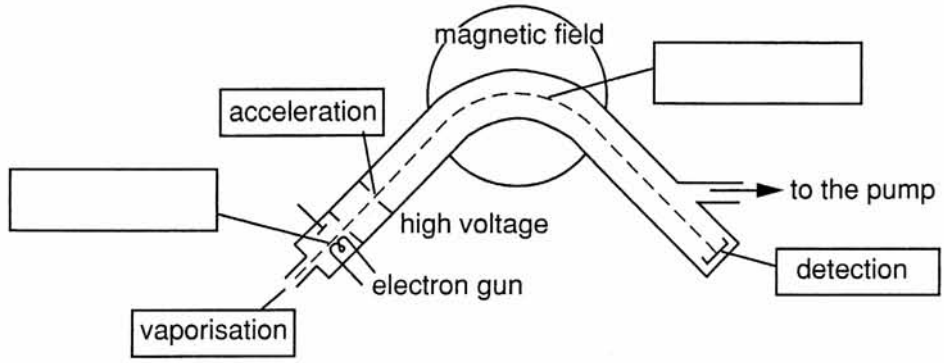
Answer **all** the questions.

1 Magnesium exists naturally as a mixture of its isotopes, ^{24}Mg, ^{25}Mg and ^{26}Mg.

(a) The isotopes in magnesium can be separated by mass spectrometry. The diagram below shows a mass spectrometer.

(i) Complete the diagram by adding the names of the two missing processes in the boxes.



[2]

(ii) Complete the table below to show the composition of the ^{25}Mg and ^{26}Mg isotopes.

	protons	neutrons	electrons
^{25}Mg			
^{26}Mg			

[2]

(iii) Complete the electronic configuration of an atom of ^{24}Mg.

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

(iv) Results from the mass spectrum of a sample of magnesium are shown below.

isotope	^{24}Mg	^{25}Mg	^{26}Mg
relative isotopic mass	24.00	25.00	26.00
% abundance	78.60	10.11	11.29

Calculate the relative atomic mass of the sample of magnesium.
Give your answer to two decimal places.

answer .....[2]

(b) Magnesium has a giant metallic structure held together by metallic bonding.

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

[2]

(ii) Use your diagram to explain how magnesium conducts electricity.

.....

.....

.....[1]

(c) Magnesium reacts with oxygen to form magnesium oxide.

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

(i) Use oxidation numbers to show that oxygen has been reduced in its reaction with magnesium.

.....

.....

.....[2]

(ii) Draw a '*dot-and-cross*' diagram to show the arrangement of electrons in magnesium oxide. Show outer electron shells only and include any charges.

[2]

(d) Old samples of magnesium oxide become contaminated with magnesium carbonate.

(i) Suggest how this contamination takes place.

.....

.....[1]

(ii) A student added an excess of hydrochloric acid to an old sample of magnesium oxide that is contaminated with magnesium carbonate.

State **two** observations that the student would make.

.....

.....[2]

(iii) Explain, with the aid of equations, why the resulting solution contained only one dissolved compound of magnesium.

.....

.....

.....

.....

.....[3]

[Total: 20]

2 This question is about the simple molecular compounds water, ammonia and sulphur dioxide.

(a) Pairs of electrons in molecules may be present as *bonding pairs* or as *lone pairs*.

(i) Complete the table below for water, ammonia and sulphur dioxide.

molecule	H_2O	NH_3	SO_2
number of bonding pairs of electrons			4 (2 double bonds)
number of lone pairs of electrons around central atom			1

[2]

(ii) Use your answers to **(a)(i)** to help you draw the shape of a molecule of NH_3 and of SO_2. Clearly show values of the bond angles in your diagrams.

molecule	NH_3	SO_2
shape of molecule with bond angles		

[4]

(b) The O—H bonds in water and the N—H bonds in ammonia have dipoles.

(i) Why do these bonds have dipoles?

.....

.....

.....[1]

(ii) Molecules of NH_3 are able to form hydrogen bonds. Draw a diagram to show the hydrogen bonding in ammonia. Include any relevant lone pairs and dipoles.

[2]

(c) Describe and explain the density of ice compared with water.

.....

.....

.....

.....

.....[2]

(d) Water, ammonia and sulphur dioxide react together to form a compound **A** which has the following percentage composition by mass:

N, 24.12%;

H, 6.94%;

S, 27.61%;

O, 41.33%.

(i) Calculate the empirical formula of compound **A**.

[2]

(ii) Suggest a balanced equation for the formation of compound **A** from the reaction of water, ammonia and sulphur dioxide.

.....[1]

[Total: 14]

3 A student carried out three experiments using chlorine gas, $Cl_2(g)$.

(a) In a first experiment, the student bubbled chlorine through an aqueous solution of potassium bromide, KBr(aq). A reaction took place.

(i) What colour is the solution after the reaction has taken place?

.....[1]

(ii) Write an equation for this reaction.

.....[2]

(iii) This reaction takes place because chlorine has a stronger oxidising power than bromine. Explain why chlorine has a stronger oxidising power than bromine.

.....

.....

.....

.....

.....

.....[3]

(b) In a second experiment, the student bubbled chlorine through 120 cm^3 of an aqueous solution of 0.275 mol dm^{-3} sodium hydroxide, NaOH(aq).

The equation for this reaction is shown below.

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

Under the reaction conditions, 1 mole of $Cl_2(g)$ occupies 24.0 dm^3.

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

.....

.....

.....[1]

(ii) How many moles of NaOH were in the 120 cm^3 volume of NaOH(aq)?

answer ..... mol [1]

(iii) Calculate the volume of $Cl_2(g)$ that was needed to react with the NaOH(aq) used.

answer .....[2]

(iv) What is a common use for the solution that the student prepared?

.....[1]

(c) In a third experiment, the student repeated the procedure in **(b)** but with hot concentrated sodium hydroxide. A different reaction took place in which sodium chlorate(V) was formed instead of NaClO.

Suggest the formula of sodium chlorate(V).

.....[1]

[Total: 12]

4 In this question, you are provided with information about ionisation energies of elements. You are also provided with some additional information that will help you answer part **(b)**.

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

.....

.....

.....

.....[3]

(b) In this question, one mark is available for the quality of use and organisation of scientific terms.

Table 4.1 provides data on elements in **Period 2** of the Periodic Table.

Table 4.2 shows the first 6 successive ionisation energies of an element **X**, which is in **Period 3** of the Periodic Table.

- Using Table 4.1, describe and explain the trend in first ionisation energies shown by the Period 2 elements, Li–N.
- Using Table 4.2, identify element **X**. Explain how you decided on your answer.

[10]

element	Li	Be	B	C	N
number of protons	3	4	5	6	7
electron configuration	$1s^2\,2s^1$	$1s^2\,2s^2$	$1s^2\,2s^2\,2p^1$	$1s^2\,2s^2\,2p^2$	$1s^2\,2s^2\,2p^3$
1st ionisation energy / kJ mol^{-1}	520	900	801	1086	1402

Table 4.1

element	ionisation energy / kJ mol^{-1}					
	1st	2nd	3rd	4th	5th	6th
X	578	1817	2745	11 578	14 831	18 378

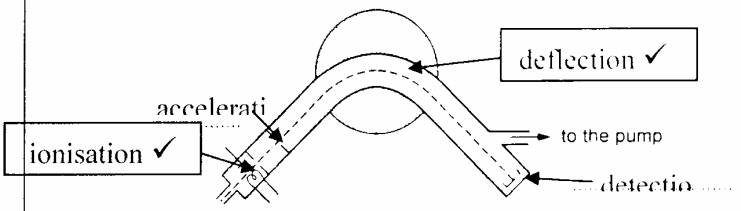
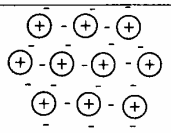
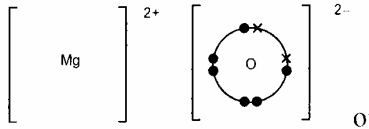
Table 4.2

Quality of Written Communication [1]

[Total: 14]

END OF QUESTION PAPER

Abbreviations, annotations and conventions used in the Mark Scheme	/ = alternative and acceptable answers for the same marking point ; = separates marking points 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	

Question			Expected Answers	Marks
1	(a)	(i)		[2]
		(ii)	protons neutrons electrons ^{25}Mg 12 13 12 ✓ ^{26}Mg 12 14 12 ✓	[2]
		(iii)	$1s^2 2s^2 2p^6 3s^2$ ✓	[1]
		(iv)	24 x 78.60/100 + 25 x 10.11/100 + 26 x 11.29/100 ✓ = 24.33 ✓ (calc value: 24.3269. This scores one mark) 24.32 with no working, award 1 mark only. 24.3 with no working, no marks (Periodic Table value)	[2]
	(b)	(i)	 positive ions ✓ electrons ✓ (must be labelled) *If Mg^{2+} shown then must be correct: Mg^{+} not worthy*	[2]
		(ii)	electrons move ✓	[1]
	(c)	(i)	Oxidation state goes from 0 in O_2 ✓ ⟶ –2 in MgO ✓	[2]
		(ii)	 or with Mg full shell. correct dot and cross ✓; correct charges ✓	[2]
	(d)	(i)	MgO has reacted with CO_2 ✓	[1]
		(ii)	Solid dissolves / disappears ✓ Fizzing / bubbles ✓	[2]
			$MgO + 2HCl \longrightarrow MgCl_2 + H_2O$ ✓ $MgCO_3 + 2HCl \longrightarrow MgCl_2 + CO_2 + H_2O$ ✓ both reactions form magnesium chloride/$MgCl_2$ ✓	[3]
				Total: 20

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Question	**Expected Answers**	**Marks**
2 (a) (i)	mark vertically: H_2O NH_3 2 3 2 1 ✓ ✓	[2]
(ii)	3D Diagram required or diagram with name labelled bond angle required NH_3 pyramidal molecule shown ✓ 107 ° ✓ (106-108°) SO_2 non-linear molecule shown ✓ 110 - 130 ° ✓	[4]
(b) (i)	oxygen/ nitrogen is more electronegative/ molecule has atoms with different electronegativities /oxygen/more electronegative atom ... attracts bonded electron pair more ✓	[1]
(ii)	H bonding from N of 1 NH_3 molecule to H of another NH_3 molecule with a $H^{\delta+}$ shown and a $N^{\delta-}$ shown ✓ with lone pair involved in bond ✓ 2nd mark is available from water molecule(s)	[2]
(c)	ice is less dense than water ✓ hydrogen bonds hold H_2O molecules apart in ice / hydrogen bonds cause an open lattice structure ✓	[2]
(d) (i)	ratio N : H : S : O = $\frac{24.12}{14} : \frac{6.94}{1} : \frac{27.61}{32.1} : \frac{41.33}{16}$:✓ = 2 : 8 : 1 : 3 Empirical formula = $N_2H_8SO_3$ ✓ $N_2H_4SO_3$ is worth 1 mark from consistent use of at nos.	[2]
(ii)	$H_2O + 2NH_3 + SO_2 \longrightarrow (NH_4)_2SO_3$ ✓ *(Award mark for $N_2H_8SO_3$)*	[1]
		Total: 14

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Question			Expected Answers	Marks
3	(a)	(i)	goes yellow/orange/brown ✓	[1]
		(ii)	$Cl_2 + 2Br^- \longrightarrow Br_2 + 2Cl^-$ ✓✓ *OR* $Cl_2 + 2KBr \longrightarrow Br_2 + 2KCl$ 1 mark for species. 1 mark for balancing	[2]
		(iii)	An electron is being gained ✓ Cl atoms are smaller/less shells (ora) ✓ In Cl, attraction for electrons is greater ✓	[3]
	(b)	(i)	Amount of substance that has the same number of particles as there are atoms in 12 g of ^{12}C/ 6×10^{23}/ Avogadro's Number ✓	[1]
		(ii)	moles = $\frac{0.275 \times 120}{1000}$ = 0.0330 mol ✓	[1]
		(iii)	moles Cl_2 = $\frac{0.0330}{2}$ = 0.0165 mol ✓ volume Cl_2 = 0.0165 x 24000 = 396 cm^3 ✓ / 0.396 dm^3 792 cm^3 worth 1 mark (no molar ratio) 1584 cm^3 worth 1 mark (x 2) units needed.	[2]
		(iv)	bleach / disinfectant /sterilising /killing germs ✓	[1]
	(c)		$NaClO_3$ ✓	[1]
				Total: 12

Abbreviations, annotations and conventions used in the Mark Scheme	/ = alternative and acceptable answers for the same marking point . = separates marking points 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	
Question	**Expected Answers**	**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).	[3]
(b)	From Li → N, ionisation energy increases ✓ number of protons/nuclear charge increases ✓ nuclear attraction increases / shell drawn in by increased nuclear charge/ atomic radius decreases ✓ across period, electrons added to same shell ✓ *Not same subshell* From Be → B, ionisation energy decreases ✓ for B, electron is removed from a p sub-shell/p orbital/different sub-shell ✓ which has a higher energy ✓ *watch for distinction between nuclear **attraction** and nuclear **charge** in candidates' scripts.* *Also watch for confusion between shell and subshell.*	[7]
	Al ✓ Sharp rise in successive ionisation energy between 3rd and 4th IE ✓ marking a change to a new or different shell / there are 3 electrons in the outer shell✓ *mention **of** 'orbital' or 'sub-shell cancels 'shell mark'* *Each marking point for Al is independent*	[3]
	QoWC: links together two pieces of information correctly within **two** of the sections below: 1. General trend across period 2. Be to B 3. Successive ionisation energies ✓	**[1]**
		Total: 14