OCR

RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced Subsidiary GCE

CHEMISTRY 2811

Foundation Chemistry

Friday **11 JANUARY 2002** Afternoon 1 hour 30 minutes

Candidates answer on the question paper.
Additional materials.
Scientific calculator
Data Sheet for Chemistry

Candidate Name	Centre Number	Candidate Number

TIME 1 hour 30 minutes

INSTRUCTIONS TO CANDIDATES

- Write your name in the space above.
- Write your Centre number and Candidate number in the boxes above.
- Answer **all** the questions.
- Write your answers in the spaces on the question paper.
- Read each question carefully and make sure you know what you have to do before starting your answer.

INFORMATION FOR CANDIDATES

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

FOR EXAMINER'S USE		
Qu.	**Max.**	**Mark**
1	16	
2	14	
3	16	
4	17	
5	11	
6	8	
7	8	
TOTAL	90	

This question paper consists of 14 printed pages 2 blank pages.

Registered Charity Number. 1066969
[Turn over

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]

(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]

[Turn over

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

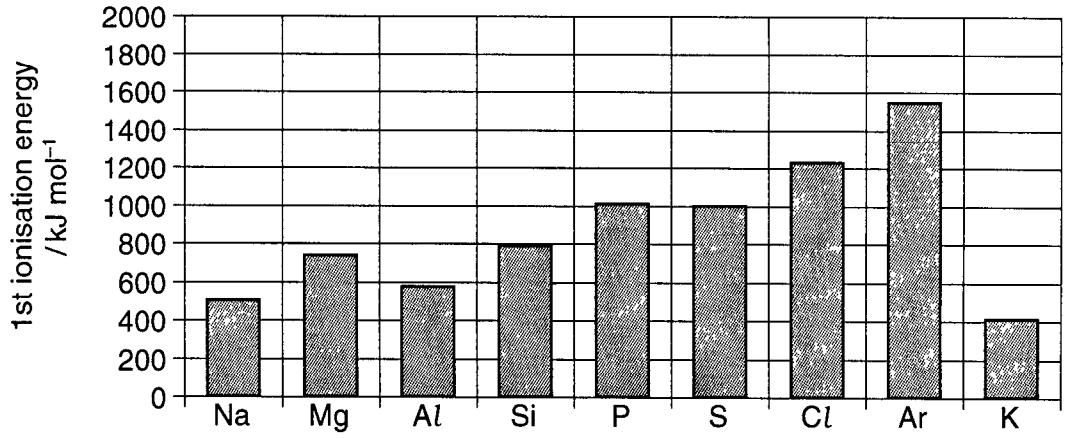


Fig. 2.1

(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]

(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]

(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]

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 δ+ or δ– to each bond.

The first box has been completed for you.

$^{\delta-}O–H^{\delta+}$	H–N	F–B	H–I

[2]

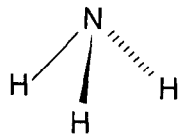
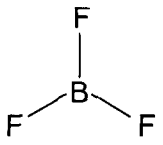
(c) Using outer electron shells only, draw '*dot-and-cross*' diagrams for molecules of NH_3 and BF_3.

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.

.....

.....

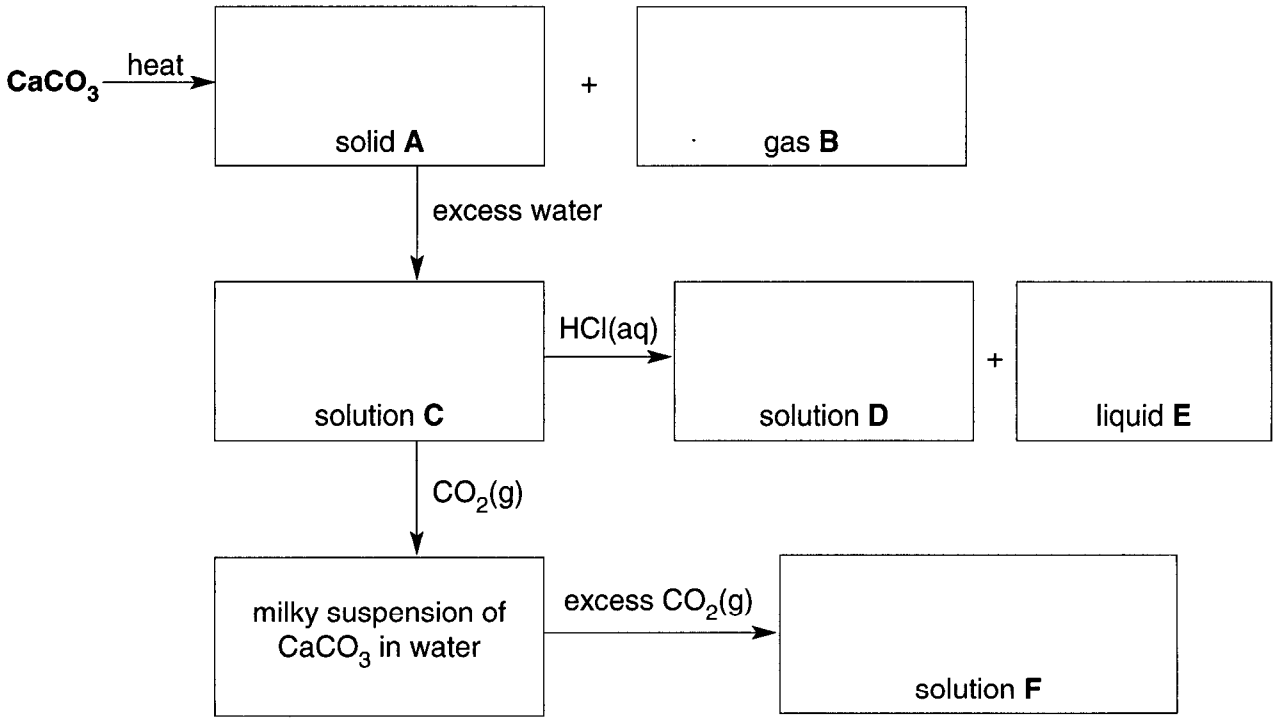
.....[2]

[Total : 17]

[Turn over

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]

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]

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]

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RECOGNISING ACHIEVEMENT

Subject: Chemistry Foundation
Code: 2811

Session: January
Year: 2002

Final Mark Scheme

RR

12th JANUARY 2002

MAXIMUM MARK	90

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 x 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) $2Mg(s) + O_2(g) \longrightarrow 2MgO(s)$ / $Mg(s) + ½\ O_2(g) \longrightarrow MgO(s)$

equation ✓ ; state symbols correct ✓

[2]

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

reduction $O_2 + 4e^- \longrightarrow 2O^{2-}$ / $½O_2 + 2e^- \longrightarrow O^{2-}$ ✓

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)

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

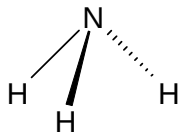
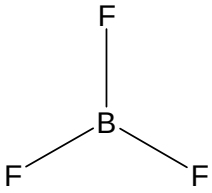
all 3 correct ✓✓ ; 2 correct scores 1 mark [2]

(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

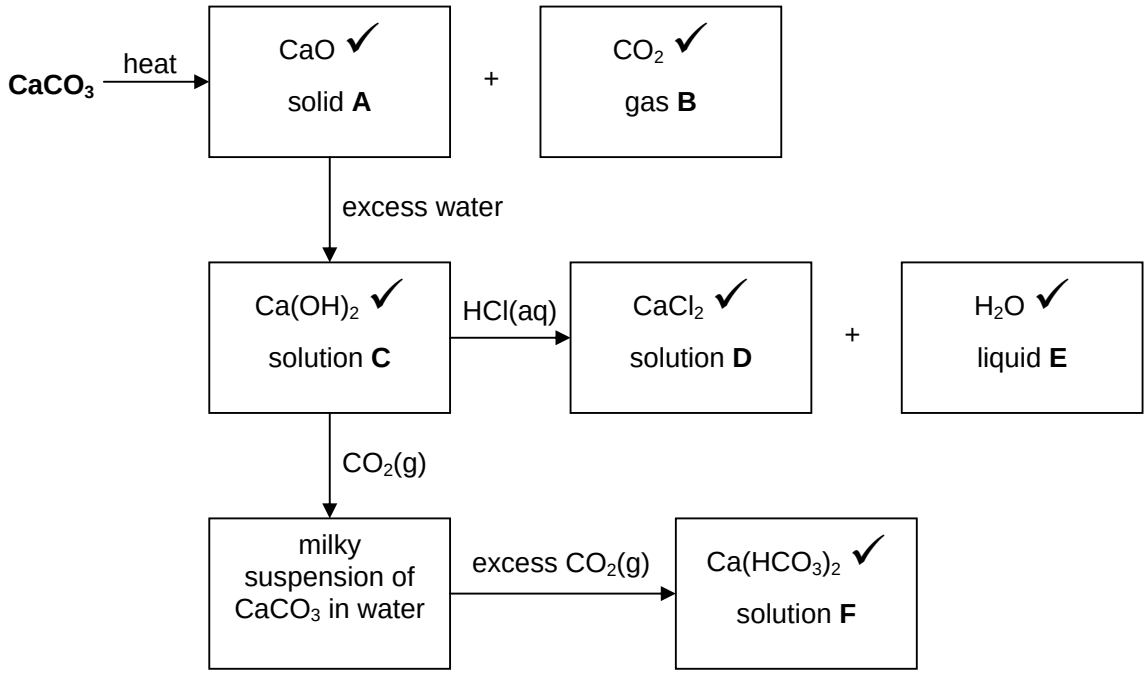
Add chlorine/bromine ✓

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 abundance ✓

6 marking points ⟶ [5 max]

[sub-total: 5]

Clear, well-organised, using specialist terms

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

[Total: 8]