 mark for molar mass of ans to (d)(i).

1 mark for multiplying by 100/9

1 mark for proportion idea i.e dividing by 120.3)

$CaPO_4$ gives M_r of 135.1/135.

[3]

[Total: 9]

8. Compare and explain the electrical conductivity of sodium chloride, diamond and graphite. In your answer, you should consider the structure and bonding of each of these materials.

In this question, 2 marks are available for the quality of written communication.

NaCl: giant ✓ ionic ✓ lattice

fixed ions in solid ✓

does not conduct when solid ✓

does conduct when aqueous/ molten ✓

mobile ions in solution or when molten ✓

6 marks max 5

Diamond **OR** graphite:

covalent ✓ giant ✓

Diamond: no free electrons/ions/charge carriers/all electrons involved in bonding ✓

does not conduct at all *(NOT poor conductor)* ✓

Graphite: layered structure ✓

delocalised electrons (between layers) ✓

conducts (by movement of delocalised electrons) ✓

7 marks max 6

Q – legible text with accurate spelling, punctuation and grammar ✓

Clear, well-organised, using specialist terms 5 or more ✓

[Total: 13]

1. (a) Mark vertically or horizontally.

species	number of	
	protons	electrons
Ca^{2+}	20	18 ✓
Cl^-	17	18 ✓

[2]

(b) $1s^2 2s^2 2p^6 3s^2 3p^6$ ✓ *$4s^0$ is OK*

[1]

(c) (i) $CaCl_2$ ✓

[1]

(ii) Ca^{2+} ion shown correctly ✓ ; 2 Cl^- ions shown correctly ✓

For Ca^{2+}, either 8 electrons or no electrons

For Cl^-, dot and crosses required.

[2]

(iii) ionic bonds/ionic bonding/electrostatic or ionic attraction/forces ✓

[1]

(d) (i) pH becomes (more) alkaline/increases ✓

$Ca(OH)_2$ forms/hydroxide ions form/H^+ is removed by electrolysis ✓

(2nd mark depends on 1st: it 'explains' why the solution becomes alkaline)

[2]

(ii) 'charge carriers' move in aqueous and do not move in solid ✓

charge carriers are ions ✓

*1st point identifies that something that is charged (electrons/ions/charge carriers) can move **and** not move when solid.*

2nd point identifies what the carriers are.

'Ions move' in isolation scores 1 mark

[2]

(e) (i) Cl_2: 0 ✓

HClO +1 *or* 1 *or* 1+ ✓

HCl −1 *or* 1− ✓ [3]

(ii) 0.003 / 3×10^{-3} mol ✓

[1]

(iii) purification/sterilisation/disinfect/killing bacteria ow ✓

*but....**not** 'bleach'/ **not** 'cleaning'/ **not** 'swimming pools'* [1]

[Total: 16]

2. (a) Energy change when **each atom in 1 mole** ✓ of **gaseous atoms** ✓

loses an electron ✓ (to form 1 mole of gaseous 1+ ions).

[3]

(b) (i) Electrons added to same shell /same or similar shielding ✓

increasing nuclear charge/number of protons ✓

electrons experience greater attraction or *pull* / atomic radius decreases ✓

[3]

(ii) Al has an electron in the p sub-shell/ has a p electron /different sub-shell/different type of orbital ✓.

*(**not** a different shell or a different orbital)*

If Al not stated then assume that response applies to it!

Al sub-shell at higher energy (than s) ✓

[2]

(c) electron is further from nucleus/ electron in a different shell ✓ (***not** sub-shell or orbital*)

electron experiences **more** shielding ✓ (***more** is essential here*)

nuclear attraction decreases /distance or shielding outweighs nuclear attraction / effective nuclear charge decreases ✓

[3]

(d) First ionisation energy of Ne = 1600 kJ mol^{-1}/ > 1600 kJ mol^{-1} ✓

[1]

(e) $Al^{2+}(g) \longrightarrow Al^{3+}(g) + e^-$ equation ✓; state symbols correct ✓

[2]

[Total: 14]

3. (a) (i) *oxidation* loss of electrons/ increase in oxidation number/gain of O/loss of H ✓

reduction gain of electrons/ decrease in oxidation number/loss of O/gain of H ✓

[2]

(ii) $2Mg(s) + O_2(g) \longrightarrow 2MgO(s)$ / $Mg(s) + \frac{1}{2} O_2(g) \longrightarrow MgO(s)$

equation ✓ ; state symbols correct ✓

[2]

(iii) *oxidation* $Mg \longrightarrow Mg^{2+} + 2e^-$ ✓

reduction $O_2 + 4e^- \longrightarrow 2O^{2-}$ / $\frac{1}{2}O_2 + 2e^- \longrightarrow O^{2-}$ ✓

Ignore state symbols

[2]

(b) (i) Solid no longer dissolves/ disappears/solid remains ✓

Ignore references to changes of pH/use of indicators

[1]

(ii) 25.0 x 2.00/1000 = 0.0500 mol ✓

[1]

(iii) 0.0250 mol MgO ✓ *(i.e. answer to (ii)/2)*

[1]

(iv) *M*(MgO) = 24.3 + 16 = 40.3 ✓

0.0250 x 40.3 ✓ = 1.0075 g = 1.01 g ✓

(i.e. answer to (iii) x answer to M(MgO))

(i.e. 1 mark for sig figs. 10.1 g would automatically score both the marks here.)

If a candidate uses 24 for Mg, answer to 3 sig figs is 1.00 g.

[3]

(v) **Not** a redox reaction **because** no species changes oxidation number ✓

evidence of working using actual oxidation numbers of **at least one species** ✓

(2nd point could well in the equation in part (b). Indicate this with an arrow to show this evidence)

[2]

(c) strong forces to be broken/high amount of energy required to break lattice /giant structure ✓

forces between ions/ionic bonding ✓

[2]

[Total: 16]

4. (a) attraction of an atom/element for electrons ✓
in a covalent bond/bonded pair/molecule ✓

[2]

(b)

$^{\delta+}H–N^{\delta-}$	$^{\delta-}F–B^{\delta+}$	$^{\delta+}H–I^{\delta-}$

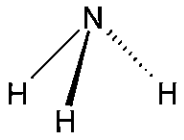
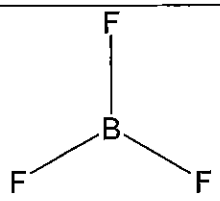
all 3 correct ✓ ✓ ; 2 correct scores 1 mark [2]

(c)

dot-and-cross diagram for NH_3 ✓	dot-and-cross diagram for BF_3 ✓
NH_3	BF_3

[2]

(d)

	
bond angle: 107 ± 1° ✓	bond angle: 120° ✓
shape: pyramidal ✓	shape: trigonal planar/planar triangle ✓

[4]

(e) NH_3 has a non-symmetrical shape/ BF_3 is symmetrical ✓
in NH_3 dipoles do not cancel *or* there is an uneven charge distribution
/ **in BF_3** dipoles cancel *or* there is an even charge distribution ✓

[2]

(f) H bond shown from N of one NH_3 molecule to H of another NH_3 molecule ✓

[1]

(g) **(i)** NH_3 has a lone pair/ NH_4^+ has no lone pair/ NH_4^+ has a dative (covalent) or coordinate bond ✓

bonded pair repels less/ lone pair repels more ✓

not *repelling atoms* [2]

(ii) Add silver nitrate (solution)/ silver ions ✓

yellow precipitate ✓

or

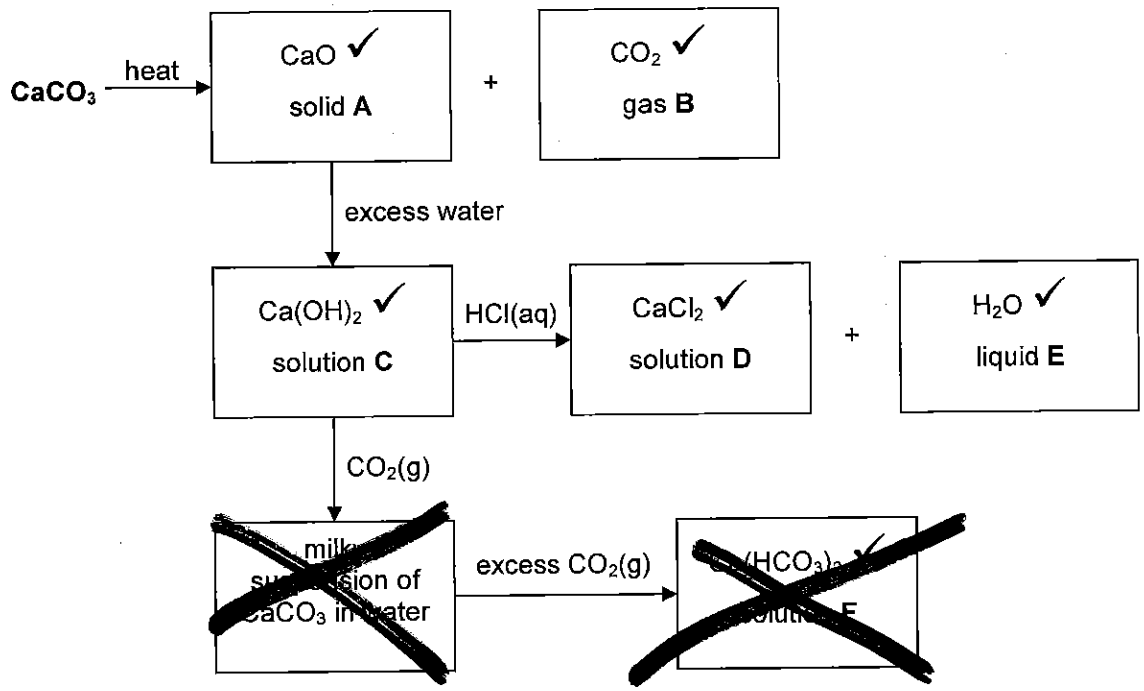
Add chlorine/bromine ✓

violet in added organic solvent or blue-black colour with added starch ✓

[2]

[Total: 17]

5. (a)



alternative answers as names:

A calcium oxide/qulicklime; **B** carbon dioxide; **C** calcium hydroxide/lime water; **D** calcium chloride; **E** water; **F** calcium hydrogencarbonate/ calcium bicarbonate

[6]

(b) *Molar mass* of $CaCO_3$ = 100.1 or 100 ✓

4 x 100.1 or 100 g $CaCO_3$ ✓ = 400.4 or 400

∴ 25 x 400.4 or 400/446.6 kg $CaCO_3$ = 22.41 or 22.39 kg ✓

Accept 22 kg or 22.4 kg

[3]

(c) **(i)** $Ca(OH)_2 + CO_2 \longrightarrow CaCO_3 + H_2O$ ✓ *ignore state symbols*

[1]

(ii) $CaCO_3$ reacts with acids ✓

[1]

[Total: 11]

6. *In this question, 1 mark is available for the quality of written communication.*

(a)

observations: 2 marks

chlorine:

Cl_2 + bromide ⟶ orange/brown/yellow/red in organic solvent ✓

bromine:

Br_2 + iodide ⟶ orange/brown/yellow/purple with organic solvent ✓

equations: 2 marks

chlorine:

$Cl_2 + 2Br^- \longrightarrow Br_2 + 2Cl^-$ / $Cl_2 + 2I^- \longrightarrow I_2 + 2Cl^-$ ✓

bromine:

$Br_2 + 2I^- \longrightarrow I_2 + 2Br^-$ ✓

2 'correct' unbalanced equations scores 1 mark

reactivity: 1 mark

Therefore reactivity decreases down group/ $Cl_2 > Br_2 > I_2$ /

/ Cl_2 displaces bromine and iodine **AND** bromine displaces iodine

(this could be shown in a table) ✓

[sub-total: 5]

(b)

how atom changes: 2 marks

as group descends, more shells are added/ increasing radius of atom ✓

and increased electron shielding ✓

result: 1 mark

down the group,.....

electron to be captured experiences less attraction

/less effective nuclear charge to capture an electron

/electrons gained less easily ✓

It must be clear that an electron is gained through this process to score the mark

[sub-total: 3]

8 marking points ⟶ [7 max]

Q – legible text with accurate spelling, punctuation and grammar ✓ [1]

[Total: 8]

7. *In this question, 1 mark is available for the quality of written communication.*

(a) calculate from weighted mean: 79 x 55.0/100 + 81 x 45.0/100 ✓

A_r = 79.9 ✓

[sub-total: 2]

(b) ionisation by electron beam/bombardment/gun ✓

acceleration/shot along/moved ✓

deflection by magnetic field/with a magnet ✓

deflection depends on mass/lighter particles deflected more ✓

particles travelling are ions ✓

relative heights or peak areas gives the abund

6 marking points ⟶ [5 max]

[sub-total: 5]

Clear, well-organised, using specialist terms

required use of **all** these words: ionisation, acceleration, deflection, detecti ✓ [1]

[Total: 8]

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	NOT	= answers which are not worthy of credit
	( )	= words which are not essential to gain credit
	____	= (underlining) key words which **must** be used to gain credit
	ecf	= error carried forward
	AW	= alternative wording
	ora	= or reverse argument

1. (a) (Atoms of) the same element / with same protons.... with different masses/different numbers of neutrons ✓ [1]

(b)

isotope	percentage composition	number of	
		protons	neutrons
^{191}Ir	38%	77	114
^{193}Ir	62%	77	116
	✓	✓	✓

*Accept 37-39% for ^{191}Ir; 61-63% for ^{193}Ir but **must** add up to 100.*

[3]

(c) (i) average atomic mass/weighted mean/average mass ✓

compared with carbon-12 ✓

1/12th of mass of carbon-12/on a scale where carbon-12 is 12 ✓

mass of 1 mole of element/mass of 1 mole of carbon-12 is equivalent to first two marks

"mass of the element that contains the same number of atoms as are in 1 mole of carbon-12" ⟶ 2 marks (mark lost because of mass units)

[3]

(ii) 38 x 191/100 + 62 x 193/100 ✓ = 192.2 ✓

Answers from other percentages above:

37 x 191/100 + 63 x 193/100 ✓ *= 192.3* ✓

39 x 191/100 + 61 x 193/100 ✓ *= 192.2* ✓

[2]

(d) (i) Simplest (whole number) ratio of atoms/moles/elements ✓

[1]

(ii) ratio Ir : F = 62.75/192 : 37.25/19 or 0.327 : 1.96 ✓

= 1 : 6 or formula = IrF_6 ✓

(or using answer for Ir from (c)(ii)) [2]

(iii) $Ir + 3F_2 \longrightarrow IrF_6$ ✓ *(consequential on response to (ii))*

[1]

[Total: 13]

2. **(a)** *trend in reactivity*: more reactive down group ✓

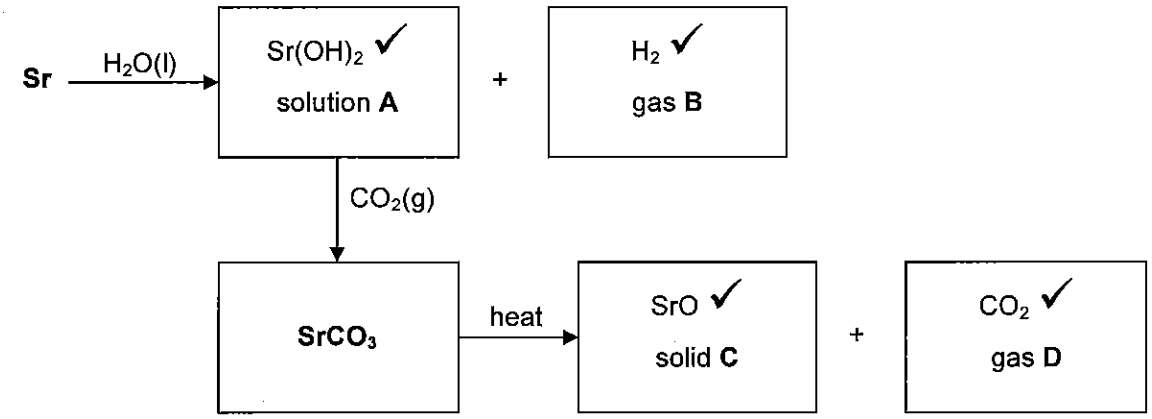
explanation: electrons lost more easily / ionisation energies decrease / less attraction or pull ✓

some attempt to relate this increase in size of atom / more shells / energy levels ✓

and **increase** in shielding ✓

[4]

(b)



[4]

[Total: 8]

3. (a) (i) $O^+(g) \longrightarrow O^{2+}(g) + e^-$ equation ✓;

state symbols **but** an electron must be in the equation somewhere ✓

[2]

(ii) Large difference between 6th and 7th ionisation energies ✓

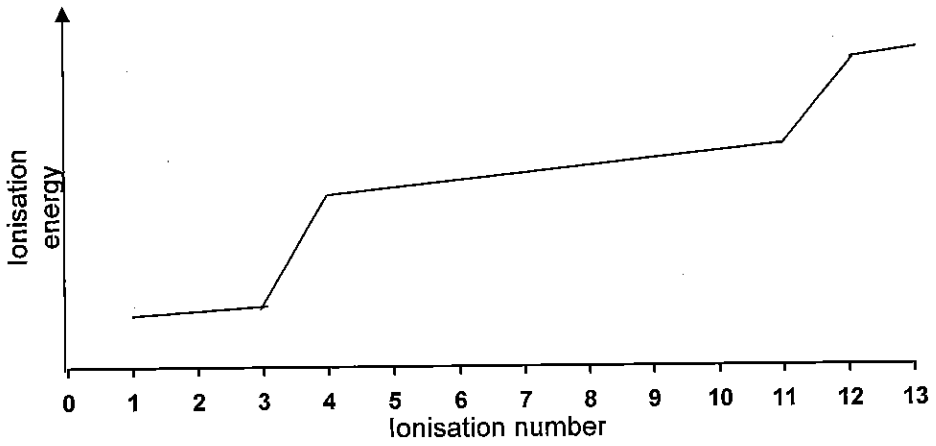
marks a different shell (closer to nucleus) ✓

[2]

(b) (i) $1s^2 2s^2 2p^6 3s^2 3p^1$ ✓

[1]

(ii)



sharp rise between ionisation 3 and ionisation 4 ✓

sharp rise between ionisation 11 and ionisation 12 ✓

i.e. the two steepest rises

(for 2,8,3 pattern the wrong way around, award 1 mark)

[2]

(c) (i) $4Al(s) + 3O_2(g) \longrightarrow 2Al_2O_3(s)$ equation ✓; state symbols ✓

[2]

(ii) Al^{3+} ions / highly charged aluminium ions ✓ are small ✓;

O^{2-} ions / anions / negative ions are large ✓;

O^{2-} ions / anions / negative ions are polarised / distorted ✓

4 ⟶ [3 max]

(d) $M(Al_2O_3) = 102$ g mol^{-1} ✓

amount of Al_2O_3 = 25/102 = 0.2451 / 0.245 / 0.25 ✓

[2]

[Total: 14]

4. (a) HOCl: +1 ✓ HCl: –1 ✓

[2]

(b) covalent bonds shown correctly ✓

all molecule correct (i.e. chlorine's and oxygen's lone pairs) ✓

[2]

(c) (i) electron **pairs** repel ✓

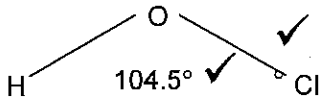
as far apart as possible ✓

the number of electron pairs (surrounding central atom) decides the shape ✓

lone pairs repel more (than bonded pairs) ✓

4 ⟶ [3 max]

(ii)



✓ ✓ allow 104 – 105

[2]

(d) (i) loss of electrons / ox number increases / gains oxygen / loses hydrogen ✓

[1]

(ii) brown / orange / yellow colour ✓

[1]

(iii) $Cl_2 + 2I^- \longrightarrow 2Cl^- + I_2$ ✓

[1]

(e) (i) *Molar mass* of NaCl = 58.5 g mol^{-1} ✓

mass of NaCl dissolved = 58.5 x 4 g = 234 g ✓

[2]

(ii) 2 mol NaCl ⟶ 1 mol Cl_2

∴ amount of Cl_2 produced = 2 mol ✓ *(i.e. half 1st answer to (e)(i))*

volume of Cl_2 produced = 24 x 2 = 48 dm^3 ✓

[2]

(iii) 1 dm^3 brine ⟶ 48 dm^3 $Cl_2(g)$

2.5 x 10^9/48 dm^3 brine ⟶ 2.5 x 10^9 dm^3 $Cl_2(g)$

∴ 5.2 x 10^7 (dm^3) ✓ (but wrong unit is wrong!)

[1]

[Total: 17]

5. (a) diagram of H bonding between water molecules (O of 1 molecule to H of another) ✓

dipoles shown ✓ with lone pair involved in bond ✓

(could be in words; could describe another molecule such as NH_3.)

[3]

Two properties from:

property higher melting/boiling point than expected ✓

explanation strength of H bonds/H-bonds need to be broken ✓

must imply that intermolecular bonds are broken

property ice is lighter than water/ max density at 4°C ✓

explanation H bonds hold H_2O molecules apart

/ open lattice in ice

/ H-bonds are longer ✓

property high surface tension/viscosity ✓

explanation strength of H bonds/H-bonds need to be broken ✓

4 max ⟶ [4]

Q – legible text with accurate spelling, punctuation and grammar ✓

[1]

[Total: 8]

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	____	= (underlining) key words which **must** be used to gain credit
	ecf	= error carried forward
	AW	= alternative wording
	ora	= or reverse argument

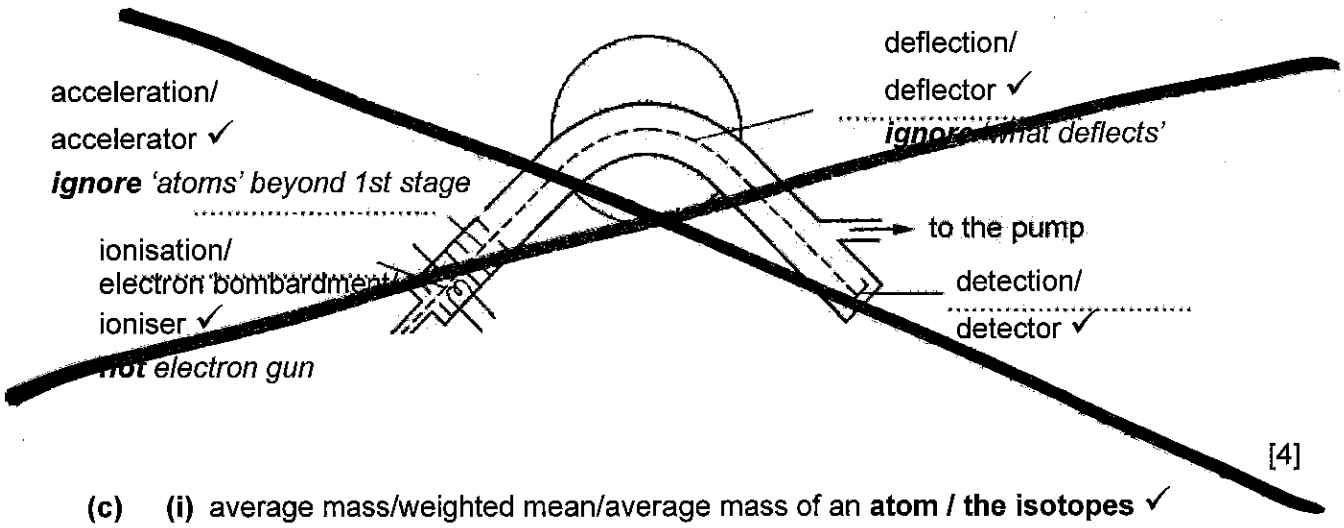
1. (a)

isotope	number of		
	protons	neutrons	electrons
^{69}Ga	31	38	31
^{71}Ga	31	40	31

✓ ✓

[2]

(b)



[4]

(c) (i) average mass/weighted mean/average mass of an **atom / the isotopes** ✓

compared with carbon-12 ✓

1/12th of mass of carbon-12/on a scale where carbon-12 is 12 ✓

***not** 12 g*

or... mass of 1 mole of atoms ✓

compared with carbon-12 ✓

1/12th of mass of 1 mol of carbon-12/on a scale where carbon-12 is 12 **g** ✓ [3]

(ii) ^{69}Ga: 61%; ^{71}Ga: 39% ✓ *(allow 62/38 ⟶ 69.76 below)*

[1]

(iii) $A_r = 69 \times 61/100 + 71 \times 39/100 = 69.78$ ✓ $= 69.8$ ✓

ignore g / grammes [2]

[Total: 12 marks]

2 **(a)** $1s^2 2s^2 2p^6 3s^2$ ✓

[1]

(b) **(i)** Mg: 0 ✓

[1]

(ii) MgO: +2 / 2 / II ✓

[1]

(c) **(i)** $3Mg(s) + N_2(g) \longrightarrow Mg_3N_2(s)$ ✓✓

1 for correct formulae and balancing; 1 for correct state symbols

[2]

(ii) N_2 is less reactive than O_2 /

bond between N atoms is stronger than bond between O atoms /

nitrogen has a triple bond **and** oxygen has a double bond

activation energy of N > activation energy of O ✓

The emphasis here should be a comparison for the mark

[1]

(d) MgO has a giant structure ✓

MgO is ionic / charged magnesium **and** oxide ions shown ✓

strong forces ✓

[3]

(e) **(i)** MgO dissolves/disappears ✓

[1]

(ii) *m*(MgO) = 24.3 + 16 = 40.3 (g mol^{-1}) ✓ *(accept 40)*

mass MgO = 0.0500 x 40.3 = 2.015 **g** / 2.02 **g** / 2.01 **g** / 2 **g** ✓

g is needed here

[2]

(iii) moles HNO_3 = 2 x 0.0500 = 0.100 mol ✓

right or wrong for 1st mark

volume HNO_3 = 0.25 dm^3 / 250 cm^3 ✓

*i.e. moles HNO_3/0.400 **dm^3** / 1000 x moles HNO_3/0.400 **cm^3***

0.05/0.400 ⟶ 0.125 dm^3 / 125 cm^3 would score 1 mark as molar ratio not used

[2]

(f) **(i)** ions move / free ions ✓

[1]

(ii) Mg^{2+} /NO_3^- / H^+/OH^- ✓✓ 2 max

[2]

[Total: 17 marks]

3. (a) (i) purification/sterilisation/kills *or* removes germs/disinfects ✓

not 'to make bleach' **not** 'cleans the water'

[1]

(ii) turns red / yellow / orange ✓

then colourless / bleaches ✓

colourless then 'nothing' scores 1 mark

*colourless then 'red' does **not** score because overall bleaching is not implied.*

[2]

(b) *reagent* silver nitrate/Ag^+ ions ✓

observation white (precipitate) / goes white ✓

} mark independently

equation $Ag^+(aq) + Cl^-(aq) \longrightarrow AgCl(s)$ /

$NaCl(aq) + AgNO_3(aq) \longrightarrow AgCl(s) + NaNO_3(aq)$ ✓

(state symbols not required)

Fluorine for reagent + 'correct' displacement equation scores 1 mark)

[3]

(c) (i) Cl : C = 85.6/35.5 : 14.4/12 ✓ = 2.4 : 1.2

= 2 : 1 ✓

Cl_2C has mass of 83. 166 = 2 x 83

molecular formula = Cl_4C_2 ✓

Cl : C = 85.6/17 : 14.4/12 ⟶ Cl_4C scores 1 mark /

Cl : C = 85.6/17 : 14.4/6 ⟶ Cl_2C scores 1 mark

Cl : C = 85.6/35.5 : 14.4/6 ⟶ ClC scores 1 mark

[3]

(ii) perc is covalent / perc is **not** ionic / C–Cl bond in perc is covalent / no Cl^- ions / perc is molecular ✓

[1]

(d) $m(NaClO_3)$ = 106.5 g mol^{-1} ✓

moles $NaClO_3$ = 4.26/106.5 = 0.04 mol ✓

moles O_2 = 0.06 mol ✓

volume O_2 = 0.06 x 24 = 1.44 (dm^3) ✓

If no molar ratio has been used, ans ⟶ 0.96 dm^3 : worth 3 marks

[4]

[Total:14 marks]

4. **(a)** Energy change when **each atom in 1 mole** ✓

of **gaseous atoms** ✓

loses an electron ✓ (to form 1 mole of gaseous 1+ ions).

1 mole of gaseous atoms loses 1 mole of electrons would score all 3 marks

$\mathbf{D}(g) \longrightarrow \mathbf{D}^+(g) + e^-$ scores 2 marks

$\mathbf{D}(g) \longrightarrow \mathbf{D}^+(g) + e^-$ ΔH / I.E. .....kJ mol^{-1} scores 3 marks

[3]

(b) $\mathbf{D}^{2+}(g) \longrightarrow \mathbf{D}^{3+}(g) + e^-$ ✓✓

(1st mark for equation; 2nd mark for state symbols

*'–' **not** required in e^- ; ignore wrong '**D**' except if H or He used; **X** is acceptable*

[2]

(c) Group 4 ✓

Sharp rise in successive ionisation energy between 4th and 5th IE ✓

marking a change to a new shell/energy level / there are 4 electrons in the outer shell✓

***mention of** 'orbital' or 'sub-shell cancels the 'shell mark'*

Each marking point in (c) is independent

[3]

[Total: 8 marks]

5. Group 2

atomic radii increases down group ✓

down group, electrons added to a new shell / more shells ✓

down group, **more** shielding ✓ : *'**more'** is essential*

increased nuclear charge outweighed / despite increased nuclear charge ✓

Period 3

atomic radii decrease across period ✓

number of protons/nuclear charge increases ✓

across period, electrons added to same shell / same or similar shielding ✓

nuclear attraction increases / shell drawn in by increased nuclear charge ✓

*watch for distinction between nuclear **attraction** and nuclear **charge** in candidates' scripts.*

[8]

Quality of Written Communication

At least **two** complete sentences that are legible and where the spelling, punctuation and grammar allow the meaning to be clear. ✓

[1]

[Total: 9 marks]

1. (a) (i) P ✓

[1]

(ii) $1s^2 2s^2 2p^6 3s^2 3p^3$ ✓

[1]

(iii) charge on ion: 3– ✓

[1]

electronic configuration of ion of **A**: $1s^2 2s^2 2p^6 3s^2 3p^6$ ✓

[1]

(b) (i) different number of neutrons ✓

[1]

(ii) Ni ✓

[1]

(c) (i) average **atomic** mass/weighted mean/average mass ✓

compared with carbon-12 ✓
1/12th of mass of carbon-12/on a scale where carbon-12 is 12 ✓

OR
The mass of 1 mole of **atoms** of an element ✓
compared with 12 g ✓
of carbon-12 ✓

[3]

(ii) 58.0x68.2/100 + 60.0x27.3/100 + 62.0x4.5/100 / 58.726 ✓

= 58.7 ✓ *(to 3 sig figs: allow full marks for answer.* 58.726 *(calc) gets 1 mark only)*

[2]

[Total: 11 marks]

2. (a) correct dot and cross ✓

[1]

(b) number of electrons increases down group ✓

⟶ greater van der Waals' forces/intermolecular forces ✓

more energy/higher temperature needed to break these intermolecular forces ✓

[3]

(c) (i) brown/orange/yellow colour ✓

[1]

(ii) $2NaBr + Cl_2 \longrightarrow Br_2 + 2NaCl$ *balanced equation* ✓

or ionic equation: $2Br^- + Cl_2 \longrightarrow Br_2 + 2Cl^-$

[1]

(iii) Cl/Cl_2 gains electron(s) ✓ Br^- loses an electron ✓

[2]

(iv) Cl is more reactive/more powerful oxidising agent than Br ✓

[1]

(v) add $AgNO_3$ / Ag^+ ✓

yellow precipitate ✓

OR

add Cl_2 / Br_2 ✓

purple in hexane / blue-black in starch ✓

[2]

[Total: 11 marks]

3. (a) correct dot and cross ✓ correct charges ✓

[2]

(b) (i) Ca: (+)2 ✓

[1]

(ii) C: (+)4 ✓

[1]

(c) moles $CaCO_3 = 20 \times 10^6/100 = 200\,000$ mol ✓

mass CaO = 200 000 x 56 = 11 200 000 g / 1.12×10^7 g / 11.2 tonnes ✓

use of 56 x 20/100 OR 56/5 is worth 1 mark
decimal point in wrong place i.e. 1.12 x 10^x is worth 1 mark.
units needed for 2nd mark.

[2]

(d) $CaO + H_2O \longrightarrow Ca(OH)_2$ ✓

[1]

(e) (i) molar mass = 40.1 + (16 + 1) x 2 = 74.1 (g mol^{-1}) ✓

[1]

(ii) moles HCl = 0.200 x 25.0/1000 = 0.005 mol ✓

[1]

(iii) moles $Ca(OH)_2$ = 0.5 x 0.005 = 0.0025 mol ✓

mass $Ca(OH)_2$ = 0.0025 x 74.1 = 0.185 g ✓ accept from 0.19 g to 0.18525 g

i.e. 0.0025 x answer to (i)

candidate who does not use 0.5 will get 0.37 g – worth 1 mark

[2]

(iv) 1 mol NaOH reacts with 1 mol HCl

/ $Ca(OH)_2$ Has more OHs / OHs needed to neutralise ✓

Therefore twice the number of moles of NaOH are needed

/ twice number of OHs in $Ca(OH)_2$ ✓

[2]

[illegible] reacted with CO_2 ✓ forming $CaCO_3$ ✓

[2]

[Total: 15 marks]

4. **(a)** 4 valid examples ✓✓✓✓

Can be names or formulae. If a formula is used, it must be correct for the structure: i.e. for simple molecular, H_2, P_4, S_8, etc is feuqired.

[4]

(b) **(i)** positive ions/metal ions/cations ✓

surrounded by free/delocalised/sea of electrons ✓

[2]

(ii) electrons move ✓

[1]

(c) solid lattice, ions are in fixed positions ✓

molten, ions are free to move and conduct ✓

[2]

(d) giant has stronger forces/simple has weaker forces ✓ *(i.e. comparison of forces)*

giant: covalent bonds break ✓
simple: molecules/intermolecular forces break / van der Waals break ✓

[3]

[Total: 12 marks]

5. electron pairs repel ✓

as far apart as possible ✓

lone pair repulsion > bonded pair repulsion / lone pair reduces bond angle ✓

[3]

4 examples, for each: shape ✓✓✓✓

either

a named molecule that matches a correct shape

or

correct number and type of electron pairs to match shape

3 correct bond angles ✓ ✓✓

[7]

[Sub-total: 10]

qowc: technical words of **three** shapes:

i.e. linear

non-linear / V-shaped / angular / bent

trigonal planar / planar triangle

tetrahedral / tetrahedron

pyramid(al) / trigonal pyramid(al)

[Sub-total: 1]

[Total: 11 marks]

Further notes on Question 5

1. Three marks that explain the theory:

electron pairs repel ✓

- This could simply be within 'electron pair repulsion theory' or 'lone pairs repel'

lone pairs repel **more** ✓

repelled as far apart as possible ✓

2. Seven marks for shapes and bond angles

Bond angles

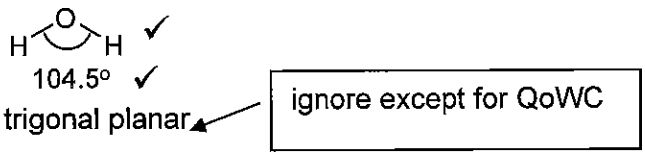
- Credit up to three correct bond angles for chosen examples. i.e. 3 max

Shapes

(a) If a candidate has drawn shapes of molecules,

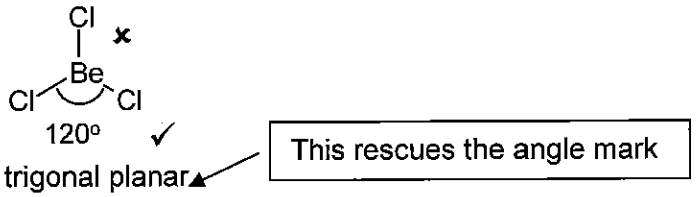
- mark the shapes irrespective of any words that describe them.
- only look at the words (pyramidal, etc) for the QoWC mark (see below)
- do **not** use an incorrect name as a 'con' or we will be looking for both the shape **and** the name for the mark.

e.g.



(b) If a candidate has drawn a 'correct' shape but for a molecule that does **not** exist, then the shape mark cannot be awarded. e.g. $BeCl_3$ shown as a trigonal planar molecule would not score the shape (but could score an angle mark of 120 ° if 'trigonal planar' is used as a fall back). The example below is certainly worth something!

e.g.



(c) If a candidate has not drawn a diagram,

- the shape mark is still possible if the correct technical word is used. If this tactic has been used then you can still award the technical words as part of the QoWC mark (see below).

e.g. CH_4 has a tetrahedral shape ✓ with a bond angle of 109.5 ° ✓

QoWC One mark

Use of any three of the 'shape technical words' with correct shapes.

i.e. testing 'correct usage' of technical words.

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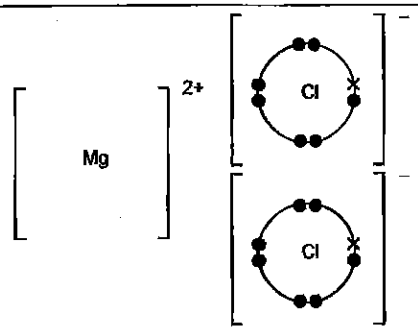
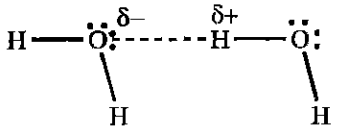
Question No.			Max Mark
1)	(a)(i)	atoms of same element/same atomic number/same number of protons ..... with different numbers of neutrons/different masses ✓	[1]
	(ii)	isotope protons neutrons electrons ^{10}B 5 5 5 ✓ ^{11}B 5 6 5 ✓	[2]
	(b)(i)	weighted mean mass of an atom/average mass of an atom/average mass of the naturally occurring isotopes ✓ compared with carbon-12 ✓ 1/12th of mass of carbon-12/on a scale where carbon-12 is 12 ✓ *mass of 1 mole of atoms of an element compared with 1/12th the mass of 1 mole of carbon-12 is an alternative* *"mass of the atoms of the element that contains the same number of atoms as are in 1 mole of carbon-12" ⟶ 2 marks* *(mark lost because of mass units)*	[3]
	(ii)	more of ^{11}B (than ^{10}B) ✓	[1]
	(c)(i)	$H_3BO_3 + 3K \longrightarrow B + 3KOH$ ✓	[1]
	(ii)	B changes from (+)3 ✓ to 0 ✓ 'oxidation number decreases' with no numbers scores one mark (*must be in terms of ox no. Ignore electrons*) *Mark independently*	[2]
	(d)	**X** = 120° ✓ 3 bonded pairs / 3 bonds ✓ Y = 104-105° ✓ 2 lone pairs *AND* (2 bonded pairs *OR* 2 bonds) ✓ electron **pair** repulsion (anywhere) / electron **pairs** get as far apart as possible (anywhere) / lone **pairs** repel (more) / **bonds** repel ✓ *Any reference to **atoms repelling** contradicts 'repel mark'*	[5]
			15

2)	(a)(i)	heating or thermal decomposition of limestone/$CaCO_3$/ correct equation: $CaCO_3 \longrightarrow CaO + CO_2$ ✓	[1]
	(ii)	farming: neutralising acid soils/reduces acidity of soil ✓	[1]
	(b)(i)	$Ca(OH_2)(aq) + 2\ HNO_3(aq) \longrightarrow Ca(NO_3)_2(aq) + 2\ H_2O(l)$ ✓	[1]
		2 sig fig minimum throughout	
	(ii)	$0.0105 \times 22.45/1000 = 2.36 \times 10^{-4}$ ✓ (calc: 2.35725×10^{-4})	[1]
	(iii)	ans to (ii) / 2 = 1.18×10^{-4} ✓ (calc: 1.178625×10^{-4})	[1]
	(iv)	ans to (iii) x 40 = 0.00472 ✓ (calc: 0.0047145 ⟶ 0.00471)	[1]
	(v)	$Ca(NO_3)_2$ = 40.1 + (14 + 48) x 2 = **164.1** (accept 164) / x = 272.1 – 164.1 = **108** ✓ x = 6 / $Ca(NO_3)_2.6H_2O$ ✓ If candidate has based this part on $Ca(OH)_2$, '$11H_2O$' would score 1 mark consequentially If (272.1 – incorrect calculated value for $Ca(NO_3)_2$), then 2nd mark can be achieved consequentially but a whole number is required.	[2]
	(c)	$Ca(s) + 2H_2O(l) \longrightarrow Ca(OH)_2(aq) + H_2(g)$ ✓ for balanced equation ✓ for state symbols of correct species in equation	[2]
	(d)(i)	$Ca^+(g) \longrightarrow Ca^{2+}(g) + e^-$ equation ✓ state symbols must be (g), (g) but can be for any attempted equation losing electron(s) ✓	[2]
	(ii)	mol Ca = 5.00/40.1 or 0.125 (0.12468379) ✓ 1 mol Ca requires 578 + 1145 = 1723 (kJ) ✓ so energy required = answer above derived from IE data x 0.125 1723 x 0.125 = 215 (kJ) 3 sig figs ✓ eg Use of 1145 only gives 143 kJ consequentially (would score 2)	[3] [4]
	(iii)	**Assume 'down the group'** ionisation energy decreases ✓ atomic radii increases / there are more shells ✓ there is more shielding ✓ *'more' is essential* attraction decreases / increased shielding and distance outweigh the increased nuclear charge ✓	
			19

3)	(a)	$1s^2 2s^2 2p^6 3s^2 3p^5$ ✓	[1]
	(b)(i)	 ✓ for correct dot-and-cross ✓ for charges allow Mg with a 'full' shell; also ignore any inner shells	[2]
	(ii)	Mg conducts as there are free/delocalised/mobile electrons ✓ *not just 'sea of electrons'* $MgCl_2$(s) does not conduct as no free/delocalised/mobile electrons or ions or charge carriers ✓ $MgCl_2$(aq) conducts as ions move ✓ $MgCl_2$ dissolves because water is a polar solvent ✓ *Any 3 observations above*	[3] max
	(c)	increasing nuclear charge/number of protons ✓ electrons added to same shell /same or similar shielding ✓ electrons experience greater attraction or greater pull ✓	[3]
	(d)	moles Cl_2 = 145/24000 = 6.04×10^{-3} mol ✓ *accept 0.006 mol* Cl_2 is in excess as 0.00604 > 0.005 mol Cl_2 / Cl_2 is in excess as 0.01208 > 0.01 mol Cl_2 ✓ *Explanation using equation required for 2nd mark* *ora*	[2]
	(e)	*Precipitation* Add $AgNO_3$ / Ag^+ (could be in equation) ✓ NaCl/Cl^- → white precipitate / dissolves in dilute NH_3 ✓ NaBr/Br^- → cream precipitate / dissolves in conc NH_3 or precipitate does not dissolve in dilute NH_3 ✓ not 'Cl' or 'Br' or 'chlorine' or 'bromine' ..... but ecf for a second occurrence $Ag^+ + Cl^- \longrightarrow AgCl$ ✓ or equation for Br^- or a full equation, *state symbols not required* eg: $AgNO_3 + NaCl \longrightarrow AgCl + NaNO_3$ 'precipitate' is required at least once – could be from : white **precipitate** or cream **precipitate** or AgCl(s)	[4]
	OR	*Displacement* Add chlorine / Cl_2 (could be in equation) ✓ (but not Cl) NaCl ⟶ no change/no reaction/pale green ✓ NaBr ⟶ goes orange/yellow/brown ✓ *If candidate mentions formation of a **precipitate** do not award observation mark* $2Br^- + Cl_2 \longrightarrow Br_2 + 2Cl^-$ ✓ or a full equation, *state symbols not required* eg: $2NaBr + Cl_2 \longrightarrow 2NaCl + Br_2$	
			16

4)	(a)	H_2O: Hydrogen bonding shown in words or in diagram: H bonding from O of 1 H_2O molecule to H of another ✓ dipoles shown or described ✓ with lone pair of O involved in the bond ✓  Two properties from: Ice is less dense/lighter than water/floats on water/ max density at 4°C ✓ explanation: H bonds hold H_2O molecules apart / open lattice in ice / H-bonds are longer ✓ Higher melting/boiling point than expected ✓ *Not just high* Accept: 'unusually high/strangely high/relatively high' explanation: H bonds need to be broken ✓ must imply that intermolecular bonds are broken High surface tension ✓ explanationstrength of H bonds across surface ✓ *mark 2 properties only: max 4*	[3] [4]
	(b)	CH_4: van der Waals' forces / interactions based on instantaneous/temporary/transient interactions ✓ HCl: (permanent) dipole – (permanent) dipole interactions ✓ intermolecular forces are stronger in HCl than in CH_4 / more energy required to break the intermolecular forces in HCl than in CH_4 ✓	[3]
		At least two sentences that show legible text with accurate spelling, punctuation and grammar so that the meaning is clear.✓ (Mark this from anywhere within Q4)	[1]
			11

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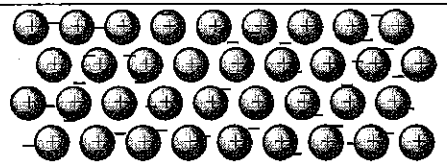
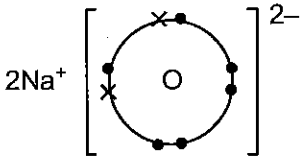
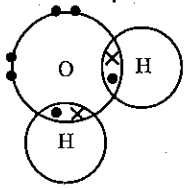
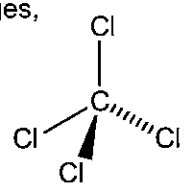
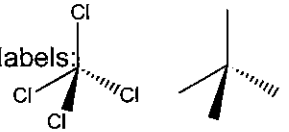
Question			Expected Answers	Marks	Additional Guidance
1	a		<table><tr><th></th><th>protons</th><th>neutrons</th><th>electrons</th></tr><tr><td>^{113}In</td><td>49</td><td>64</td><td>49</td></tr><tr><td>^{115}In</td><td>49</td><td>66</td><td>49</td></tr></table> ^{113}In line correct ✓ ^{115}In line correct ✓	2	mark by **row**
	b		A_r = 113 x 4.23/100 + 115 x 95.77/100 / 114.9154 ✓ (calculator value) = 114.9 ✓ to 1 decimal place	2	**Allow** one mark for A_r = 114.9154 with no working out **Allow** two marks for A_r = 114.9 with no working out If a candidate uses incorrect values in 1st line, then the 2nd mark can still be awarded if the calculated value is from 113.1 to 114.9 expressed to one decimal place. ie if %s are the wrong way round in 1st line, then an answer of 113.1 gets the 2nd mark.
	c		 **with labels:** scattering of labelled electrons between other species ✓ regular 2-D arrangement of labelled + ions with some attempt to show electrons ✓	2	**1st mark** is for any symbol that is labelled an **electron** that is between something else: ie: between + ions, atoms, protons, nuclei, +, p, circles, etc. **Allow**: e or e^- with no label Do **not** allow '–' with no label **2nd mark** for labelled **+ ions, positive ions, cations** that can be touching and must be 2-D (ie not just a row). **Allow** In^+ or In+ with charge from 1+ to 7+ NOT protons (commonest mistake)

Question			Expected Answers	Marks	Additional Guidance
	d	i	M_r = weighted mean/average mass of a **molecule** ✓ compared with carbon-12 ✓ 1/12th (of mass) of carbon-12/ on a scale where carbon-12 is 12 ✓ *(but not 12 g)*	3	**1st mark**: reference to **molecule** is essential **Allow** just 'average mass of molecule' or 'mean mass of molecule' *alternative **allowable** definitions:* mass of one mole of molecules ✓ compared to $1/12^{th}$ ✓ (the mass of) one mole/12 g of carbon-12 ✓ mass of one mole of molecules ✓ $1/12^{th}$ ✓ the mass of one mole/12 g of carbon-12 ✓
		ii	ratio: In : I = 23.19/115 : 76.81/127 Empirical formula: InI_3 ✓ Molecular formula = In_2I_6 ✓ *OR* mass In = 23.19 x 992/100 *OR* 230 (g) *AND* mass I = 76.81 x 992/100 *OR* 762 (g) ✓ moles In = 230/115 *OR* 2 *AND* moles I = 762/127 *OR* 6 ✓ Molecular formula = In_2I_6 ✓	3	**Allow** use of 114.9 for In (ie from answer to 1(b)) If a candidate uses atomic numbers, the ratio is still 1:3. The 2nd and 3rd marks can still be awarded by error carried forwards. Although unlikely, an correct answer of In_2I_6 with no working should be awarded **all** three marks. If candidate shows inverse for ratios: ie In : I = 115/23.19 : 127/76.81 .....then the candidate can be awarded the 2nd mark **only** for In_3I by error carried forwards.
			Total	**12**	

Question			Expected Answers	Marks	Additional Guidance
2	a	i	Ca ✓	1	***Allow*** *names throughout (i)–(vi)*
		ii	N✓	1	
		iii	Cl✓	1	
		iv	B✓	1	**Allow** Al
		v	K✓	1	
		vi	C/Si/B✓	1	
	b	i	cation shown with either 8 or 0 electrons ***AND*** anion shown with 8 electrons ***AND*** correct number of crosses and dots for example chosen ✓ Correct charges on both ions ✓ e.g.  	2	***An ionic compound must be chosen and it must have correct formula to score at all*** **For 1st mark,** if 8 electrons shown around cation then 'extra' electron(s) around anion must match symbol chosen for electrons in cation. *Circles not required* **Ignore** inner shell electrons **Allow:** $2[Na^+]$ $2[Na]^+$ $[Na^+]_2$ (brackets not required) Do **not** allow: for Na_2O, $[Na_2]^{2+}$ $[Na_2]^+$ $[2Na]^{2+}$ $[Na]$
		ii	electron pair(s) in covalent bond shown correctly using dots and crosses in a molecule of a compound ✓ correct number of outer shell electrons in example chosen ✓ e.g.  2 'x o' between O and H for 1st mark correct outer shell electrons for O and H for 2nd mark	2	***A covalent compound must be chosen and it must have correct formula to score at all*** For '*dot-and-cross*' diagram, accept different symbols for electrons from each atom. ie X and / If example chosen is molecule of an element, then 2nd mark can be awarded if candidate has used dots and crosses for **all** outer shell electrons around each atom. *Circles not required*

Question	Expected Answers	Marks	Additional Guidance
c		4	***USE annotations with ticks, crosses, con, ecf, etc for this part.***
	(across a period)		Ignore 'down a period', 'across a group'
	atomic radius decreases/ outer electrons closer to nucleus ✓ electrons are (pulled in) closer		If candidate responds with 'electrons are same distance from the nucleus' anywhere is a CON. ..... but ignore '**about** the same distance'
	nuclear charge increases/ protons increase ✓		Ignore 'atomic number increases' Ignore 'nucleus gets bigger' 'charge increases' is not sufficient **Allow** 'effective nuclear charge increases' *OR* 'shielded nuclear charge increases'
	greater attraction/ greater pull ✓		A comparison must be included: ie 'greater pull', 'more pull', 'held more tightly'; so ..... 'pulled in closer' would score the 1st marking point but not the 3rd marking point here
	electrons added to the same shell *OR* screening / shielding remains the same or similar ✓		**Allow** 'very small increase' for 'similar'
	Total	14	

Question			Expected Answers	Marks	Additional Guidance
3	a	i	moles = 55/24,000 = 2.3×10^{-3} / 0.0023 (mol) ✓	1	**Allow** calc $2.291666667 \times 10^{-3}$ and correct rounding to a minimum of 2 sig fig, ie 0.0023 (ie rounding is being assessed here)
		ii	[bleach] = $1000 \times 2.3 \times 10^{-3} / 3 = 0.77$ (mol dm^{-3}) ✓	1	From (a)(i), allow use of calc value = 0.763888888 For any rounded value of $2.291666667 \times 10^{-3}$ down to a minimum of 2 sig fig, ie 0.0023, **allow** any value in range **0.76** to **0.77** mol dm^{-3} (ie rounding has been assessed above) For **ECF**, = 1000 x ans to (i) / 3
		i ii iii	moles HCl at start = $1.0 \times 6.0/1000 = 6 \times 10^{-3}$ ✓ moles HCl that reacted = $2 \times 2.3 \times 10^{-3}$ $= 4.6 \times 10^{-3}$ / 0.0046 mol ✓ excess HCl = $6 \times 10^{-3} - 4.6 \times 10^{-3}$ $= 1.4 \times 10^{-3}$ mol / 0.0014 mol ✓ (mark is for answer)	3	Marking screen shows parts (i) and (iii) **ECF** = ans to (i) x 2 **ECF**: moles HCl at start – moles HCl that reacted Common mistake: If a candidate does not multiply ans to (i) by 2, then ECF answer will be 0.00371 (from 0.00229) or 0.0037 (from 0.0023) Both answers would gain 2 marks for this part.
	b	i	iodine / I_2 produced ✓ correct balanced equation: $Cl_2 + 2I^- \longrightarrow I_2 + 2Cl^-$ / $Cl_2 + 2NaI \longrightarrow I_2 + 2NaCl$ ✓	2	I_2 as a product in an attempted equation would score 1st mark
		i ii	chlorine reacts with water forming Cl^- *OR* chloride / $Cl_2 + H_2O \longrightarrow ClO^- + 2H^+ + Cl^-$ ✓ AgCl(s) / precipitate is silver chloride *OR* AgCl(s) ✓ chloride *OR* Cl^- reacts with silver nitrate *OR* Ag^+ ✓ $Ag^+ + Cl^- \longrightarrow AgCl$ / $AgNO_3 + HCl \longrightarrow AgCl + HNO_3$ ✓	4	**Allow**: $Cl_2 + H_2O \longrightarrow HClO + HCl$ can be credited for this marking point in equation as AgCl(s) can be credited for this marking point in equation as Cl^- State symbols **not** required $Ag^+ + Cl^- \longrightarrow AgCl(s)$ would get last three marks!

Question			Expected Answers	Marks	Additional Guidance
	c	i	attraction of an atom/nucleus for electrons ✓ attraction for electrons in a (covalent) bond ✓	2	For **1st mark**, atom/nucleus is essential Commonest correct answer: 'Attraction of an atom for the electrons in a covalent bond'
		ii	four bonds shown with at least 2 wedges, one in; one out ✓  bond angle = 109.5° ✓	2	For bond into paper, accept:  **Allow** correct shape with no atom labels:  Bond angle can just be stated as this is the only one bond angle that applies, so no labelling required. **Allow** 109° – 110°
		iii	Cl is more electronegative (than H or C) ✓ CCl_4 is symmetrical ✓ In CCl_4 dipoles cancel ✓	3	***USE annotations with ticks, crosses, con, ecf, etc for this part.*** **Allow**: Cl is δ– /slightly negative *OR* shown as dipole: $H^{\delta+}–Cl^{\delta-}$ *OR* $C^{\delta+}–Cl^{\delta-}$ Do **not** allow 'negative' OR Cl^- *OR* chloride ion *OR* chlorine ion **Allow** CCl_4 is tetrahedral
			Total	**18**	

Question			Expected Answers	Marks	Additional Guidance
4	a		**A**: CaO ✓ **B**: CO_2 ✓ **C**: $Ca(OH)_2$ ✓ **D**: $CaCl_2$ ✓ **E**: H_2O ✓ [redacted]	6	**Brackets essential** **Allow** any order of atoms in a correct formula
	b		$2Ca(s) + O_2(g) \longrightarrow 2CaO(s)$ / $Ca(s) + ½ O_2(g) \longrightarrow CaO(s)$ state symbols for Ca, O_2 and CaO ✓ correct balanced equation ✓ Oxidation is loss of electrons AND reduction is gain of electrons ✓ Ca loses 2 electrons AND O gains 2 electrons OR Ca loses 2 electrons AND O_2 gains 4 electrons✓	4	***USE annotations with ticks, crosses, con, ecf, etc for this part.*** **Allow** 'multiples', ie $4Ca(s) + 2O_2(g) \longrightarrow 4CaO(s)$ **Allow** balanced equation with a species on both sides, ie $Ca(s) + O_2(g) \longrightarrow CaO(s) + ½ O_2(g)$ Must be in terms of electrons Ignore any reference to oxidation number **Allow** equations (**accept** 'e' without '–' sign): $Ca \longrightarrow Ca^{2+} + 2e^- / Ca - 2e^- \longrightarrow Ca^{2+}$ $O_2 + 4e^- \longrightarrow 2O^{2-} / O + 2e^- \longrightarrow O^{2-}$
			reactivity increases (down the group) ✓ atomic radii increases/ there are more shells ✓ there is more shielding/ more screening ✓ Increased shielding and distance outweigh the increased nuclear charge / the nuclear attraction decreases ✓ easier to remove outer electrons/ ionisation energy decreases/ ✓	5	***USE annotations with ticks, crosses, con, ecf, etc for this part.*** 'down the group' not required **'more'** *is essential* allow 'more electron repulsion from inner shells' **Allow** 'nuclear pull' ignore any reference to 'effective nuclear charge'
			QWC – At least two sentences that show legible text with accurate spelling, punctuation and grammar so that the meaning is clear. ✓	1	QWC mark **must** be indicated with a tick or cross through the Quality of Written Communication prompt at the bottom of page 9. **Then scroll up to start of (b), counting ticks.**
			Total	**16**	

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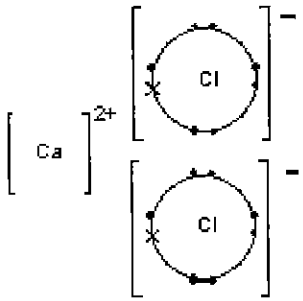
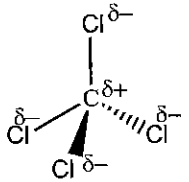
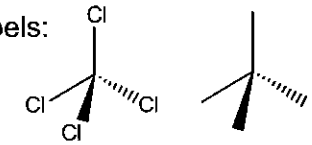
Question			Expected Answers	Marks	Additional Guidance
1	(a)	i	20✓	1	
		ii	2✓	1	
		iii	5 ✓	1	
	(b)	i	69.8 ✓	1	
		ii	96.0 ✓	1	**Allow** 96
		iii	moles of $NaNO_3$ = 0.05 ✓ mass = 0.05 x 85 = 4.25 (g) ✓	2	4.8 g worth 1 (wrong M_r) Accept 4.3 but not 4.2 (ecf for calculated moles x 85)
		iv	2.51 x 10^{21}✓	1	**Allow** 2.5 x 10^{21} Calc: 2.508333333 x 10^{21} **Allow** calc value and any degree of correct rounding down to 2.5 x 10^{21}
	(c)		(+)7 ✓	1	Sign not required but do not credit '–7' Accept VII
			Total	9	

Question			Expected Answers	Marks	Additional Guidance
2	(a)		Energy change when **each atom in 1 mole** ✓ of **gaseous** atoms ✓ **loses an electron** ✓ (to form 1 mole of gaseous 1+ ions)	3	Not 'element' alone Compensate missed marks from correct equation
	(b)		Si ✓ Sharp rise in successive ionisation energy between 4th and 5th IE ✓ marking a change to a new shell / there are 4 electrons in the outer shell✓	3	Not consequential Not sub-shell
	(c)		 atomic radii increases/ there are more shells/atoms get bigger ✓ there is more shielding/ more screening ✓ ionisation energy decreases because the Increased shielding and distance outweigh the increased nuclear charge / the nuclear attraction decreases ✓	3	***USE annotations with ticks, crosses, con, ecf, etc for this part.*** 'down the group' not required ***'more'*** *is essential* allow 'more electron repulsion from inner shells' **Allow** 'nuclear pull' ignore any reference to 'effective nuclear charge'
			Total	**9**	

Question			Expected Answers	Marks	Additional guidance
3	(a)		Ca^{2+}: 20 protons; 18 electrons ✓ Cl^-: 17 protons; 18 electrons ✓	2	
	(b)		cation shown with either 8 or 0 electrons ***AND*** anion shown with 8 electrons ***AND*** correct number of crosses and dots ✓ Correct charges on both ions ✓ 	2	**For 1st mark,** if 8 electrons shown around cation then 'extra' electron(s) around anion must match symbol chosen for electrons in cation. *Circles not required* **Ignore** inner shell electrons For charges, **Allow:** $2[Cl^-]$ $2[Cl]^-$ $[Cl^-]_2$ (brackets not required except for last one) Do **not** allow: for $CaCl_2$, $[Cl_2]^{2-}$ $[Cl_2]^-$ $[2Cl]^{2-}$ $[Cl]$ Max 1 if only one Cl^-
	(c)		solid: ions are fixed (AW) ✓ aqueous: ions are free (to move) (AW) ✓	2	If charge carriers are wrong but comparison is given, then award one mark, *e.g.* solid: *electrons* are fixed in lattice *AND* aqueous: *electrons* are free to move ✓ (1 mark
	(d)	i	molar mass $CaCO_3$: 100.1 (g mol^{-1}) ✓ 4.85/100.1 = 0.0485 mol ✓	2	Not 100 for molar mass calc. 0.048451548 **Allow** rounding of calculator value back to 2 sig figs allow 0.048-0.049 **ECF** If working shown for an incorrect molar mass, then the 2nd mark can be awarded as 4.85/calculated molar mass
		ii	5.38 or 5.39 g or 5.4 g ✓	1	For information: 0.0485 x 111.1 = 5.39 0.048451548 x 111.1 = 5.38

Question			Expected Answers	Marks	Additional guidance
					ECF: moles from (i) x 111.1 or 111
		iii	0.0970 or 0.097 or 0.0969 ✓ volume = 64.7 or 64.6 cm^3 or 65 ✓	2	For information: 2 x 0.0485 = 0.0970 mol 2 x 0.048451548 = 0.0969 **ECF** moles from (i) x 2 For information (0.0970/1.50) x 1000 = 64.7 cm^3 (0.0969/1.50) x 1000 = 64.6 cm^3 **ECF** (moles above/1.50) x 1000
	(e)		$Ca/CaO/Ca(OH)_2$ ✓ $Ca + 2HCl \longrightarrow CaCl_2 + H_2$ / $CaO + 2HCl \longrightarrow CaCl_2 + H_2O$ / $Ca(OH)_2 + 2HCl \longrightarrow CaCl_2 + 2H_2O$ ✓	2	Ignore state symbols **Allow** any other suitable alternatives
	(f)	i	Ca : H : S : O = 19.82/40.1 : 0.99/1 : 31.74/32.1 : 47.45/16 or 1 : 2 : 2 : 6 ✓ empirical formula = $CaH_2S_2O_6$ ✓	2	Using atomic numbers gives $CaHS_2O_6$ worth 1 **Allow** $Ca(HSO_3)_2$!
		ii	$Ca(OH)_2 + 2SO_2 \longrightarrow CaH_2S_2O_6$ ✓	1	If you see it, **allow** $Ca(HSO_3)_2$!
			Total	**16**	

Question			Expected Answers	Marks	Additional Guidance
4	(a)		down group/from Cl to I/, number of electrons/shells increases ✓ more/ stronger/ van der Waals'/ intermolecular forces/ induced dipoles/ instantaneous dipoles ✓ greater forces to break/more energy has to be put in to break forces ✓	3	Answers involving ionisation energies score 0
	(b)		$I_2 \rightarrow IO^-$, 0 to +1 ✓: oxidised $I_2 \rightarrow I^-$, 0 to –1 ✓: reduced **correct** 'oxidised' **and** 'reduced' above/I is both oxidised and reduced / disproportionation ✓	3	Sign not required but do not credit '–1' '–' Sign required here
	(c)	i	goes orange/red/yellow ✓ $Cl_2 + 2Br^- \longrightarrow Br_2 + 2Cl^-$ ✓	2	Ignore brown Ignore spectator ions
		ii	$Ag^+(aq) + Cl^-(aq) \longrightarrow AgCl(s)$ correct equation ✓ correct state symbols ✓	2	Allow state symbols for (slightly) incorrect equations
	(d)	i	attraction of an atom for electrons ✓ in a (covalent) bond/ bonding pair ✓	2	
		ii	correct 3-D tetrahedral shape shown showing one outward wedge and 1 inward wedge; 3 bonds below horizontal ✓ correct dipoles: δ+ on C and δ– on each Cl ✓  	2	For bond into paper, accept:  **Allow** correct shape with no atom labels:  Only need to show one dipole
		iii	the polarities/ dipoles cancel out / the molecule is symmetrical	1	
			Total	**15**	

Question	Expected Answers	Marks	Additional Guidance
5	Magnesium structure/bonding: giant ✓ metallic ✓ conducts by delocalised/free/mobile electrons ✓ melting point high because of the electrostatic attraction / attraction between (positive) ions and electrons ✓ Diamond does not conduct/poor conductor: no mobile charge carriers/electrons/ions ✓ structure/bonding: giant (✓) covalent ✓ melting point: high because strong/ lots of (covalent) bonds are broken ✓ Ice does not conduct: no mobile charge carriers/electrons/ions ✓ structure/bonding: H-bonds/intermolecular forces/ simple molecular ✓ melting point: Low because H bonds/intermolecular/ weak forces between molecules (are broken)/ higher than expected because H-bonds broken/ H-bonds stronger than other (named) intermolecular forces ✓	10	***USE annotations with ticks, crosses, con, ecf, etc for this part.*** ***Credit information if given in annotated diagrams*** ***Watch out for contradictions, especially of bonding type*** **Allow**: positive ions with a sea of electrons for both structure and bonding marks if labelled, one if not. Giant only awarded if not given above must refer to bonds being broken once
	QWC – At least two sentences that show legible text with accurate spelling, punctuation and grammar so that the meaning is clear. ✓	1	QWC mark **must** be indicated with a tick or cross through the Quality of Written Communication prompt at the bottom of page 9. **Then scroll up to start of (b), counting ticks.**
	Total	11	

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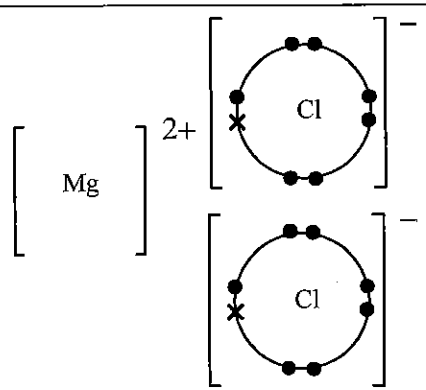
Question			Expected Answers	Marks	Additional Guidance
1	a	i	Atoms or isotopes of same element/same atomic number/number of protons with different numbers of neutrons/different masses ✓	1	Not elements with a different no of neutrons
		ii	^{33}S: 16p; 17n; 16e ✓ ^{34}S: 16p; 18n; 16e ✓	2	Mark by **row**
	b	i	M_r = weighted mean mass of an atom/the isotopes of an element ✓ compared with carbon-12 ✓ 1/12th (of mass) of carbon-12/ on a scale where carbon-12 is 12 ✓ *(but not 12 g)*	3	**Allow** 'average mass of atom' or 'mean mass of atom' *alternative **allowable** definitions:* mass of one mole of atoms ✓ compared to 1/12th ✓ (the mass of) one mole/12 g of carbon-12 ✓ mass of one mole of atoms ✓ $1/12^{th}$ ✓ the mass of one mole/12 g of carbon-12 ✓
		ii	$A_r = 32 \times \frac{94.93}{100} + 33 \times \frac{0.76}{100} + 34 \times \frac{4.29}{100} + 36 \times \frac{0.02}{100}$ **OR** 32.0942 ✓ = 32.09 ✓ to four significant figures	2	**Allow** one mark for A_r = 32.0942 with no working out **Allow** two marks for A_r = 32.09 with no working out If a candidate uses incorrect values in 1st line, then the 2nd mark can still be awarded if the calculated value is from 32.01 to 35.99 expressed to two decimal places. This allows for any %'s the wrong way round in 1st line.
		iii	mass spectrometer ✓	1	**Allow** 'mass spectrometry' **OR** 'mass spectrum', **Allow** 'mass spectroscope' **OR** mass spectroscopy
	c	i	(2) water(s) of crystallisation/ 2 mol of H_2O for 1 mol $CaSO_4$ ✓	1	**Allow** the salt is hydrated, crystals contain water.
		ii	172.2 (g mol^{-1}) ✓	1	**Allow** 172.19
		iii	(+)6 ✓	1	**Allow** lack of + sign but '–6' is wrong
		iv	SO_4^{2-} ✓	1	**Allow** 'SO_4', 2– charge **Allow** '–2'
			Total	**13**	

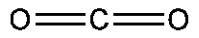
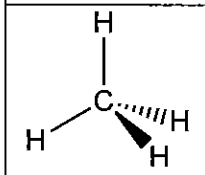
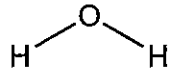
Question			Expected Answers	Marks	Additional Guidance
2	a		(electrostatic) attraction between oppositely charged ions/ specific example given ✓	1	**Allow** 'oppositely charged atoms'
	b	i	cation shown with either 8 or 0 electrons ***AND*** anion shown with 8 electrons ***AND*** correct number of crosses and dots for example chosen ✓ Correct charges on both ions ✓ 	2	**For 1st mark,** if 8 electrons shown around cation then 'extra' electron(s) around anion must match symbol chosen for electrons in cation. *Circles not required* **Ignore** inner shell electrons **Allow:** $2[Cl^-]$ $2[Cl]^-$ $[Cl^-]_2$ Do **not** allow: $[Cl_2]^-$ $[Cl]_2^-$ $[2Cl]^-$ Accept correct answers without brackets.
		ii	$1s^2 2s^2 2p^6 3s^2 3p^6$ ✓	1	**Allow** subscripts
	c	i	attraction between positive ions ✓ and free/delocalised electrons ✓	2	**Allow** 'sea of electrons'; Do **not** allow just 'electrons' 1st mark is for positive ions **OR** delocalised/free electrons anywhere 2nd mark is for 'attraction between the correct charged particles **Allow** labelled diagram showing a scattering of labelled electrons between positive ions for 1st mark
		ii	Al^{3+} compared to Mg^{2+}/ the aluminium ion has a higher charge (density)/there are more delocalised/free/outer electrons (per atom) ✓	1	**Allow** magnesium ion has a smaller charge (density)/there are less delocalised electrons (per atom) ✓ Allow Al has 3 delocalised electrons, Mg has 2 delocalised electrons. ie Do **not** allow just 'Al has more electrons. (it must be clear that these are the outer shell electrons)

	d	**i**	Co has fewer protons (ORA)/ Periodic Table is in order of number of protons ✓	1	**Allow** 'Co has an atomic number (1) less than Ni'
		ii	(On average) **isotopes** of Co have more neutrons than Ni ✓	1	'Isotopes' essential Allow 'In Co, there is a higher proportion of heavier isotopes/ isotopes with a higher mass number' Do not allow just 'higher mass number'
	e	**i**	moles Al = $\frac{2.025}{27.0}$ = 0.075 ✓	1	
		ii	moles H_2 = 1.5 x 0.075 = 0.1125 mol ✓ volume H_2 = 0.1125 x 24 = 2.7 dm^3 ✓	2	**ECF,** 1.5 x answer to **(i)**
		iii	moles HCl = 3 x 0.075 = 0.225 mol ✓ volume HCl = $\frac{1000 \times 0.225}{1.80}$ = 125 cm^3 ✓	2	**ECF**, 3 x answer to **(i) or** 2 x no of moles in (ii) **ECF**, $\frac{1000 \times \text{moles HCl}}{1.80}$
			Total	**14**	

Question			Expected Answers	Marks	Additional guidance
3	a		solid **A**: BaO ✓ solution **B**: $BaCl_2$ ✓ precipitate **C**: [redacted] ✓ precipitate **D**: AgCl ✓	4	Watch order of letters in the boxes. See the pattern on the left
	b		Ba : C : O = $\frac{60.89}{137}$: $\frac{10.67}{12.0}$: $\frac{28.44}{16.0}$ or 1 : 2 : 4 ✓ empirical formula = BaC_2O_4 (or, if you see it, allow $Ba(CO_2)_2$!) ✓	2	If a candidate uses atomic numbers, the ratio is still 1:2:4. The 2nd mark can still be awarded by error carried forward. Although unlikely, a correct answer of BaC_2O_4 with no working should be awarded **both** marks. If candidate shows inverse for ratios: ie Ba : C : O = $\frac{137}{60.89}$: $\frac{12.0}{10.67}$: $\frac{16.0}{28.44}$ .....then the candidate can be awarded the 2nd mark **only** for Ba_4C_2O by error carried forward.
	c	i	$Ba(g) \longrightarrow Ba^+(g) + e^-$ equation ✓ state symbols as (g) ✓	2	ignore absence of '$^-$ sign' on e^- ignore state symbol with e^- **Allow** $Ba(g) - e^- \longrightarrow Ba^+(g)$
		ii	(1st ionisation energy) decreases (down the group) ✓ atomic radii increases/ there are more shells ✓ there is more shielding/ more screening ✓ Increased shielding and distance outweigh the increased nuclear charge/	4	'down the group' not required '**more**' *is essential* allow 'more electron repulsion from inner shells' **Allow** 'nuclear pull' not held less tightly. ignore any reference to 'effective nuclear charge'

			the nuclear attraction decreases ✓		
	d	**i**	Group 2 (elements) react by losing electrons ✓ Group 7 (elements) react by gaining electrons ✓ (As atoms get larger/more shielding), it is easier to lose electrons **AND** more difficult to gain electrons ✓	3	**Allow** Group 2 form + ions **Allow** Group 7 form – ions **Both** comparisons needed for third mark
		ii	chlorine has displaced or oxidised iodine/iodine forms ✓ $Cl_2 + 2I^- \longrightarrow 2Cl^- + I_2$ **OR** $Cl_2 + 2KI \longrightarrow I_2 + 2KCl$ ✓	2	I_2 as a product in an attempted equation scores 1st mark **Ignore** state symbols **Ignore** any reference to iodide
			Total	**17**	

Question	Expected Answers	Marks	Additional Guidance
4	Na has fewer protons/less nuclear charge ✓ electrons added to the same shell *OR* screening/shielding remains the same or similar ✓ Na has less attraction/ less pull	3	**Allow** Mg has more protons/more nuclear charge **Allow** 'across a period, nuclear charge increases/protons increase' A comparison must be included **Allow** a comparison in terms of 'effective nuclear charge' *OR* 'shielded nuclear charge' **ignore** reference to distance **Ignore** comparison of atomic number **Ignore** comparison of nuclear size 'Na charge is less' OR 'Mg charge is greater' is not sufficient **Allow** Mg has more attraction/more pull **Allow** 'across a period, more attraction/more pull' A comparison must be included
	iodine exists as small molecules /I_2/simple molecular structure ✓ van der Waals' forces/intermolecular forces (must be broken) ✓ diamond exists as a giant structure ✓ covalent bonds (must be broken) ✓ Strength of forces linked to boiling point: van der Waals' forces are weak/ small amount of energy to break van der Waals' forces/ covalent bonds are strong/ large amount of energy to break covalent bonds ✓	5	**Allow** induced dipole/instantaneous dipoles interactions 'giant covalent structure' scores both 'diamond marks **Allow** lattice for giant structure Mark this anywhere.

				7	**Allow** bond angles +/- 0.5° **For full marks must say repel at least once.**	
			CO_2: linear/bond angle = 180˚/ diagram✓ two areas of electron density repel ✓		**Allow** 2 bonds/bonding pairs repel	Acceptable diagrams: 
			CH_4: tetrahedral/bond angle =109.5˚/diagram ✓ four bonded pairs repel ✓		**Allow** 4 bonds repel	 four bonds shown with at least 2 wedges, one in; one out For bond into paper, accept: 
			H_2O: non-linear/bond angle =104.5˚/ diagram ✓ two bonded pairs and two lone pairs repel/ diagram ✓ lone pairs repel more (than bonded pairs)✓		**Allow** 2 bonds and 2 lone pairs repel	

				QWC – At least two sentences that show legible text with accurate spelling, punctuation and grammar so that the meaning is clear. ✓	1	QWC mark **must** be indicated with a tick or cross through the Quality of Written Communication prompt at the bottom of page 9. **Then scroll up to start of question, counting ticks.** **Watch out that you have counted ticks on BOTH pages 8 and 9** Mark **QWC** anywhere within Q4
				Total	**16**	