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Principal: Mrs O. Tomlinson

OCR CHEMISTRY A

AS LEVEL

UNIT 1 MORE PAST PAPER QUESTIONS

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Answer **all** the 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*.

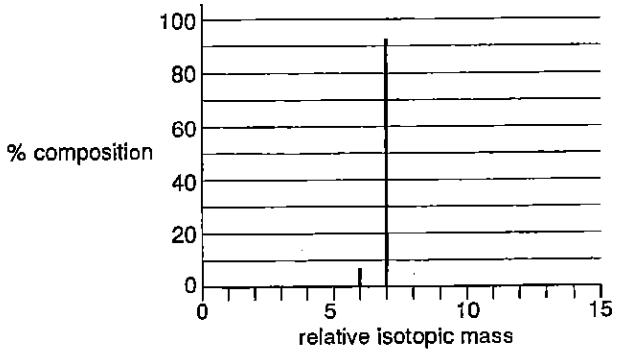
.....

.....[1]

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

.....[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			
^{7}Li			

[3]

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

[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?

.....

.....[1]

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

.....

.....[1]

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

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

.....

.....

.....

.....[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.

.....

.....

.....

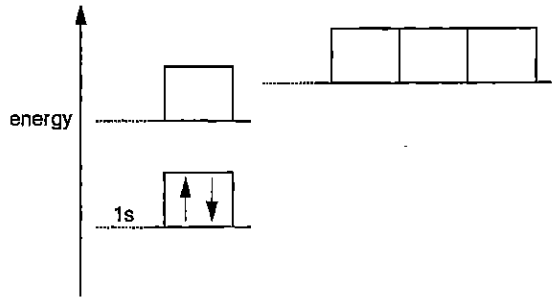
.....

.....

.....[3]

[Total : 15]

2 Electrons are arranged in energy levels. The diagram below for the 7 electrons in a nitrogen atom 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]

(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.

$1s^2$ .....[1]

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

magnesium ion .....

nitride ion .....[2]

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

magnesium ion $1s^2$.....

nitride ion $1s^2$.....[2]

(iv) Deduce the formula of magnesium nitride.

.....[1]

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

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

.....[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.

.....[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 .....

observation 2 .....[2]

(b) In this experiment, 0.040 g $CaCO_3$ is added to 25 cm^3 of 0.050 mol dm^{-3} HCl.

(i) Explain what is meant by 0.050 mol dm^{-3} HCl.

.....

.....

.....[2]

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

[2]

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

[1]

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

[1]

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

.....[1]

[Total : 9]

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

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

(i) Explain the term *electronegativity*.

.....

.....

.....[2]

(ii) Why are water molecules polar?

.....

.....[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.

[4]

(ii) State the bond angle in a water molecule.

.....[1]

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

property .....

explanation .....

.....

property .....

explanation .....

.....[4]

[Total : 12]

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

The sulphuric acid is prepared from sulphur in a 3 stage process.

Stage 1:
The sulphur is burnt in oxygen to produce sulphur dioxide.
$S + O_2 \longrightarrow SO_2$

Stage 2:
The sulphur dioxide reacts with more oxygen using a catalyst to form sulphur trioxide.
$2SO_2 + O_2 \longrightarrow 2SO_3$

Stage 3:
The sulphur trioxide is dissolved in concentrated sulphuric acid to form 'oleum', $H_2S_2O_7$, which is then diluted in water to produce sulphuric acid.

(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]

[1]

(ii) the mass of sulphur trioxide that formed.
M_r: SO_3, 80.1

[1]

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

.....[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 the **diluted** sulphuric acid for neutralisation.

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

[1]

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

[2]

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

[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,

.....[1]

(ii) the element with the largest first ionisation energy,

.....[1]

(iii) an element with a giant molecular structure.

.....[1]

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

.....

.....

.....

.....[3]

(c) Predict and explain whether a sodium **ion** is *larger*, *smaller* or the *same size* as a sodium **atom**.

.....

.....

.....

.....[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.

$$Cl_2(g) + 2NaOH(aq) \longrightarrow NaClO(aq) + NaCl(aq) + H_2O(l)$$

(i) Determine the oxidation number of chlorine in

Cl_2 .....

NaClO .....

NaCl .....[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.

.....[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.

.....[1]

(ii) Suggest how bromine could be removed from the sea water after this oxidation.

.....

.....[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.

[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.

[2]

[Total : 10]

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

You should use diagrams to illustrate your answer.

8 Sodium reacts with chlorine forming sodium chloride.

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

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

[Total : 16]

Answer **all** questions.

1 **(a)** State what is meant by

(i) an *ionic bond*,

.....

.....[1]

(ii) a *covalent bond*.

.....

.....[2]

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

sodium chloride	hydrogen chloride

[3]

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

.....

.....[1]

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

s orbital	p orbital

[2]

For Examiner Use

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

	number of electrons
a p **orbital**	
a d **sub-shell**	
the third **shell** (n = 3)	

[3]

[Total : 12]

For Examiner Use

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
boiling point/°C	883	1107	2467	2355	280	445	−35
bonding							
structure							

(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.

.....

.....

.....[3]

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

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

.....

.....

.....[2]

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

.....

.....

.....[2]

[Total : 9]

3 Hydrogen chloride, HCl, is a colourless gas which dissolves very readily in water forming hydrochloric acid. [1 mol of gas molecules occupy 24.0 dm^3 at room temperature and pressure r.t.p.]

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

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

[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?

[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.

.....

.....

.....[2]

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

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

(i) MgO

observation .....

.....

equation .....[2]

(ii) $MgCO_3$

observation .....

.....

equation .....[2]

[Total : 8]

4 Sulphur and sulphur compounds are common in the environment.

(a) A sample of sulphur from a volcano contained 88.0% by mass of ^{32}S and 12.0% by mass of ^{34}S.

(i) Complete the table below to show the atomic structure of each isotope of sulphur.

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

[2]

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

.....

.....

.....

.....[3]

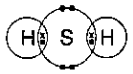
(iii) Calculate the relative atomic mass of the volcanic sulphur. Your answer should be given to three significant figures.

[2]

For Examiner Use

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

A 'dot-and-cross' diagram, showing outer shell electrons only, of a hydrogen sulphide molecule is shown below.



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

explanation .....

.....

.....[3]

(c) Every year, between 20 and 50 million tonnes of sulphur are released into the atmosphere from the oceans in the form of DMS, a compound of carbon, hydrogen and sulphur. DMS causes the bracing feeling by the sea.

DMS has the percentage composition by mass of C: 38.6%; H: 9.7%; S: 51.7%.

Calculate the empirical formula of DMS.

[2]

[Total : 12]

For Examiner Use

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,

.....[1]

(ii) reduction.

.....[1]

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

element .....

oxidation state changes from ..... *to* ..... [2]

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

(i) Calculate how many moles of Ba reacted.

[1]

(ii) 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.]

[1]

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

[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.

compound .....

equation .....[2]

For Examiner Use

(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*.

.....

.....

.....

.....[3]

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

.....

.....

.....

.....

.....

.....[4]

[Total : 16]

For Examiner Use

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

Table 7.1

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

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

Outline how van der Waals' forces arise between molecules.

.....

.....

.....

.....[2]

(b) Liquid H_2O has additional intermolecular forces.

(i) What are these forces?

.....[1]

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

.....

.....

.....

.....

.....[5]

For Examiner Use

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

.....[1]

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

.....

.....

.....[2]

[Total : 11]

For Examiner Use

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**: $1s^2$ .....

a calcium **ion**: $1s^2$ ..... [2]

(b) Calculate the approximate number of calcium ions in an adult human skeleton.
[The Avogadro constant, $L = 6 \times 10^{23}\ mol^{-1}$.]

[2]

(c) Suggest why calcium **atoms** are **not** present in a human skeleton.

.....

.....

.....[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?

.....**[1]**

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

[3]

[Total : 9]

For Examiner's Use

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.

[Total : 13]

Answer **all** questions

1 This question refers to calcium chloride, made up of Ca^{2+} and Cl^- ions.

(a) Complete the table below.

species	number of	
	protons	electrons
Ca^{2+}		
Cl^-		

[2]

(b) Complete the electronic configuration of Ca^{2+}.

$1s^2$ .....[1]

(c) (i) What is the formula of calcium chloride?

.....[1]

(ii) Using outer electron shells only, draw a '*dot-and-cross*' diagram of calcium chloride.

[2]

(iii) How is a solid structure of calcium chloride held together?

.....[1]

(d) When an electric current is passed through aqueous calcium chloride, chlorine gas is released. The overall equation for the reaction taking place is shown below.

$$CaCl_2(aq) + 2H_2O(l) \longrightarrow Ca(OH)_2(aq) + H_2(g) + Cl_2(g)$$

(i) Predict what would happen to the pH of the solution. Explain your answer.

.....

.....[2]

(ii) Explain why an aqueous solution of calcium chloride conducts electricity whereas solid calcium chloride does not.

.....

.....

.....[2]

For Examiner's Use

(e) 72 cm^3 of chlorine gas were collected and shaken with water.

The following reaction takes place.

$$Cl_2(g) + H_2O(l) \longrightarrow HClO(aq) + HCl(aq)$$

(i) Determine the oxidation number of chlorine in

Cl_2 .....

$HClO$ .....

HCl .....[3]

(ii) How many moles of Cl_2 were collected?

[Under the conditions used, 1 mol of gas molecules occupies 24 dm^3.]

Answer .....[1]

(iii) State a widespread use for this reaction.

.....[1]

[Total : 16]

2 The first ionisation energies of the elements Na to K are represented in Fig. 2.1 below.

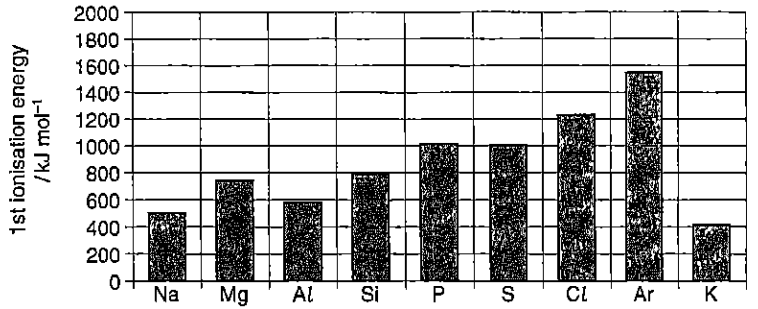


Fig. 2.1

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

.....

.....

.....

.....[3]

(b) Explain why

(i) the first ionisation energies show an overall increase from Na to Ar;

.....

.....

.....[3]

(ii) the first ionisation energy of Al is less than that of Mg.

.....

.....

.....[2]

(c) Explain the difference between the first ionisation energies of Ar and K.

.....

.....

.....

.....[3]

For Examiner's Use

(d) Refer to Fig. 2.1 to answer this question.

Estimate a value for the first ionisation energy of Ne.

First ionisation energy of Ne = ... $kJ\,mol^{-1}$ [1]

(e) Write the equation, including state symbols, for the change that accompanies the **third** ionisation energy of aluminium.

.....[2]

[Total : 14]

3 The formation of magnesium oxide, MgO, from its elements involves both oxidation and reduction in a redox reaction.

(a) (i) What is meant by the terms *oxidation* and *reduction*?

oxidation .....

.....

reduction .....

.....[2]

(ii) Write a full equation, including state symbols, for the formation of MgO from its elements.

.....[2]

(iii) Write half equations for the oxidation and reduction processes that take place in this reaction.

oxidation .....

reduction .....[2]

(b) MgO reacts when heated with acids such as nitric acid, HNO_3.

$$MgO(s) + 2HNO_3(aq) \longrightarrow Mg(NO_3)_2(aq) + H_2O(l)$$

A student added MgO to 25.0 cm^3 of a warm solution of 2.00 mol dm^{-3} HNO_3 until all the acid had reacted.

(i) How would the student have known that the reaction was complete?

.....

.....[1]

(ii) Calculate how many moles of HNO_3 were used.

Answer .....moles [1]

(iii) Deduce how many moles of MgO reacted with this amount of HNO_3.

Answer .....moles [1]

For Examiner's Use

(iv) Calculate what mass of MgO reacted with this amount of HNO_3.

[A_r: Mg, 24.3; O, 16.0]

Give your answer to three significant figures.

Answer .....g [3]

(v) Using oxidation numbers, explain whether the reaction between MgO and HNO_3 is a redox reaction.

.....

.....

.....

.....[2]

(c) MgO has a very high melting point.

Explain this property of MgO.

.....

.....

.....[2]

[Total : 16]

[Turn over

For Exam. Us

4 The compounds NH_3, BF_3 and HI all have covalent bonding and simple molecular structures. The Pauling electronegativity values shown in Table 4.1 below can be used to predict polarity in these compounds.

H 2.1

Li 1.0	Be 1.5	B 2.0	C 2.5	N 3.0	O 3.5	F 4.0
Na 0.9						Cl 3.0
K 0.8						Br 2.8
						I 2.5

Table 4.1

(a) Explain the term *electronegativity*.

.....

.....

.....[2]

(b) The electronegativity values in Table 4.1 can be used to predict the polarity of a bond.

In the boxes below, show the polarity of each bond by adding $\delta+$ or $\delta-$ to each bond.

The first box has been completed for you.

$^{\delta-}O–H^{\delta+}$	H–N	F–B	H–I

[2]

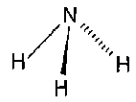
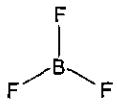
(c) Using outer electron shells only, draw '*dot-and-cross*' diagrams for molecules of NH_3 and BF_3.

NH_3	BF_3

[2]

(d) The diagrams below show the shapes of molecules of NH_3 and BF_3.

In the spaces below each diagram, state the bond angle in each molecule and state the name of each shape.

	
bond angle:	bond angle:
shape:	shape:

[4]

(e) Explain why NH_3 has polar molecules whereas molecules of BF_3 are non-polar.

.....

.....

.....[2]

(f) Polar molecules of NH_3 form hydrogen bonds. Draw a diagram to show this hydrogen bonding.

[1]

(g) NH_3 reacts with HI to form the ionic compound NH_4I, made up of NH_4^+ and I^- ions.

$$NH_3 + HI \longrightarrow NH_4I$$

(i) Explain why the H–N–H bond angle in NH_3 is less than that in NH_4^+.

.....

.....

.....[2]

(ii) Describe a simple test to confirm the presence of I^- ions in an acidified solution of NH_4I.

.....

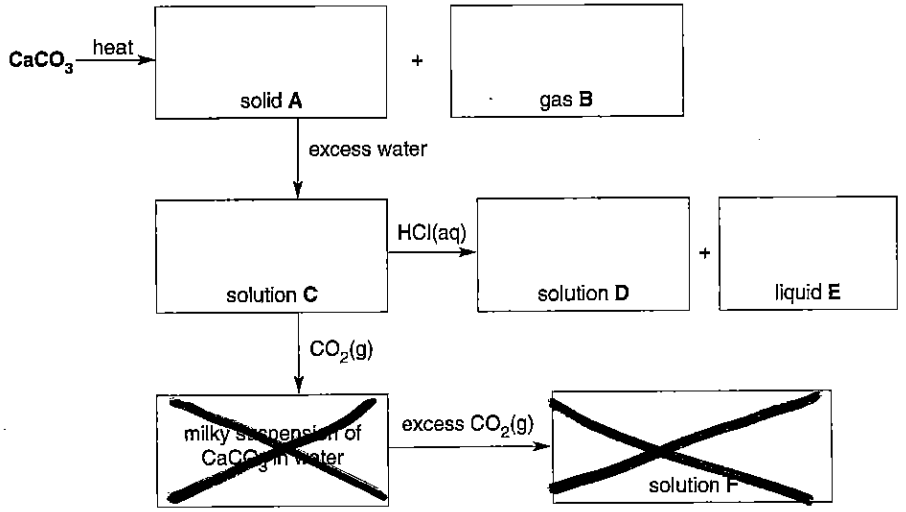
.....

.....[2]

[Total : 17]

5 In the UK, over 60 million tonnes of limestone are quarried each year. Much of this limestone is used to produce cement. The main chemical in limestone is calcium carbonate, $CaCO_3$.

(a) Complete the flow-chart below for reactions starting from calcium carbonate. You should identify each of the substances **A–F** by name or formula.



[6]

(b) Cement is a mixture of calcium and aluminium silicates, formed by heating limestone with clay.

$$4CaCO_3(s) + Al_2Si_2O_7(s) \longrightarrow \underbrace{2CaSiO_3(s) + Ca_2Al_2O_5(s)}_{\text{cement}} + 4CO_2(g)$$
clay

A typical bag of cement has a mass of 25 kg. Calculate the mass of limestone (taken as calcium carbonate) required to make 25 kg of cement.

The molar mass of cement, taken as ($2CaSiO_3 + Ca_2Al_2O_5$), is 446.6 g mol^{-1}

[A_r: Al, 27.0; C, 12.0; Ca, 40.1; O, 16.0; Si, 28.1]

[3]

(c) Lime mortar is a thick paste made by adding water to a mixture of slaked lime, $Ca(OH)_2$, and sand. As mortar dries out the slaked lime reacts with carbon dioxide in the air, forming calcium carbonate which causes the mortar to harden.

(i) Write an equation to represent the hardening of mortar. Assume the sand does not react.

.....[1]

(ii) In time, lime mortar crumbles and needs to be replaced. Suggest why this happens more quickly when the mortar is exposed to air contaminated with acidic pollution.

.....

.....

.....[1]

[Total : 11]

[Turn over

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

The halogens have different reactivities.

(a) Describe how displacement reactions can be used to show the different reactivities of chlorine, bromine and iodine.

In your answer, you should include equations and observations. [4]

(b) Explain the trend in reactivity of the halogens. [4]

[Total : 8]

For Examiner's Use

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

Analysis of a sample of bromine in a mass spectrometer showed that it contained a mixture of the ^{79}Br and ^{81}Br isotopes in the proportions: ^{79}Br, 55.0%; ^{81}Br, 45.0%.

(a) Calculate the relative atomic mass of bromine in this sample.

[2]

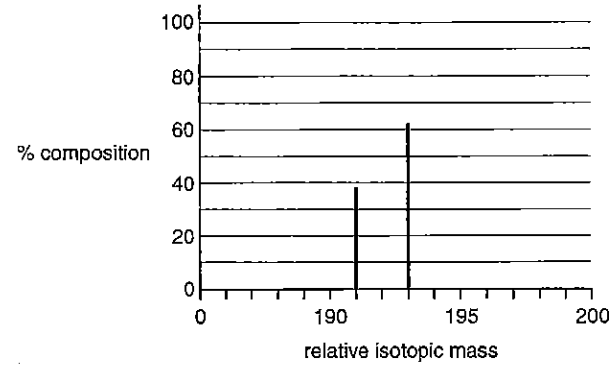
(b) Outline the basic principles of a mass spectrometer and how mass spectrometry can be used to confirm this isotopic abundance. [6]

[Total: 8]

For Examiner's Use

Answer **all** questions

1 Iridium, atomic number 77, is a very dense metal. Scientists believe that meteorites have deposited virtually all the iridium present on Earth. A fragment of a meteorite was analysed using a mass spectrometer and a section of the mass spectrum showing the isotopes present in iridium is shown below.



(a) Explain the term *isotopes.*

.....

.....[1]

(b) Use the mass spectrum to help you complete the table below for each iridium isotope in the meteorite.

isotope	percentage composition	number of	
		protons	neutrons
^{191}Ir			
^{193}Ir			

[3]

(c) **(i)** Define the term *relative atomic mass.*

.....

.....

.....

.....[3]

For Examiner's Use

(ii) Calculate the relative atomic mass of the iridium in this meteorite. Give your answer to **one** decimal place.

[2]

(d) Iridium reacts with fluorine to form a yellow solid **Y** with the percentage composition by mass: Ir, 62.75%; F, 37.25%.

The empirical formula of **Y** can be calculated from this information.

(i) Define the term *empirical formula*.

.....

.....[1]

(ii) Calculate the empirical formula of **Y**.

[2]

(iii) Write a balanced equation for the reaction between iridium and fluorine.

.....[1]

[Total : 13]

For Examiner's Use

2 This question concerns elements and compounds from Group 2 of the Periodic Table.

(a) State the trend in reactivity of the Group 2 elements with oxygen. Explain your answer.

trend in reactivity .....

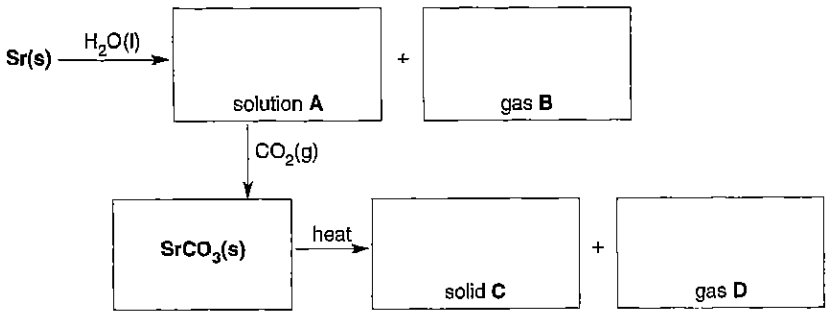
explanation .....

.....

.....

.....[4]

(b) The reactions of strontium are typical of a Group 2 element. Write the formulae for substances **A–D** in the flow chart below.



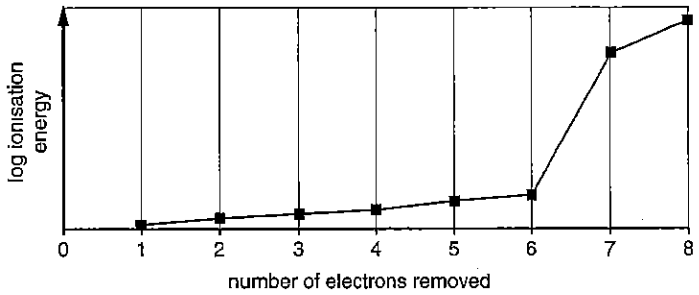
[4]

[Total : 8]

For Examiner's Use

3 This question is about aluminium oxide, Al_2O_3.

(a) Successive ionisation energies provide evidence for the arrangement of electrons in atoms.
The graph below shows the 8 successive ionisation energies of **oxygen**.



(i) Write an equation, including state symbols, to represent the **second** ionisation energy of oxygen.

.....[2]

(ii) How does this graph provide evidence for the existence of two electron shells in oxygen?

.....

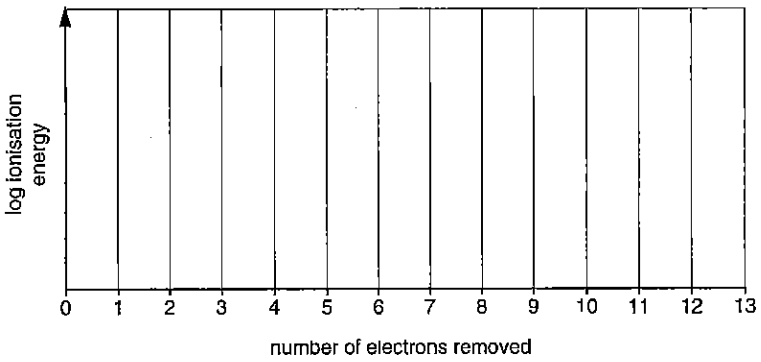
.....

.....[2]

(b) (i) Complete the electronic configuration for an **aluminium** atom.

$1s^2$ .....[1]

(ii) On the axes below, sketch a graph to show the **thirteen** successive ionisation energies of aluminium. [2]



For Examiner's Use

(c) Aluminium oxide can be formed by reacting together aluminium and oxygen.

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

.....[2]

(ii) The bonding in aluminium oxide is intermediate between ionic and covalent bonding. Explain why aluminium oxide has intermediate bonding.

.....

.....

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.....[3]

(d) Gemstones such as rubies, sapphires and topaz mainly contain aluminium oxide. Artificial rubies can be made by heating aluminium oxide with very small traces of transition metal oxides and cooling slowly. The traces of these oxides give the rubies their colours.

Calculate how many moles of Al_2O_3 are needed to make a 25.0 g ruby.

Assume that all the mass of this ruby is aluminium oxide.

Answer ..... mol
[2]

[Total : 14]

[Turn over

For Examiner's Use

4 A major use of chlorine is in the purification of drinking water. When chlorine is added to water, the following reaction takes place.

$$Cl_2(g) + H_2O(l) \longrightarrow HOCl(aq) + HCl(aq)$$

(a) Determine the oxidation number of chlorine in

HOCl, ...

HCl .....[2]

(b) HOCl has covalently bonded molecules.

Draw a '*dot-and-cross*' diagram of a molecule of HOCl.

[2]

(c) **(i)** Outline how the electron pair repulsion theory can be used to predict the shape of a covalent molecule.

.....

.....

.....

.....[3]

(ii) Using your answers to **(b)** and **(c)(i)**, draw a diagram to show the likely shape of a molecule of HOCl. Predict the bond angle in this molecule and show this clearly on your diagram.

[2]

(d) Chlorine, Cl_2, is a strong oxidising agent and oxidises aqueous iodide ions, $I^-(aq)$, to iodine, I_2.

(i) What is meant by the term *oxidation*?

.....

.....[1]

(ii) Suggest what you would expect to see when $Cl_2(g)$ is bubbled through a solution containing $I^-(aq)$.

.....[1]

For Examiner's Use

(iii) Write a balanced **ionic** equation for the oxidation of $I^-(aq)$ by $Cl_2(g)$.

.....[1]

(e) Industrially, chlorine, $Cl_2(g)$, is prepared by passing an electric current through a concentrated solution of sodium chloride, NaCl, known as brine.

In this question, assume brine has a concentration of NaCl of 4.00 mol dm^{-3}.

(i) Calculate the mass of NaCl dissolved in 1.00 dm^3 of brine.

Answer ..... g
[2]

(ii) Calculate the volume of $Cl_2(g)$ obtained from 1.00 dm^3 of brine.

$$2NaCl(aq) + 2H_2O(l) \longrightarrow Cl_2(g) + 2NaOH(aq) + H_2(g)$$

Assume that 1 mole of $Cl_2(g)$ occupies 24.0 dm^3.

Answer ..... dm^3
[2]

(iii) Every day in the UK 2.5 x 10^9 dm^3 of $Cl_2(g)$ are produced for many uses, including water treatment and the manufacture of plastics.

Assuming that all Cl_2 is produced from brine, calculate the volume of brine required for Cl_2 production each day in the UK.

Assume that 1 mole of $Cl_2(g)$ occupies 24.0 dm^3.

Answer .....
[1]

[Total : 17]

[Turn over

For Examiner's Use

5 Describe the nature of hydrogen bonding and explain **two** anomalous properties of water in terms of this bonding.

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

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QWC [1]

[Total : 8]

For Examiner's Use

Answer **all** the questions.

1 Gallium, atomic number 31, exists naturally as a mixture of its isotopes, ^{69}Ga and ^{71}Ga.

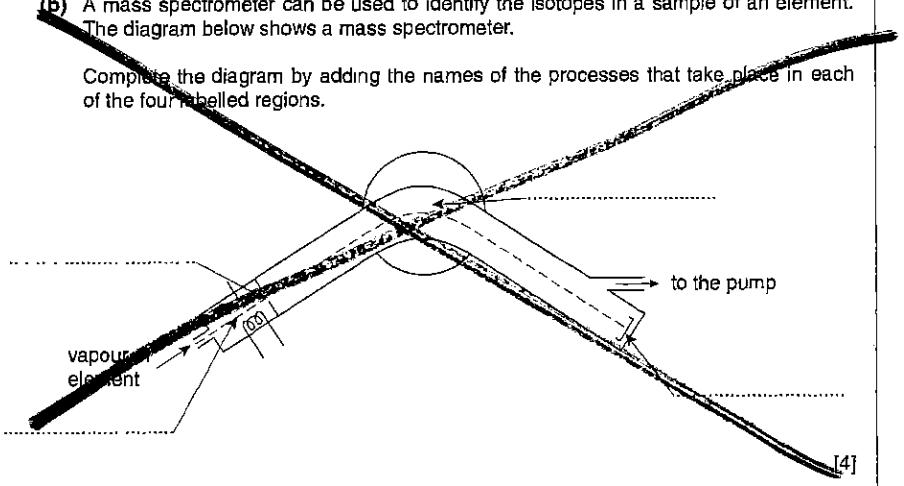
(a) Complete the table below to show the atomic structure of each isotope of gallium.

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

[2]

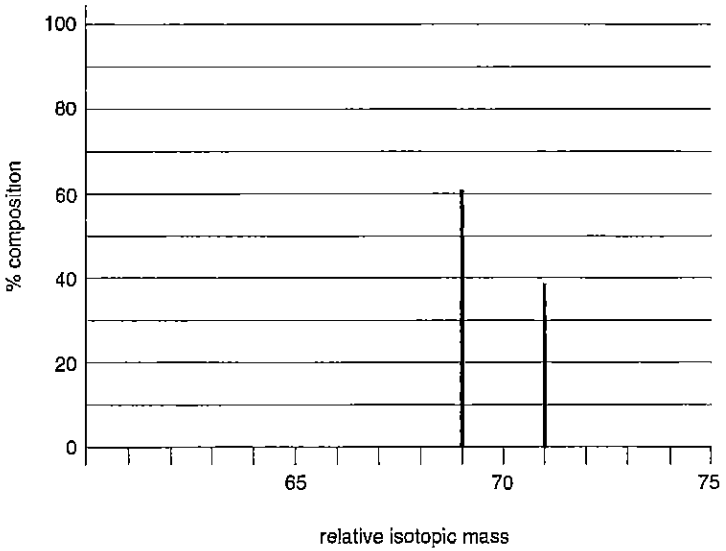
(b) A mass spectrometer can be used to identify the isotopes in a sample of an element. The diagram below shows a mass spectrometer.

Complete the diagram by adding the names of the processes that take place in each of the four labelled regions.



[4]

(c) A sample of gallium was analysed in a mass spectrometer to produce the mass spectrum below. The relative atomic mass of gallium can be calculated from this mass spectrum.



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

.....

.....

.....

..... [3]

(ii) Estimate the percentage composition of each isotope present in the sample.

[1]

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

answer ..... [2]

[Total : 12]

2 When magnesium is heated in air, it reacts with oxygen to form magnesium oxide.

$$2Mg(s) + O_2(g) \longrightarrow 2MgO(s)$$

(a) Complete the electronic configuration of a magnesium atom.

$1s^2$ ..... [1]

(b) What is the oxidation state of magnesium in

(i) Mg ..... [1]

(ii) MgO? ..... [1]

(c) When magnesium is heated in air, it also reacts with nitrogen to form solid magnesium nitride, Mg_3N_2.

(i) Construct an equation, with state symbols, for this reaction between magnesium and nitrogen.

..... [2]

(ii) Suggest why magnesium reacts with air to form much more MgO than Mg_3N_2.

.....

..... [1]

(d) Magnesium oxide has an extremely high melting point which makes it suitable as a lining for furnaces.

Explain, in terms of its structure and bonding, why magnesium oxide has this property.

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..... [3]

For Examiner's Use

(e) When magnesium oxide is added to warm dilute nitric acid, a reaction takes place forming a solution of magnesium nitrate.

$$MgO(s) + 2HNO_3(aq) \longrightarrow Mg(NO_3)_2(aq) + H_2O(l)$$

A student reacted 0.0500 mol MgO with 0.400 mol dm^{-3} nitric acid.

(i) What would you see during this reaction?

.....

..... [1]

(ii) Calculate the mass of MgO that reacted.

[2]

(iii) Calculate the volume of 0.400 mol dm^{-3} HNO_3 required to react exactly with this amount of MgO.

[2]

(f) The solution formed in this reaction contains ions.

(i) Why does this solution conduct electricity?

.....

..... [1]

(ii) State the formulae of **two** ions present in this solution.

..... [2]

[Total : 17]

For Examiner's Use

3 This question is about chlorine and chlorine compounds.

(a) Chlorine reacts with water to form a solution.

$$Cl_2(g) + H_2O(l) \longrightarrow HCl(aq) + HOCl(aq)$$

(i) Why is chlorine added to water on a large scale?

..... [1]

(ii) Green universal indicator is added to this solution.

What colour changes would you see

immediately ..... [1]

after some time? ..... [1]

(b) Describe a simple test that you could carry out to show that chloride ions are present in a sample of sea water.

reagent .....

observation .....

equation .....

[3]

(c) Some dry-cleaning solvents include the chlorine compound *Perc*.

Perc has the following percentage composition by mass: Cl, 85.6%; C, 14.4%.

The relative molecular mass of *Perc* is 166.

(i) Calculate the molecular formula of *Perc*.

[3]

(ii) Suggest why *Perc* would **not** react in the test in **(b)**.

.....

..... [1]

(d) Sodium chlorate, $NaClO_3$, is a chlorine compound used as a weed killer.

When heated, $NaClO_3$ releases oxygen gas.

$$2NaClO_3(s) \longrightarrow 2NaCl(s) + 3O_2(g)$$

Calculate the volume of O_2 that can be formed at room temperature and pressure by heating 4.26 g of $NaClO_3$.

1 mol of gas molecules occupies 24.0 dm^3 at room temperature and pressure.

[4]

[Total : 14]

4 The first six successive ionisation energies of an element **D** are shown in Table 4.1 below.

Table 4.1

element	ionisation energy / kJ mol^{-1}					
	1st	2nd	3rd	4th	5th	6th
D	1086	2353	4621	6223	37832	47278

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

.....

.....

.....

..... [3]

(b) Write an equation, with state symbols, to represent the **third** ionisation energy of element **D**.

..... [2]

(c) Use Table 4.1 to deduce which group of the Periodic Table contains element **D**. Explain your answer.

group .....

explanation .....

.....

..... [3]

[Total : 8]

For Examiner's Use

5 In this question, one mark will be awarded for the quality of written communication.

In the Periodic Table, describe and explain the trend in atomic radii shown by

- the Group 2 elements Be-Ra
- the Period 3 elements, Na-Ar.

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.....[8]

Quality of Written Communication [1]

[Total : 9]

For Examiner Use

Answer **all** the questions.

1 This question is about two elements, **A** and **B**, in the Periodic Table.

(a) Each atom of element **A** has 15 electrons.

(i) Identify element **A**.

..... [1]

(ii) Complete the electronic configuration of an atom of **A**.

$1s^2$ ..... [1]

(iii) Predict the charge on an ion of **A** and complete its electronic configuration.

charge on ion .....

electronic configuration of ion of **A** $1s^2$ ..... [2]

(b) Element **B** exists as a mixture of three isotopes.

(i) What is the difference between the atomic structures of isotopes?

..... [1]

(ii) The atoms of element **B** have eight electrons in the 3d sub-shell.

Identify element **B**.

..... [1]

For Examiner's Use

(c) A sample of element **B** was analysed in a mass spectrometer. The relative atomic mass of element **B** can be calculated from the results shown in Table 1.1 below.

Table 1.1

	isotope 1	isotope 2	isotope 3
relative isotopic mass	58.0	60.0	62.0
percentage composition / %	68.2	27.3	4.5

(i) Explain what is meant by the *relative atomic mass of element B*.

.....

.....

.....

..... [3]

(ii) Using the information in Table 1.1, calculate the relative atomic mass of this sample of **B**. Give your answer to three significant figures.

[2]

[Total: 11]

For Examiner Use

2 The halogens chlorine, bromine and iodine each exist as diatomic molecules at room temperature and pressure.

(a) Draw a *'dot-and-cross'* diagram of a bromine molecule, showing outer electrons only.

[1]

(b) The boiling points of the halogens chlorine to iodine are shown below.

halogen	boiling point / °C
chlorine	−35
bromine	59
iodine	184

Explain why the halogens show this trend in boiling points.

.....

.....

.....

..... [3]

(c) When chlorine, Cl_2, is added to aqueous sodium bromide, NaBr, a reaction takes place.

(i) State what you would see in this reaction.

..... [1]

(ii) Write an equation for this reaction.

..... [1]

(iii) What happens to electrons during this reaction?

.....

.....

..... [2]

(iv) Why does no reaction take place when bromine is added to aqueous sodium chloride?

.....

..... [1]

(v) Describe a simple test to confirm the presence of iodide ions in aqueous sodium iodide.

.....

.....

..... [2]

[Total: 11]

3 Calcium oxide, CaO, is used for making cement which is widely used in the construction industry. Calcium oxide can be prepared as 'quicklime' by heating limestone in a lime kiln to about 550 °C. The calcium carbonate in the limestone decomposes into calcium oxide and carbon dioxide.

$$CaCO_3 \longrightarrow CaO + CO_2$$

(a) Draw a *'dot-and-cross'* diagram of calcium oxide, showing outer electrons only.

[2]

(b) In $CaCO_3$, what is the oxidation state of

(i) Ca,

..... [1]

(ii) C?

..... [1]

(c) Calculate the mass of CaO that could be made from limestone containing 20 tonnes of $CaCO_3$.

molar masses: $CaCO_3$, 100 g mol^{-1}; CaO, 56 g mol^{-1}.

1 tonne = 10^6 g.

[2]

(d) When water is added to quicklime, a vigorous reaction takes place forming slaked lime, $Ca(OH)_2$.

Write an equation for the formation of slaked lime in this reaction.

..... [1]

(e) Farmers often add 'lime' to acid soils. The lime is mostly present as slaked lime.

A chemist neutralised 25.0 cm^3 0.200 mol dm^{-3} HCl with slaked lime.

$$Ca(OH)_2(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + 2H_2O(l)$$

(i) What is the molar mass of $Ca(OH)_2$?

[1]

(ii) How many moles of HCl were neutralised?

[1]

(iii) Calculate the mass of $Ca(OH)_2$ that neutralises this HCl.

[2]

(iv) The chemist neutralised the same amount of HCl with NaOH. Explain why the chemist would need to use more moles of NaOH than $Ca(OH)_2$.

.....

.....

..... [2]

(f) A clear solution of slaked lime in water was made by dissolving $Ca(OH)_2$ in an excess of water. When this solution was left exposed to the air, the solution slowly became milky as a fine white precipitate formed.

Suggest why this happened.

.....

.....

..... [2]

[Total: 15]

4 Chemicals show a range of different structures. The table below shows four types of structure.

structure	example
giant metallic	
giant ionic	
giant molecular	
simple molecular	

(a) Complete the table by giving an example of each type of structure. Write its name or formula in the second column.

[4]

(b) A giant metallic structure has metallic bonding.

(i) Draw a labelled diagram to show metallic bonding.

[2]

(ii) How does a substance with a giant metallic structure conduct electricity?

.....

..... [1]

For Examiner Use

(c) Explain why a substance with a giant ionic lattice conducts electricity when molten but **not** when solid.

.....

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..... [2]

(d) Explain why a substance with a **giant** molecular structure has a higher boiling point than a substance with a **simple** molecular structure.

.....

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..... [3]

[Total: 12]

For Examiner's Use

5 In this question, one mark is available for the quality of written communication.

Explain how you can predict the shapes of, and bond angles in, simple molecules. In your answer, you should choose examples of **four** different molecular shapes.

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..... [10]

Quality of Written Communication [1]

[Total: **11**]

Answer **all** the questions.

1 A sample of the element boron, B, was analysed using a mass spectrometer and was found to contain two isotopes, ^{10}B and ^{11}B.

(a) **(i)** Explain the term *isotopes.*

.....

.....[1]

(ii) Complete the table below for the two isotopes of boron.

isotope	protons	neutrons	electrons
^{10}B			
^{11}B			

[2]

(b) The relative atomic mass of boron in the sample analysed was 10.8.

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

.....

.....

.....

.....[3]

(ii) What does the value for the relative atomic mass suggest about the relative proportions of the boron isotopes in the sample?

Explain your reasoning.

.....

.....

.....[1]

(c) The element boron was first isolated in 1808 by reacting boric acid, H_3BO_3, with potassium.

(i) In addition to boron, the reaction produces an alkali.

Suggest a balanced equation for this reaction.

.....[1]

(ii) Explain, using oxidation numbers, why boron in boric acid has been reduced.

.....

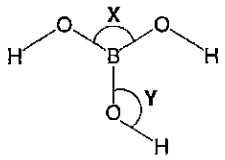
.....

.....[2]

(d) The structure of a molecule of boric acid is shown below.

Predict values for the bond angles labelled **X** and **Y** in a boric acid molecule.

Explain your reasoning.



bond angle **X**.....

reasoning.....

.....

.....

bond angle **Y**.....

reasoning.....

.....

.....[5]

[Total: 15]

2 Quicklime, CaO, and slaked lime, $Ca(OH)_2$, are bases made by the chemical industry with uses in building and farming.

(a) **(i)** How is quicklime made by the chemical industry?

.....[1]

(ii) Give one use of slaked lime in farming.

.....[1]

(b) Slaked lime is slightly soluble in water forming a solution commonly referred to as limewater. A student carried out a titration to find the concentration of limewater. 25.0 cm^3 of limewater was neutralised by 22.45 cm^3 of 0.0105 mol dm^{-3} nitric acid, HNO_3.

(i) Balance the equation for the reaction that takes place.

.....$Ca(OH)_2(aq)$ + ...$HNO_3(aq)$ ⟶ .....$Ca(NO_3)_2(aq)$ + ...$H_2O(l)$ [1]

(ii) Calculate how many moles of HNO_3 were used.

..... mol [1]

(iii) Determine how many moles of $Ca(OH)_2$ reacted with the HNO_3.

..... mol [1]

(iv) Calculate the concentration, in mol dm^{-3}, of the $Ca(OH)_2$ in the limewater.

..... mol dm^{-3} [1]

(v) After the titration, the student allowed the water to evaporate to obtain a hydrated crystalline solid with a molar mass of 272.1 g mol^{-1}.

Determine the formula of the hydrated solid. Show your working.

[2]

(c) Limewater can be made by adding calcium metal to water.

Write an equation, with state symbols, for this reaction.

.....[2]

(d) When calcium metal reacts, each calcium atom loses two electrons. The energy change required to convert Ca atoms into Ca^{2+} ions involves both first and second ionisation energies. The first and second ionisation energies of calcium are shown below.

ionisation number	1st	2nd
ionisation energy/kJ mol^{-1}	578	1145

(i) Write an equation, including state symbols, that represents the second ionisation energy of calcium.

.....[2]

(ii) Calculate how much energy, in kJ, would be needed to form 5.00 g of $Ca^{2+}(g)$ ions from Ca(g).

Give your answer to three significant figures.

answer = ... kJ [3]

(iii) The first ionisation energies of the elements in Group 2 show a trend.

State and explain this trend.

.....

.....

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.....[4]

[Total: 19]

3 This question is about the chemistry of chlorine and its compounds.

(a) Complete the electronic configuration of an atom of Cl.

$1s^2$ .....[1]

(b) Chlorine reacts with magnesium to form magnesium chloride.

$$Mg(s) + Cl_2(g) \longrightarrow MgCl_2(s)$$

(i) Draw a '*dot-and-cross*' diagram for $MgCl_2$.

[2]

(ii) Solid $MgCl_2$ does not conduct electricity but solid magnesium does.

Solid $MgCl_2$ dissolves in water and the resulting solution does conduct electricity.

Explain these observations.

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.....[3]

(c) Chlorine and magnesium are both elements in Period 3 of the Periodic Table. The radius of a Cl atom is smaller than that of an atom of Mg.

Explain why.

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.....[3]

(d) Bleach is a solution of sodium chlorate(I), NaClO, made by reacting chlorine with aqueous sodium hydroxide.

$$Cl_2(g) + 2NaOH(aq) \longrightarrow NaClO(aq) + NaCl(aq) + H_2O(l)$$

A student prepared some bleach by reacting 145 cm^3 of chlorine gas with an aqueous solution containing 0.0100 mol NaOH.

Under these conditions, 1.00 mol of $Cl_2(g)$ has a volume of 24.0 dm^3.

Determine whether Cl_2 or NaOH was in excess of its reacting quantity.

Show all your working.

[2]

(e) You are supplied with two solutions: NaCl(aq) and NaBr(aq).

Outline how you could distinguish between these two solutions using simple experiments. Include relevant equations.

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.....[4]

[Total: 15]

4 In this question, one mark is available for the quality of spelling, punctuation and grammar.

Water, methane and hydrogen chloride all have simple molecular structures but differ in their intermolecular forces.

(a) Describe, with the aid of a diagram, the hydrogen bonding in water.

State and explain **two** anomalous properties of water in terms of this bonding.

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(b) The boiling points of methane and hydrogen chloride are shown in the table below.

substance	boiling point/°C
methane	−164
hydrogen chloride	−85

Explain why methane and hydrogen chloride have different boiling points.

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.....[3]

Quality of Written Communication [1]

[Total: 11]

END OF QUESTION PAPER

OCR
RECOGNISING ACHIEVEMENT

ADVANCED SUBSIDIARY GCE **2811/01**

CHEMISTRY

Foundation Chemistry

WEDNESDAY 4 JUNE 2008

Morning
Time: 1 hour

Candidates answer on the question paper
Additional materials (enclosed): *Data Sheet for Chemistry* (Inserted)

Additional materials (required):
Scientific calculator

Candidate Forename		Candidate Surname	

Centre Number						Candidate Number				

INSTRUCTIONS TO CANDIDATES

- Write your name in capital letters, your Centre Number and Candidate Number in the boxes above.
- Answer **all** the questions.
- Use blue or black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure that you know what you have to do before starting your answer.
- Do **not** write in the bar codes.
- Write your answer to each question in the space provided.

INFORMATION FOR CANDIDATES

- The number of marks for each question is given in brackets [ ] at the end of each question or part question.
- The total number of marks for this paper is **60**.
- You will be awarded marks for the quality of written communication where this is indicated in the question.
- You may use a scientific calculator.
- A copy of the *Data Sheet for Chemistry* is provided as an insert with this question paper.
- You are advised to show all the steps in any calculations.

FOR EXAMINER'S USE		
Qu.	Max.	Mark
1	12	
2	14	
3	18	
4	16	
TOTAL	60	

This document consists of **10** printed pages, **2** blank pages and a *Data Sheet for Chemistry*.

Answer **all** the questions.

1 The element indium, atomic number 49, is a very soft, silvery-white metal with a brilliant shine. One strange property of indium is that it makes a high-pitched 'scream' when bent! It occurs as a mixture of two isotopes, ^{113}In and ^{115}In.

(a) Complete the table below for the isotopes of indium.

isotope	protons	neutrons	electrons
^{113}In			
^{115}In			

[2]

(b) A sample of indium contains 4.23% of ^{113}In and 95.77% ^{115}In.

Calculate the relative atomic mass of the indium sample.

Give your answer to one decimal place.

A_r = ... [2]

(c) Indium has metallic bonding.

Draw a **labelled** diagram to show metallic bonding.

[2]

(d) A compound of indium and iodine has the following percentage composition by mass:

In, 23.19%; I, 76.81%. The relative molecular mass of this compound is 992.

(i) Define the term *relative molecular mass.*

.....

.....

.....

.....[3]

(ii) Calculate the molecular formula of this compound.

molecular formula = ... [3]

[Total: 12]

2 This question refers to the first 20 elements in the Periodic Table. These are shown below.

																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca																

(a) From these first 20 elements **only**, identify an element that fits each of the following descriptions.

(i) The element that forms a 2+ ion with the same electronic configuration as Ar.

..... [1]

(ii) The element that forms a 3– ion with the same electronic configuration as Ne.

..... [1]

(iii) The element that has atoms with a 3p subshell containing five electrons.

..... [1]

(iv) An element that forms a compound with fluorine with trigonal planar molecules.

..... [1]

(v) The element with the smallest first ionisation energy.

..... [1]

(vi) An element with a giant covalent lattice.

..... [1]

(b) Elements form many compounds.

Choose compounds, formed from the first 20 elements **only**, to illustrate ionic and covalent bonding.

Showing outer electrons only, draw '*dot-and-cross*' diagrams of your chosen examples.

(i) '*Dot-and-cross*' diagram for a compound with ionic bonding.

[2]

(ii) '*Dot-and-cross*' diagram for a compound with covalent bonding.

[2]

(c) Across a period in the Periodic Table, elements often show characteristic trends.

Describe and explain the trend in atomic radius across Period 3.

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.....[4]

[Total: 14]

3 **(a)** A student prepared some chlorine gas on a small scale by reacting hydrochloric acid with household bleach.

The reaction is shown below.

$$2HCl(aq) + NaClO(aq) \longrightarrow Cl_2(g) + NaCl(aq) + H_2O(l)$$

The student reacted 1.0 cm^3 of 6.0 mol dm^{-3} HCl with 3.0 cm^3 household bleach. 55 cm^3 of chlorine gas were produced. The hydrochloric acid was in excess and this ensured that all the NaClO in the bleach was reacted.

Under these conditions, 1.0 mol of $Cl_2(g)$ has a volume of 24 dm^3.

(i) Calculate how many moles of $Cl_2(g)$ were produced.

answer = ... mol [1]

(ii) Calculate the concentration, in mol dm^{-3}, of NaClO in the bleach.

concentration = ... mol dm^{-3} [1]

(iii) Calculate the number of moles of HCl that remained **after** the reaction.

answer = ... mol [3]

(b) A student carries out two experiments.

(i) The student bubbles some chlorine gas through a solution of sodium iodide. The solution turns a brown colour.

Explain this observation and write an equation for the reaction that takes place.

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.....

.....[2]

(ii) The student bubbles chlorine gas through aqueous silver nitrate. A white precipitate forms.

Explain this observation including equations for any reactions that take place.

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.....[4]

(c) HC*l* is a polar molecule but CCl_4 is a non-polar molecule. This difference can be explained by consideration of electronegativity and molecular shapes.

(i) Explain the term *electronegativity*.

.....

.....

.....[2]

(ii) Draw a 3-D diagram to show the shape of a molecule of CCl_4. State the bond angle.

[2]

(iii) Explain why HC*l* is a polar molecule but CCl_4 is a non-polar molecule.

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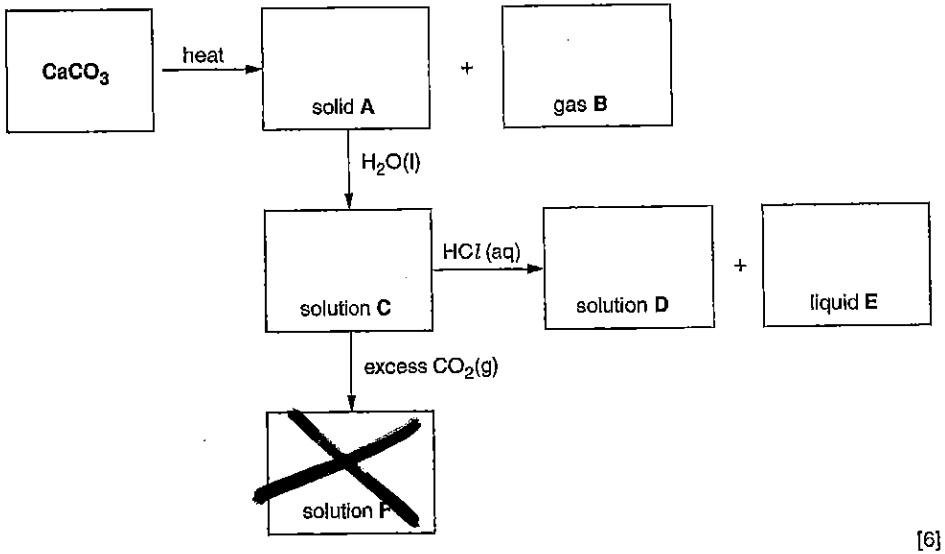
.....[3]

[Total: 18]

4 This question looks at the chemistry of Group 2 elements and their compounds.

(a) The flowchart below shows some reactions involving calcium compounds.

Identify substances **A–F** by writing their **formulae** in the boxes.



[6]

(b) In this question, one mark is available for the quality of spelling, punctuation and grammar.

All the Group 2 elements react with oxygen.

- Write a balanced equation, with state symbols, for the reaction of calcium with oxygen.
  Using this reaction, explain what is meant by oxidation and reduction in terms of electrons. [4]
- State and explain the trend in reactivity of the Group 2 elements with oxygen. [5]

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Quality of Written Communication [1]

[Total: 16]

END OF QUESTION PAPER

Answer **all** the questions.

1 The answer to each part of this question is a number.

(a) (i) How many neutrons are there in an atom of chlorine-37?

..... **[1]**

(ii) How many electrons are needed to fill one orbital?

..... **[1]**

(iii) How many electrons are there in the 3p sub-shell of a chlorine atom?

..... **[1]**

(b) (i) Calculate the relative atomic mass of a sample of gallium containing 60% ^{69}Ga and 40% ^{71}Ga. Give your answer to **three** significant figures.

[1]

(ii) Calculate the relative formula mass of $(NH_4)_2CO_3$.

[1]

(iii) Calculate the number of grams of $NaNO_3$ in 200 cm^3 of a 0.250 mol dm^{-3} solution.

[2]

(iv) Calculate the number of molecules in 100 cm^3 of SO_2 gas at room temperature and pressure.

1.00 mol of SO_2 molecules occupies 24.0 dm^3 at room temperature and pressure.
$L = 6.02 \times 10^{23}$ mol^{-1}.

[1]

(c) Determine the oxidation number of chlorine in $NaClO_4$.

..... **[1]**

[Total: 9]

2 Element **A** is in **Period 3**, Na–Ar, of the Periodic Table.

Some of the successive ionisation energies of element **A** are shown below.

ionisation energy/kJ mol^{-1}						
1st	2nd	3rd	4th	5th	6th	7th
789	1577	3232	4356	16091	19785	23787

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

.....

.....

.....

..... **[3]**

(b) Identify element **A** from the elements in Period 3, Na–Ar.

Explain how you decided on your answer.

element **A:** .....

explanation: .....

.....

.....

..... **[3]**

(c) Elements in the same **group** in the Periodic Table have different ionisation energies.

Explain why there is a trend in first ionisation energies for elements in the same group.

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..... **[3]**

[Total: 9]

3 Calcium chloride, $CaCl_2$, is used for dust control on roads and in car parks.

Calcium chloride is made up of Ca^{2+} and Cl^- ions.

(a) Complete the table below.

species	protons	electrons
Ca^{2+}		
Cl^-		

[2]

(b) Draw a '*dot-and-cross*' diagram of $CaCl_2$. Show outer electron shells only.

[2]

(c) Solid calcium chloride does **not** conduct electricity. An aqueous solution of calcium chloride does conduct.

Explain the different conductivities of solid and aqueous calcium chloride.

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..... **[2]**

(d) Calcium chloride can be made by reacting limestone with hydrochloric acid.

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

In the laboratory, a student carries out this reaction using 4.85 g $CaCO_3$ and 1.50 mol dm^{-3} HCl. She then evaporates water from the solution to obtain solid $CaCl_2$.

(i) How many moles of $CaCO_3$ were reacted?

answer = ...mol **[2]**

(ii) What mass of $CaCl_2$ is formed by the reaction of 4.85 g of $CaCO_3$?

answer = ... g **[1]**

(iii) Calculate the volume, in cm^3, of 1.50 mol dm^{-3} HCl that reacts with 4.85 g of $CaCO_3$.

answer = ... cm^3 **[2]**

(e) Choose another chemical that could be reacted with hydrochloric acid to make calcium chloride.

Write a balanced equation for the reaction.

..... **[2]**

(f) Compound **B** is a calcium compound used in making paper. Compound **B** is manufactured by passing SO_2 gas through a solution of calcium hydroxide.

Compound **B** has the following percentage composition by mass:

Ca, 19.82%; H, 0.99%; S, 31.74%; O, 47.45%.

(i) Determine the empirical formula for compound **B**.

[2]

(ii) Construct a balanced equation for the manufacture of compound **B** from calcium hydroxide by this method.

..... **[1]**

[Total: 16]

4 The boiling points of the halogens chlorine, bromine and iodine are shown below.

halogen	boiling point/°C
chlorine	–35
bromine	59
iodine	184

(a) Explain this trend in the boiling points of the halogens.

..... **[3]**

(b) Iodine reacts with water as shown below.

$$I_2(s) + H_2O(l) \longrightarrow IO^-(aq) + 2H^+(aq) + I^-(aq)$$

Determine the changes in oxidation number of iodine in this reaction and comment on your answers.

..... **[3]**

(c) A student carries out the following investigation.

- **Step 1:** The student adds an excess of chlorine gas to an aqueous solution of potassium bromide.
- **Step 2:** The student adds aqueous silver nitrate to the resulting solution.

(i) In **step 1**, what would the student observe?

Write an ionic equation for the reaction that takes place.

observation: .....

ionic equation: ..... **[2]**

(ii) For **step 2**, write an ionic equation, including state symbols, for the reaction that takes place.

..... **[2]**

(d) Many covalent compounds of the halogens, such as CCl_4, have polar bonds. Polarity can be explained in terms of electronegativity.

(i) Explain what is meant by the term *electronegativity*.

.....

.....

..... **[2]**

(ii) Molecules of the covalent compound CCl_4 have polar bonds.

Draw a diagram to show the shape of a molecule of CCl_4.

On your diagram, show the polarity of the bonds.

[2]

(iii) A molecule of CCl_4 is non-polar. Explain why.

.....

..... **[1]**

[Total: 15]

5 In this question, one mark is available for the quality of spelling, punctuation and grammar.

Many physical properties can be explained in terms of bonding and structure. The table below shows some properties of magnesium, diamond and ice.

substance	magnesium	diamond	ice
electrical conductivity of solid	good	poor	poor
melting point	649 °C	3550 °C	0 °C

Explain these properties in terms of bonding and structure.

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.... [10]

Quality of Written Communication **[1]**

[Total: 11]

END OF QUESTION PAPER

Answer **all** the questions.

1 The element sulphur, S, has been known since ancient times and was originally named 'brimstone'.

(a) Sulphur exists as a mixture of four isotopes, ^{32}S, ^{33}S, ^{34}S and ^{36}S.

(i) What is meant by the term *isotopes*?

.... [1]

(ii) Complete the table below to show the composition of the ^{33}S and ^{34}S isotopes.

isotope	protons	neutrons	electrons
^{33}S			
^{34}S			

[2]

(b) A sample of sulphur was collected from a volcano. The relative atomic mass of the sulphur was determined.

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

.... [3]

(ii) The sample of sulphur had the following percentage composition by mass:

^{32}S, 94.93%; ^{33}S, 0.76%; ^{34}S, 4.29%; ^{36}S, 0.02%.

Calculate the relative atomic mass of the sample of sulphur.

Give your answer to **four** significant figures.

answer = ... **[2]**

(iii) What instrument is used to determine the isotopic abundances in sulphur?

..... **[1]**

(c) Sulphur also occurs naturally in sulphates. Gypsum is a common sulphate ore, containing mainly calcium sulphate as $CaSO_4.2H_2O$.

(i) What is meant by the '$2H_2O$' in the formula $CaSO_4.2H_2O$?

.....

..... **[1]**

(ii) What is the molar mass of $CaSO_4.2H_2O$?

answer = ...g mol^{-1} **[1]**

(iii) What is the oxidation number of sulphur in $CaSO_4.2H_2O$?

..... **[1]**

(iv) State the formula and charge of the negative ion in $CaSO_4.2H_2O$.

..... **[1]**

[Total: 13]

2 Magnesium and aluminium are both metals in Period 3 of the Periodic Table.

(a) Magnesium forms compounds that have ionic bonding.

What is meant by the term *ionic bonding*?

.....

..... **[1]**

(b) Magnesium forms an ionic chloride, $MgCl_2$.

(i) Draw a '*dot-and-cross*' diagram to show the bonding in $MgCl_2$.

Show outer electron shells only.

[2]

(ii) Complete the electron configuration, in terms of sub-shells, for a chloride ion.

$1s^2$..... **[1]**

(c) At room temperature, magnesium and aluminium both exist as solid lattices.

(i) In terms of the particles involved, explain how these solid lattices are held together.

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..... **[2]**

(ii) Aluminium has a higher melting point than magnesium.

Suggest why.

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..... **[1]**

(d) Cobalt and nickel are both metals in the d-block of the Periodic Table. Cobalt is placed before nickel despite having a greater relative atomic mass.

(i) State why Co is placed before Ni in the Periodic Table.

.....

..... [1]

(ii) Suggest why Co has a greater relative atomic mass than Ni.

.....

..... [1]

(e) Aluminium reacts with acids, releasing hydrogen gas.

A student reacted 2.025 g of aluminium metal with an excess of 1.80 mol dm^{-3} hydrochloric acid, HCl.

The equation for this reaction is shown below.

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

(i) Calculate how many moles of Al reacted.

answer = ... mol [1]

(ii) Calculate the volume, in dm^3, of $H_2(g)$ that formed from 2.025 g Al at room temperature and pressure, r.t.p.

1.00 mol of $H_2(g)$ has a volume of 24.0 dm^3 at r.t.p.

volume = ... dm^3 [2]

(iii) Calculate the volume, in cm^3, of 1.80 mol dm^{-3} HCl that reacts exactly with 2.025 g of Al.

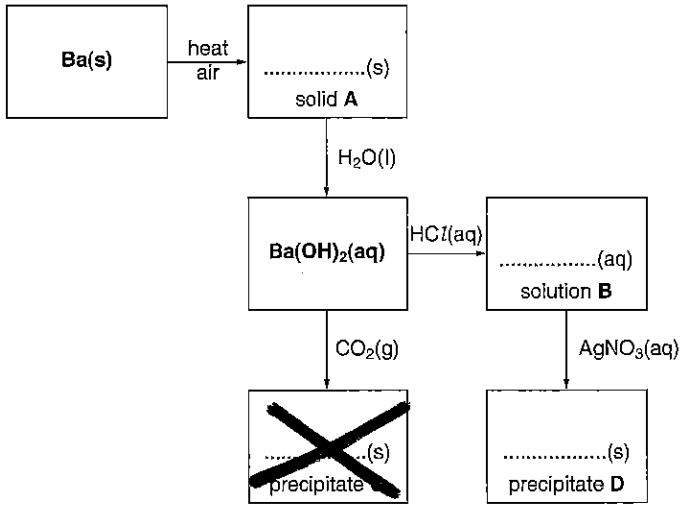
volume = ... cm^3 [2]

[Total: 14]

3 This question looks at reactions of Group 2 elements and their compounds.

(a) The flowchart below shows some reactions involving barium.

Write the **formulae** of substances **A–D** in the boxes.



[4]

(b) Barium forms a compound with carbon and oxygen with the following percentage composition by mass:

Ba, 60.89%; C, 10.67%; O, 28.44%.

Calculate the empirical formula of the compound.

[2]

(c) The reactivity of the Group 2 elements increases down the group. Ionisation energy is one factor responsible for this trend.

(i) Write an equation, with state symbols, to represent the **first** ionisation energy of barium.

..... **[2]**

(ii) State and explain the trend in first ionisation energies in Group 2.

.....

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..... **[4]**

(d) The Group 2 elements become more reactive down the group.
The Group 7 elements become **less** reactive down the group.

(i) Explain this difference between Group 2 and Group 7.

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..... **[3]**

(ii) A student bubbled chlorine gas through a colourless aqueous solution of potassium iodide. The solution turned brown in colour.

Explain what has happened. Use an equation in your answer.

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..... **[2]**

[Total: 17]

4 In this question, one mark is available for the quality of spelling, punctuation and grammar.

Explain the following.

- Sodium atoms are larger than magnesium atoms. **[3]**
- Iodine has a low boiling point but diamond has a high boiling point. **[5]**
- Carbon dioxide, methane and water have molecules with different bond angles. **[7]**

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Quality of Written Communication [1]

[Total: 16]

END OF QUESTION PAPER