SECTION B

Answer **all** the questions.

16 This question is about enthalpy changes.

(a) **Table 16.1** shows enthalpy changes that can be used to determine the enthalpy change of hydration of fluoride ions, F^-.

Enthalpy change	Energy / kJ mol^{-1}
Hydration of Ca^{2+}	–1609
Solution of CaF_2	+13
Lattice enthalpy of CaF_2	–2630

Table 16.1

(i) Explain what is meant by the term *enthalpy change of hydration*.

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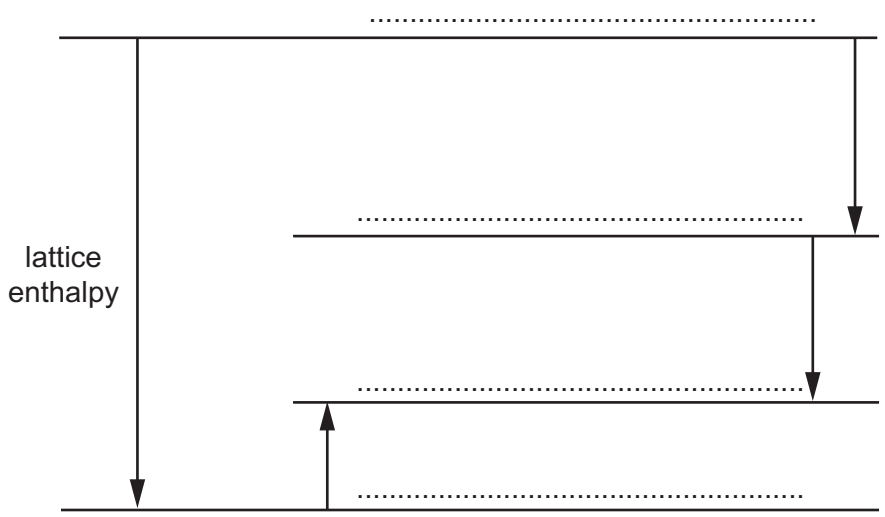
..... **[2]**

(ii) The enthalpy change of hydration of F^- can be determined using the enthalpy changes in **Table 16.1** and the incomplete energy cycle below.

On the dotted lines, add the species present, including state symbols.



[4]

(iii) Calculate the enthalpy change of hydration of fluoride ions, F^-.

enthalpy change of hydration = ... $kJ\,mol^{-1}$ **[2]**

(iv) Predict how the enthalpy changes of hydration of F^- and Cl^- would differ.

Explain your answer.

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

(b) Fluorine reacts with steam as shown in the equation below.

$$2F_2(g) + 2H_2O(g) \rightarrow O_2(g) + 4HF(g) \qquad \Delta H = -598\,kJ\,mol^{-1}$$

Average bond enthalpies are shown in the table.

Bond	Average bond enthalpy / kJ mol^{-1}
O–H	+464
O=O	+498
H–F	+568

(i) Explain what is meant by the term *average bond enthalpy*.

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

(ii) Calculate the bond enthalpy of the F–F bond.

bond enthalpy = ... kJ mol^{-1} **[3]**

19 This question is about the chemistry of the elements in Group 2 and the halogens.

(a) A student prepares an aqueous solution of magnesium chloride by reacting magnesium with excess hydrochloric acid.

Write an equation, including state symbols, for this reaction and state the observation(s) the student should make whilst carrying out this experiment.

equation: **……**

observation(s): **……**

[2]

(b) Lattice enthalpies give an indication of the strength of ionic bonding.

How would the lattice enthalpies of magnesium chloride and calcium chloride differ?

Explain your answer.

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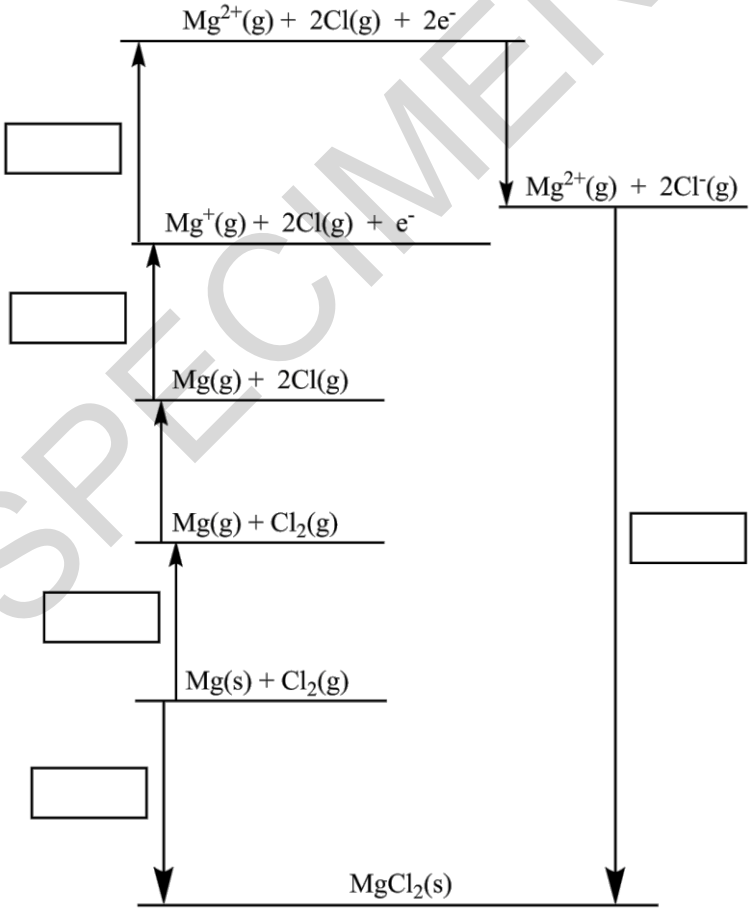
…… **[3]**

(c) The table below shows the enthalpy changes that are needed to determine the lattice enthalpy of magnesium chloride, $MgCl_2$.

Letter	Enthalpy change	Energy / kJ mol^{-1}
A	1st electron affinity of chlorine	–349
B	1st ionisation energy of magnesium	+736
C	atomisation of chlorine	+150
D	formation of magnesium chloride	–642
E	atomisation of magnesium	+76
F	2nd ionisation energy of magnesium	+1450
G	lattice enthalpy of magnesium chloride	

(i) On the cycle below, write the correct letter in each box.



[3]

(ii) Use the Born–Haber cycle to calculate the lattice enthalpy of magnesium chloride.

lattice enthalpy = ... kJ mol^{-1} **[2]**

(d)* Describe and explain the relative reactivity of the halogens, chlorine, bromine and iodine, in their redox reactions with halides, using reactions on a test-tube scale.

Include reaction equations and observations in your answer.

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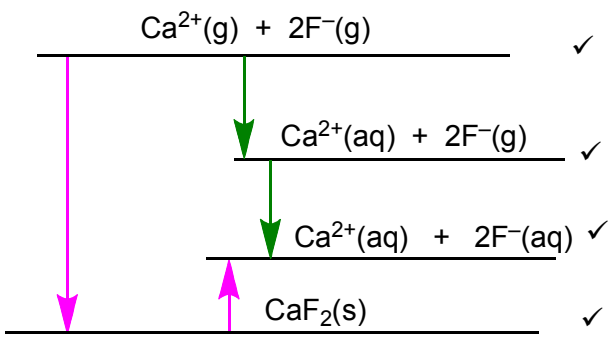
…… **[6]**

SECTION B

Question			Answer	Marks	Guidance
16	(a)	(i)	(enthalpy change when) 1 mole of gaseous ions react **OR** 1 mole of hydrated/aqueous ions are formed ✓ gaseous ions dissolve in **water** **OR** gaseous ions form aqueous/hydrated ions ✓	2	**IGNORE** 'energy released' **OR** 'energy required'
	(a)	(ii)	 ✓ ✓ ✓ ✓	4	Correct species **AND** state symbols required for each mark. (mark independently) On 2nd line, **ALLOW** $Ca^{2+}(g) + 2F^-(aq)$ (i.e. F^- hydrated before Ca^{2+}) On 3rd line, **ALLOW** $CaF_2(aq)$ **DO NOT ALLOW** when first seen but **ALLOW ECF** for '**2**' missing and for use of the following ions Fl^- F_2^- $Ca^{+/3+}$

Question			Answer	Marks	Guidance
	(a)	(iii)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = –504 (kJ mol^{-1}) award 2 marks** **IF answer = –1008 (kJ mol^{-1}) award 1 mark** **----------** $2 \times \Delta_{hyd}H(F^-)$ = [–2630 + 13] – (–1609) **OR** – 2617 + 1609 **OR** –1008 (kJ mol^{-1}) ✓ $\Delta_{hyd}H(F^-) = \frac{-1008}{2}$ = –504 ✓ (kJ mol^{-1})	**2**	**IF** alternative answer, check to see if there is any **ECF** credit possible using working below. '–' sign is needed. **COMMON ERRORS** for 1 mark: (+)2694: *signs all reversed* –2113: *sign wrong for –1609* –2126: *sign wrong for 2630* –517: *sign wrong for 13* +504: *sign wrong* **IF ALL 3 relevant values from the information at the start of Q16a(iii) have NOT been used, award zero marks unless one number has a transcription error, where 1 mark can be awarded ECF**
	(a)	(iv)	***Correct comparison of Δ_{hyd} linked to sizes*** $\Delta_{hyd}H(F^-)$ more negative/exothermic (than $\Delta_{hyd}H(Cl^-)$) **AND** F^- has smaller size (than Cl^-) ✓ ***Comparison of attraction between ions and water*** F^- OR smaller sized ion linked to greater attraction **to H_2O** ✓	**2**	**ORA** **IGNORE '**atomic' before radius when comparing size of ions **IGNORE** charge density **IGNORE** electronegativity **IGNORE** nuclear attraction **DO NOT ALLOW** 'forms stronger hydrogen bonds with water' **OR** 'forms stronger van der Waals' forces with water' **ALLOW** 'forms bonds' for attraction' **DO NOT ALLOW** F^- greater attraction to H_2O if given as larger ion Assume 'F' / 'Fluorine' means 'ions' but **DO NOT ALLOW** 'F molecules'

Question			Answer	Marks	Guidance
	(b)	(i)	**Average bond enthalpy** Breaking of one mole of bonds ✓ In gaseous molecules ✓	2	 **IGNORE** energy required **OR** energy released **IGNORE** heterolytic / homolytic **DO NOT ALLOW** bonds formed **DO NOT ALLOW** ionic bonds **IGNORE** species for molecules
	(b)	(ii)	**FIRST, CHECK ANSWER ON ANSWER LINE** **IF answer = (+) 158 award 3 marks** **----------** **Bond enthalpy of F–F** (ΔH for (O–H) bonds broken =) 1856 **OR** 4 × 464 (kJ mol^{-1}) ✓ (ΔH for bonds made =) 2770 (kJ mol^{-1}) **OR** 498 **AND** 2272 (kJ mol^{-1}) **OR** 498 **AND** 4 × 568 (kJ mol^{-1}) ✓ (bond enthalpy) F–F = $\frac{2770 - 1856 - 598}{2}$ = (+)158 (kJ mol^{-1}) ✓	3	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **IGNORE** sign **IGNORE** sign **ALLOW ECF** **Common errors** **Award 2 marks** for; –158 (Wrong sign) (±)316 (No ÷ 2) (+) 622 (use of 2 x 464) (+) 457 (omitting – 598) (+) 756 (use of +598) **Award 1 mark** for; (+) 970 (use of 2 x 464 and +598)
			Total	15	

Question			Answer	Marks	Guidance
19	(a)		$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$ ✓ Effervescence **AND** solid dissolves ✓	2	State symbols are required **ALLOW** solid disappears
	(b)		Lattice enthalpy of $MgCl_2$ is more exothermic than $CaCl_2$ … ✓ because magnesium ion/Mg^{2+} is smaller (than calcium ions/Ca^{2+}) **OR** Mg^{2+} has a greater charge density … ✓ … therefore the attraction between Mg^{2+} and Cl^- is greater (than between Ca^{2+} and Cl^-) ✓	3	**ORA** throughout **ALLOW** 'charge density' here **only** **ALLOW** magnesium/Mg is smaller **DO NOT ALLOW** Mg^{2+} has a smaller **atomic** radius **DO NOT ALLOW** chlorine ions **DO NOT ALLOW** Mg has greater attraction **ALLOW** 'attracts with more force' for greater attraction but **DO NOT ALLOW** 'greater force' (could be repulsion)
	(c)	(i)	**F** **B** **G** **E** **D** **FIVE** correct ✓✓✓ **FOUR** correct ✓✓ **THREE** correct ✓	3	**ALLOW** 1450 736 **G** 76 –642 **IF** only one or two correct, award 0 marks.
		(ii)	–642 – (+76 + (2 × 150) + 736 + 1450 + (2 × –349)) ✓ –642 – 1864 = – 2506 ✓ (kJ mol^{-1})	2	**ALLOW** for 1 mark: –2705 (2 x 150 and 2 x 349 not used for Cl) –2356 (2 x 150 not used for Cl) –2855 (2 x 349 not used for Cl) +2506 (wrong sign) **DO NOT ALLOW** any other answers

Question	Answer	Marks	Guidance
(d)*	*Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** Describes and explains concisely the trend in reactivity of the halogens **AND** Full observations of redox reactions backed up by at least two equations *There is a well-developed explanation which is clear and logically structured. The observations and equations are relevant to those trends explained.* *Clear and confident knowledge of relevant technical language.* **Level 2 (3–4 marks)** Describes and explains the trend in reactivity of the halogens **AND** Is able to recall a redox reaction by suitable observations and correctly link to an equation *There is an explanation with some structure. The observations and equations are in the most-part relevant to the trend explained.* *Sound grasp of relevant technical language.* **Level 1 (1–2 marks)** Describes the trend in reactivity of the halogens with some attempt at explanation **AND** Is able to recall a redox reaction either by suitable observation or by equation	6	**Indicative scientific points may include:** **Trend in reactivity** • More shells or increasing radius down the group • Increased shielding down the group • More difficult to gain an electron **Observations** • Reaction of Cl_2 or Br_2 with I^-: orange/brown solution **OR** purple in organic • Reaction of Cl_2 with Br^-: yellow solution **OR** orange in organic **Reaction equations** • $Cl_2 + 2Br^- \rightarrow Br_2 + 2Cl^-$ • $Cl_2 + 2I^- \rightarrow I_2 + 2Cl^-$ **OR** $Br_2 + 2I^- \rightarrow I_2 + 2Br^-$ • Order of reactivity linked to observations

Question			Answer	Marks	Guidance
			The information about the trend is basic and communicated in an unstructured way. The information is supported by only observation or equation and the relationship to the trend may not be clear. *Basic grasp of relevant technical language* **0 marks** No response or no response worthy of credit.		
			Total	**16**	