Q1.

This question is about metal chlorides.

(a) **Table 1** shows some enthalpy change data.

Table 1

	Enthalpy change / kJ mol^{-1}
$Ca^{2+}(g) \rightarrow Ca^{2+}(aq)$	–1650
$Cl^{-}(g) \rightarrow Cl^{-}(aq)$	–364
$Ca^{2+}(g) + 2\ Cl^{-}(g) \rightarrow CaCl_2(s)$	–2237

Use the data in **Table 1** to calculate the molar enthalpy change when calcium chloride dissolves in water.

Molar enthalpy change ____________________ kJ mol^{-1}

(2)

(b) Use your answer to part (a) to deduce how the temperature changes when calcium chloride dissolves in water.

____

____

(1)

(c) Explain why the enthalpy of hydration of fluoride ions is more negative than the enthalpy of hydration of chloride ions.

____

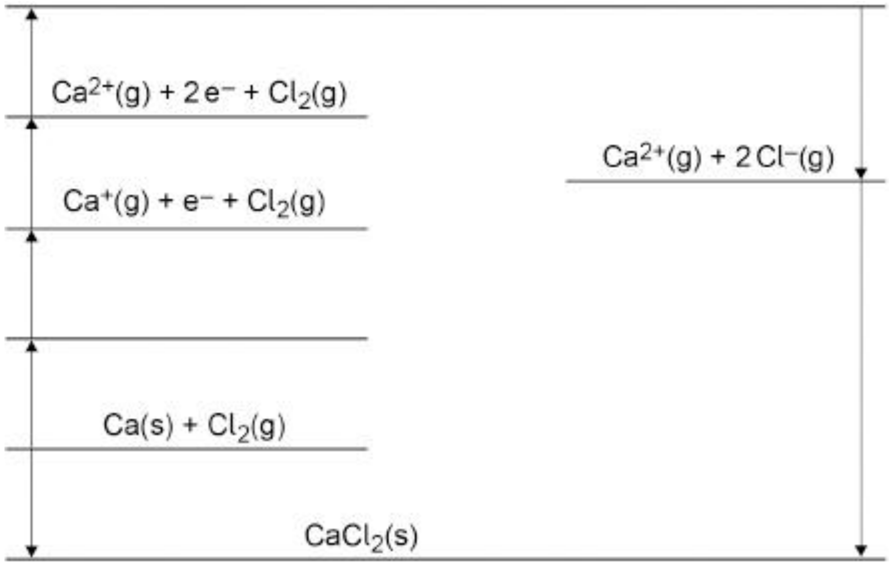
____

____

____

(2)

(d) The figure below shows an incomplete Born–Haber cycle for calcium chloride.



Complete the Born–Haber cycle by writing the formulas of the missing species on each of the two blank lines.

(2)

(e) **Table 2** shows some enthalpy change data.

Table 2

	Enthalpy change / kJ mol^{-1}
Enthalpy of atomisation of calcium	+193
First ionisation energy of calcium	+590
Enthalpy of atomisation of chlorine	+121
Electron affinity of chlorine	–364
Enthalpy of formation of calcium chloride	–795
Enthalpy of lattice formation of calcium chloride	–2237

Use the figure in (d) and data from **Table 2** to calculate the second ionisation energy of calcium.

Second ionisation energy ______________________ kJ mol^{-1}

(2)

(f) Explain why the second ionisation energy of calcium is greater than the first ionisation energy of calcium.

(1)

(g) **Table 3** shows lattice enthalpies based on a perfect ionic model and lattice enthalpies from Born–Haber cycles for three metal chlorides.

Table 3

	Lattice enthalpy of dissociation / kJ mol^{-1}	
	Perfect ionic model	**Born–Haber cycle**
Calcium chloride	2223	2237
Potassium chloride	690	701
Silver chloride	770	905

Discuss the values in **Table 3**.

In your answer you should

- compare the three values based on a perfect ionic model
- compare the values based on a perfect ionic model to the values from a Born–Haber cycle for each compound.

(6)

(Total 16 marks)

Q2.

A value for enthalpy of solution can be determined in two ways:

- from a cycle, using lattice enthalpy and enthalpies of hydration
- from the results of a calorimetry experiment.

(a) Define the term enthalpy of lattice dissociation.

____

____

____

____

(2)

(b) The enthalpy of solution for ammonium nitrate is the enthalpy change for the reaction shown.

$$NH_4NO_3(s) + aq \rightarrow NH_4^+(aq) + NO_3^-(aq) \qquad \Delta H = +26\ kJ\ mol^{-1}$$

Table 1

	$NH_4^+(g)$	$NO_3^-(g)$
Enthalpy of hydration $\Delta_{hyd}H$ / kJ mol^{-1}	−307	−314

Draw a suitably labelled cycle and use it, with data from **Table 1**, to calculate the enthalpy of lattice dissociation for ammonium nitrate.

Enthalpy of lattice dissociation ________________ kJ mol^{-1}

(3)

(c) A student does an experiment to determine a value for the enthalpy of solution for ammonium nitrate.

The student uses this method.

- Measure 25.0 cm^3 of distilled water in a measuring cylinder.
- Pour the water into a beaker.
- Record the temperature of the water in the beaker.
- Add 4.00 g of solid NH_4NO_3 to the water in the beaker.
- Stir the solution and record the lowest temperature reached.

Table 2 shows the student's results.

Table 2

Initial temperature / °C	20.2
Lowest temperature / °C	12.2

Calculate the enthalpy of solution, in kJ mol^{-1}, for ammonium nitrate in this experiment.

Assume that the specific heat capacity of the solution, $c = 4.18$ J K^{-1} g^{-1}

Assume that the density of the solution = 1.00 g cm^{-3}

Enthalpy of solution _______________ kJ mol^{-1}

(3)

(d) The uncertainty in each of the temperature readings from the thermometer used in this experiment is ±0.1°C

Calculate the percentage uncertainty in the temperature change in this experiment.

Percentage uncertainty ____________________

(1)

(e) Suggest a change to the student's method, using the same apparatus, that would reduce the percentage uncertainty in the temperature change.

Give a reason for your answer.

Change ____

____

Reason ____

____

(2)

(f) Another student obtained a value of +15 kJ mol^{-1} using the same method.

Suggest the main reason for the difference between this experimental value for the enthalpy of solution and the correct value of +26 kJ mol^{-1}

____

____

(1)

(g) **Table 3** shows some entropy data at 298 K

Table 3

	Entropy *S* / J K^{-1} mol^{-1}
$NH_4NO_3(s)$	151
$NH_4^+(aq)$	113
$NO_3^-(aq)$	146

Calculate a value for the Gibbs free-energy change (ΔG), at 298 K, for the reaction when ammonium nitrate dissolves in water.

$$NH_4NO_3(s) + aq \rightarrow NH_4^+(aq) + NO_3^-(aq) \qquad \Delta H = +26\ kJ\ mol^{-1}$$

Use data from **Table 3** and the value of ΔH from the equation.
Assume for the solvent, water, that the entropy change, $\Delta S = 0$

Explain what the calculated value of ΔG indicates about the feasibility of this reaction at 298 K

ΔG ________________ kJ mol^{-1}

Explanation ____

____

____

(4)

(h) Ammonium nitrate decomposes as shown.

$$NH_4NO_3(s) \rightarrow N_2(g) + \frac{1}{2}O_2(g) + 2\,H_2O(g) \qquad \Delta H = +123\ \text{kJ mol}^{-1}$$

The entropy change (ΔS) for this reaction is +144 J K^{-1} mol^{-1}

Calculate the temperature at which this reaction becomes feasible.

Temperature _______________ K

(2)

(Total 18 marks)

Q3.

This question is about enthalpy changes for calcium chloride and magnesium chloride.

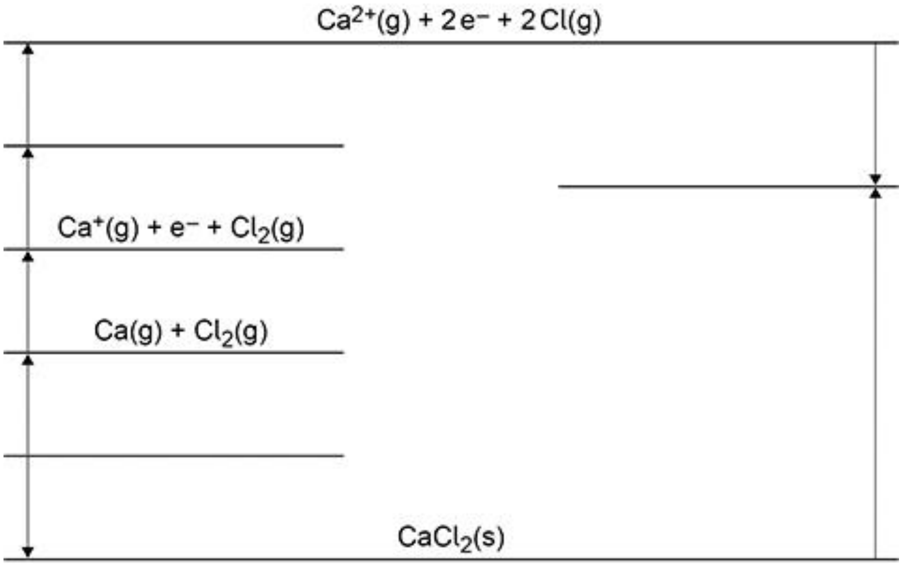
(a) State the meaning of the term enthalpy change.

____

____

(1)

The figure below shows an incomplete Born–Haber cycle for the formation of calcium chloride.



(b) Complete the figure above by writing the formulas, including state symbols, of the appropriate species on each of the three blank lines.

(3)

(c) **Table 1** shows some enthalpy data.

Table 1

	Enthalpy change / kJ mol^{-1}
Enthalpy of formation of calcium chloride	–795
Enthalpy of atomisation of calcium	+193
First ionisation energy of calcium	+590
Second ionisation energy of calcium	+1150
Enthalpy of atomisation of chlorine	+121
Electron affinity of chlorine	–364

Use the figure in part (a) and the data in **Table 1** to calculate a value for the enthalpy of lattice dissociation of calcium chloride.

Enthalpy of lattice dissociation _______________ kJ mol^{-1}

(2)

(d) Magnesium chloride dissolves in water.

Give an equation, including state symbols, to represent the process that occurs when the enthalpy of solution of magnesium chloride is measured.

____

(1)

(e) **Table 2** shows some enthalpy data.

Table 2

	Enthalpy change / kJ mol^{-1}
Enthalpy of lattice dissociation of $MgCl_2$	+2493
Enthalpy of hydration of $Mg^{2+}(g)$	–1920
Enthalpy of hydration of $Cl^{-}(g)$	–364

Use your answer to part (d) and the data in **Table 2** to calculate a value for the enthalpy of solution of magnesium chloride.

Enthalpy of solution _______________ kJ mol^{-1}

(2)

(f) The enthalpy of hydration of $Ca^{2+}(g)$ is –1650 kJ mol^{-1}

Suggest why this value is less exothermic than that of $Mg^{2+}(g)$

____

____

____

____

(2)

(Total 11 marks)

Q4.

This question is about enthalpy changes.

(a) The figure below shows a Born–Haber cycle for the formation of strontium chloride, $SrCl_2$

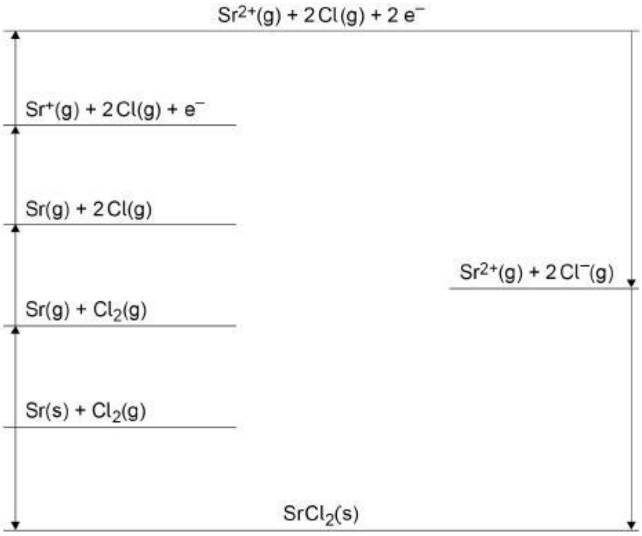


Table 1 shows some thermodynamic data.

Table 1

	Enthalpy change / kJ mol^{-1}
First ionisation energy of strontium	+548
Second ionisation energy of strontium	+1060
Enthalpy of atomisation of chlorine	+121
Enthalpy of atomisation of strontium	+164
Enthalpy of formation of strontium chloride	–828
Enthalpy of lattice formation of strontium chloride	–2112

Use the data in **Table 1** to calculate a value for the electron affinity of chlorine.

Electron affinity _______________ kJ mol^{-1}

(3)

(b) Draw a line from **each** substance to the enthalpy of lattice formation of that substance.

Substance	**Enthalpy of lattice formation / kJ mol^{-1}**
$MgCl_2$	–2018
MgO	–2493
$BaCl_2$	–3889

(1)

Table 2 shows the theoretical lattice enthalpy, based on a perfect ionic model, and an experimental value for the enthalpy of lattice formation of silver chloride.

Table 2

	Theoretical	**Experimental**
Enthalpy of lattice formation / kJ mol^{-1}	–770	–905

(c) State why there is a difference between the theoretical and experimental values.

____

____

(1)

(d) **Table 3** shows enthalpy of hydration values for ions of some Group 1 elements.

Table 3

	$Li^+(g)$	**$Na^+(g)$**	**$K^+(g)$**
Enthalpy of hydration / kJ mol^{-1}	–519	–406	–322

Explain why the enthalpy of hydration becomes less exothermic from Li^+ to K^+

____

____

____

____

(2)

(e) Calcium bromide dissolves in water.

Table 4 shows some enthalpy data.

Table 4

	Enthalpy change / kJ mol^{-1}
Enthalpy of solution of calcium bromide	–110
Enthalpy of lattice formation of calcium bromide	–2176
Enthalpy of hydration of calcium ions	–1650

Use the data in **Table 4** to calculate the enthalpy of hydration, in kJ mol^{-1}, of bromide ions.

Enthalpy of hydration of bromide ions _______________ kJ mol^{-1}

(3)

(Total 10 marks)

Q5.

The diagram shows an incomplete Born−Haber cycle for the formation of caesium iodide. The diagram is not to scale.

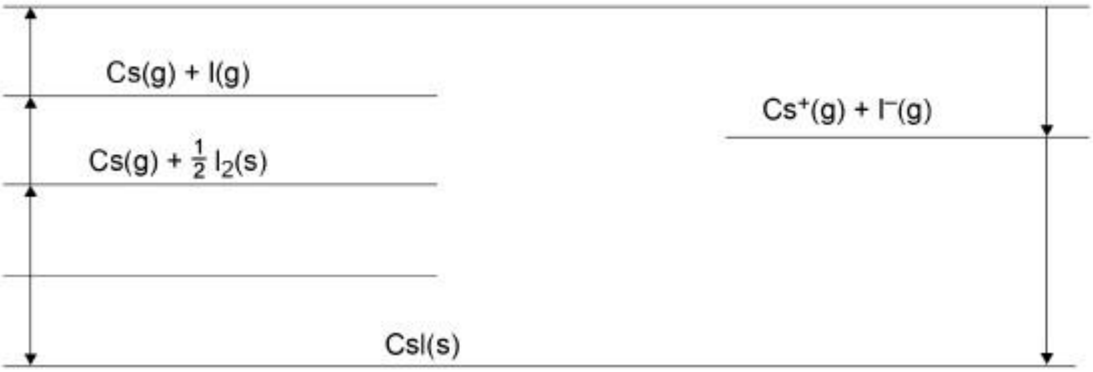


Table 1 gives values of some standard enthalpy changes.

Table 1

Name of enthalpy change	**$\Delta H^\ominus$ / kJ mol^{-1}**
Enthalpy of atomisation of caesium	+79
First ionisation energy of caesium	+376
Electron affinity of iodine	−314
Enthalpy of lattice formation of caesium iodide	−585
Enthalpy of formation of caesium iodide	−337

(a) Complete the diagram above by writing the formulas, including state symbols, of the appropriate species on each of the two blank lines.

(2)

(b) Use the diagram above and the data in **Table 1** to calculate the standard enthalpy of atomisation of iodine.

Standard enthalpy of atomisation of iodine ______________________________ kJ mol^{-1}

(2)

(c) The enthalpy of lattice formation for caesium iodide in **Table 1** is a value obtained by experiment.
The value obtained by calculation using the perfect ionic model is −582 kJ mol^{-1}

Deduce what these values indicate about the bonding in caesium iodide.

(1)

(d) Use data from **Table 2** to show that this reaction is **not** feasible at 298 K

$$CsI(s) \rightarrow Cs(s) + \frac{1}{2}I_2(s) \qquad \Delta H^\ominus = +337 \text{ kJ mol}^{-1}$$

Table 2

	CsI(s)	**Cs(s)**	**I_2(s)**
$S^\ominus$ / J K^{-1} mol^{-1}	130	82.8	117

(4)

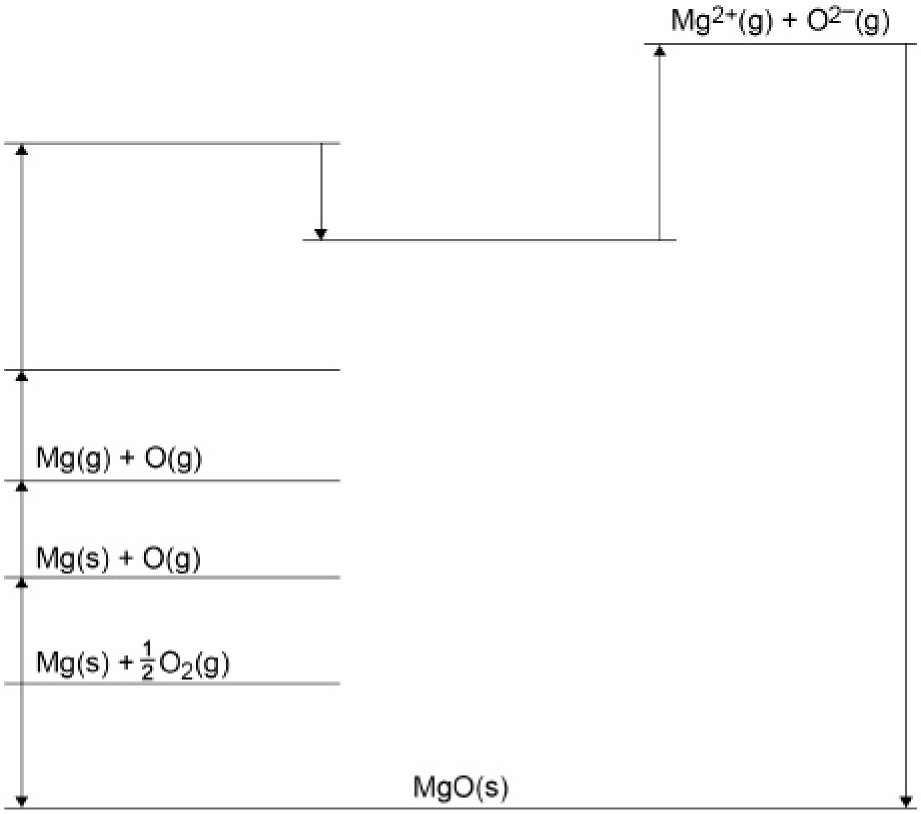
(Total 9 marks)

Q6.

This question is about lattice enthalpies.

(a) The diagram shows a Born–Haber cycle for the formation of magnesium oxide.

Complete the diagram by writing the missing symbols on the appropriate energy levels.



(3)

(b) The table contains some thermodynamic data.

	Enthalpy change / kJ mol^{-1}
Enthalpy of formation for magnesium oxide	–602
Enthalpy of atomisation for magnesium	+150
First ionisation energy for magnesium	+736
Second ionisation energy for magnesium	+1450
Bond dissociation enthalpy for oxygen	+496
First electron affinity for oxygen	–142
Second electron affinity for oxygen	+844

Calculate a value for the enthalpy of lattice formation for magnesium oxide.

Enthalpy of lattice formation ____________________ kJ mol^{-1}

(3)

(Total 6 marks)

Mark schemes

Q1.

(a) (Enthalpy change = lattice dissociation energy + hydration energies of ions)

M1 Enthalpy change = **+**2237 − (**2** x 364) − 1650

M2 = − 141 kJ mol^{-1}

2

(b) Temperature goes up/increases

Allow answer consequential on (a)

1

(c) M1 fluoride ions/F^- (ions) are smaller

OR

M1 F^- has a higher charge density

Do not accept fluorine atoms/ions are smaller

M2 stronger <u>attraction</u> (of fluoride ion) to δ+ on H/ electron deficient H (in water)

M2 do not accept ionic bonds

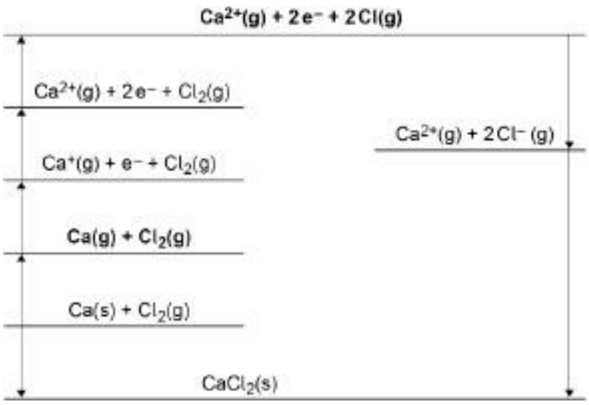
Do not accept more energy to break bonds

Do not accept stronger attraction to H^+

Ignore electronegativity and shielding

2

(d)



2

(e) −795 = 193 + 590 + 2nd IE + (121 **x 2**) + (−364 **x 2**) − 2237

= (+) 1145 (kJ mol^{-1})

M1: Allow −795 = −1940 + 2nd IE

2

(f) Electron removed from a positive charge/ion

OR

Electron removed from smaller ion/electron removed closer to nucleus

OR

Stronger attraction between same number of protons and fewer electrons

1

(g)

This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.	
Level 3 **5-6 marks**	**All stages are covered and each stage is generally correct and virtually complete.** Answer is communicated coherently and shows a logical progression from stage 1 to stage 2 and stage 3
Level 2 **3-4 marks**	**All stages are covered but stage(s) may be incomplete or may contain inaccuracies OR** **two stages are covered and are generally correct and virtually complete.** Answer is mainly coherent and shows progression from stage 1 to stage 2 and/or stage 3.
Level 1 **1-2 marks**	**Two stages are covered but stage(s) may be incomplete or may contain inaccuracies OR** **only one stage is covered but is generally correct and virtually complete.** Answer includes isolated statements and these are presented in a logical order.
0 marks	Insufficient correct chemistry to gain a mark.

Stage 1 comparing values from perfect ionic model

1a Value for $CaCl_2$ is larger
OR
Values for KCl **and** AgCl are similar
OR
Values for $CaCl_2$ > AgCl > KCl

1b Ca^{2+} has a larger charge/ is a smaller ion
OR
Ag^+ **and** K^+ have smaller charge or larger ions

1c $CaCl_2$ has stronger ionic bonds or stronger attraction between + and - ions ($Ca^{2+}$and Cl^-)
OR
AgCl **and** KCl have weaker ionic bonds or weaker attraction between + and - ions (Ag^+/ K^+ and Cl^-)

Stage 2 similarities in the perfect ionic model and Born-Haber cycle values

2a $CaCl_2$ has similar values (between the perfect ionic model and Born-Haber cycle)

2b KCl has similar values (between the perfect ionic model and Born-Haber cycle)

2c $CaCl_2$ **and** KCl have (almost) perfect ionic bonding or + ions are point charges/(perfectly) spherical

Stage 3 difference in the perfect ionic model and Born-Haber cycle values

3a AgCl has larger difference in values (between the perfect ionic model and Born-Haber cycle)

3b AgCl contains (some) covalent character

3c Ag^+ more polarising/distorts electron cloud more

[16]

Q2.

(a) The enthalpy change / ΔH when one mole of a (solid) ionic compound

__Ignore__ standard states / conditions

__Allow__ heat change at constant pressure when...

__Ignore__ heat change (alone) / energy change

1

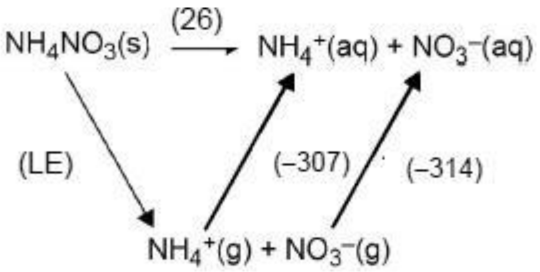
dissociates (fully) into gaseous ions

__M2 Allow__ suitable equation with state symbols for ions

__Not__ one mole of gaseous ions

1

(b)



__Allow__ + water or +aq

M1 = cycle (3 'corners' with formulae and state symbols and suitable arrows)

__Allow__ equivalent Born-Haber style energy cycle

__Not__ ecf to M2 and M3 from incorrect cycle

1

LE = 26 + 307 + 314

M2 = working e.g. 26 = LE − 307 − 314

= (+)647

1

M3 = answer (+)647 gets 3/3 if M1 given or 2/3 if not
−647 = 2/3 if M1 given or 1/3 if not
+595 / −595 = 2/3 if M1 given or 1/3 if not
−621/+621 = 1/3 if M1 given
__Not__ ecf for M3 from incorrect expression in M2

1

(c) ($q = mc\Delta T$ =) 25.0 × 4.18 × (20.2 − 12.2) **OR** 25.0 × 4.18 × 8
(= 836 (J) or 0.836 (kJ))

Not *if m = 29*

Ignore *sign of q*

1

4.00 g NH_4NO_3 = 4.00/80 **OR** 0.0500 mol

1

ΔH⦵soln = 836/0.05 = 16720 = (+)16.7(2) kJ mol^{-1}

Allow *ecf from M1 and/or from M2*

–16.7(2) = 2/3

+19.4 = 2/3 (using m = 29 in M1)

−19.4 = 1/3

+2.68 = 2/3

−2.68 = 1/3

+587 or +588 = 2/3

−587 or −588 = 1/3

Allow *2 sig figs or more*

1

(d) (2 × 0.1/8) × 100 = 2.5%

Allow *ecf from ΔT in (c)*

1

(e) use a larger mass/amount of NH_4NO_3 / solid

Marking points are independent

Allow *smaller volume of water / less water*

Allow *use more NH_4NO_3*

Not *larger volume of water*

Ignore *higher concentration (of NH_4NO_3)*

Ignore *any references to changing apparatus e.g. insulation*

1

so temperature change/decrease is greater
OR final temperature is lower

Allow *temperature increase is greater*

Not *final temperature is higherr*

1

(f) heat gain (from the surroundings) / incomplete dissolvingg

Allow *incomplete reaction*

Allow *thermal energy gain*

Not *heat loss*

Ignore *energy gain*

Ignore *references to mistakes in method*

1

(g) ΔS = (113 + 146) − 151 = +108 (J K^{-1} mol^{-1})

1

$\Delta G = \Delta H - T\Delta S$ **OR** $26 - (298 \times 108 \times 10^{-3})$

__Allow__ ecf $26 - (298 \times M1 \times 10^{-3})$

__Allow__ ecf $26 - (298 \times M1)$

__Allow M2__ for $26000 - (298 \times 108)$

__Allow M2__ for $26 - (298 \times 108)$

1

$\Delta G = -6.184 / -6.18 / -6.2$

-32158 = __M1__ and __M2__

-32.2 = __M1__ and __M2__

-6184 = __M1__ and __M2__

$(+)58.2$ = __M2__ and __M3__ (ecf if -108 for M1)

1

negative value for ΔG indicates reaction is feasible/spontaneous

__Allow__ positive value for ΔG indicates reaction is NOT feasible/spontaneous

__Allow__ < 0 or > 0 as appropriate

__M4__ is standalone

1

(h) Converting ΔH into J **OR** ΔS into kJ

1

$(T = \Delta H/\Delta S = 123/144 \times 10^{-3}$ **OR** $123000/144) = 854(.1666666)$ (K)

0.854 (K) = 1/2

0.00117 (K) = 1/2 (calculation upside down)

2SF minimum

1

[18]

Q3.

(a) Heat (energy) change at constant pressure

Ignore conditions even if wrong

Ignore energy change

1

(b) M2 $Ca^{2+}(g) + 2\ e^{-} + Cl_2(g)$

Alternative M2 $Ca^{+}(g) + e^{-} + 2\ Cl(g)$

1

M3 $Ca^{2+}(g) + 2\ Cl^{-}(g)$

1

M1 $Ca(s) + Cl_2(g)$

1

(c) M1 $-795 + LE = 193 + 590 + 1150 + (\mathbf{2} \times 121) + (\mathbf{2} \times -364)$

Numbers and factors used correctly from cycle

1

M2 LE = (+) 2242 (kJ mol^{-1})

Rearrangement to calculate LE

If one or both factors of 2 missing award 1 mark for (+) 2485, (+)2121 or (+)2606 (kJ mol^{-1})

Allow 1 mark for – 2242 (kJ mol^{-1})

1

(d) $MgCl_2(s) \rightarrow Mg^{2+}(aq) + 2\ Cl^-(aq)$

Allow $MgCl_2(s) \rightleftharpoons Mg^{2+}(aq) + 2\ Cl^-(aq)$

Allow $MgCl_2(s) + aq \rightleftharpoons Mg^{2+}(aq) + 2\ Cl^-(aq)$

1

(e) M1 ΔH soln $MgCl_2$ = ΔH latt diss+ ΔH hyd Mg^{2+} + **2**ΔH hyd Cl^-
OR 2493 –1920 + (**2** x –364)

M1 for expression with or without numbers

1

M2 = – 155 (kJ mol^{-1})

M2 for answer

If factor of 2 missing for ΔH *hyd* Cl^-, *allow 1 mark for 209*

1

(f) M1 Ca^{2+} (ion) bigger/lower charge to size ratio (than Mg^{2+})

Allow converse answers

M1 Do not accept Ca^{2+} *is a bigger atom/molecule*

M1 Allow Ca^{2+} *has more shells/ more distance of outer e to nucleus*

Ignore more shielding

1

M2 weaker attraction/bond to ($O^{\delta-}$ in) water

1

[11]

Q4.

(a) **M1**

$\Delta_f H = \Delta_a H\ (Sr) + 2\Delta_a H\ (Cl) + \Delta_{1st\ IE} H\ (Sr) + \Delta_{2nd\ IE} H\ (Sr) + 2\Delta_{EA} H\ (Cl) + \Delta_{LE} H\ (Sr)$

Or

$-828 = 164 + (2 \times 121) + 548 + 1060 + (2 \times \Delta_{EA} H) + (-2112)$

1

M2 2 x $\Delta_{EA}H$ = – 730

1

M3 $\Delta_{EA}H$ = – 365 (kJ mol^{-1})

*Allow **M3** = **M2**÷2*

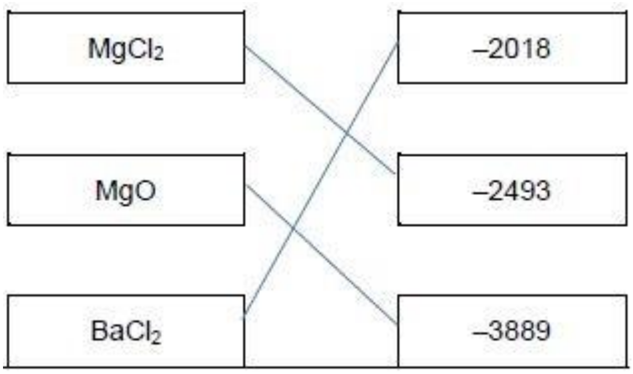
(+) 365, –304.5, and –730 = 2 marks

(+) 304.5, (+) 730 and –609 = 1 mark

(+) 609 = 0 marks 1

1

(b)



All three lines must be shown

1

(c) (Has) covalent character or partial covalent bonding (as well as ionic bonding)

*Allow chloride **ion** has been polarised or chloride **ion** distorted*

Ignore not perfectly ionic

Ignore ions are not spheres

Do not allow references to molecules or ions with covalent character

Do not allow it is covalently bonded alone

1

(d) **M1** (From Li^+ to K^+) size (of ion) increases OR charge density (of ion) decreases

***M1** Allow K+ has more shells or larger distance between nucleus and outer electrons or larger ionic radius*

Do not allow atomic radius or molecules

1

M2 (Electrostatic) attraction between metal ion and $O^{\delta-}$ of water decreases or attraction between lone pair on O and + ion decreases

M2** Not dependent on **M1

Allow converse arguments

1

(e) **M1** $\Delta_{sol}H = \Delta_{LEdissociation}H + \Delta_{hyd}H\ (Ca^{2+}) + 2x\ \Delta_{hyd}H\ (Br^-)$
or
M1 $-110 = 2176 + (-1650) + 2x\ \Delta_{hyd}H\ (Br^-)$

1

M2 $(2x\ \Delta_{hyd}H\ (Br^-)) = -636$

1

M3 $\Delta_{hyd}H\ (Br^-) = -318$ (kJ mol^{-1})

*Allow **M3** = **M2** ÷ 2*

(+)1858, (+)318 and –636 = 2 marks

+3716, –1858 and (+)636 = 1 mark

–3716 = 0 marks

1

[10]

Q5.

(a) Top line $Cs^+(g) + e^- + I(g)$

1

Lower line $Cs(s) + \frac{1}{2}I_2(s)$

1

(b) 79 + × + 376 − 314 = −337 +585

1

So enthalpy change = 107 (kJ mol^{-1})

Allow I mark for -107 (kJ mol^{-1})

Allow answer to 2sf or more

1

(c) (Almost/Mostly) purely/ perfectly ionic

If ionic not mentioned, allow no/little covalent bonding/character

Penalise references to atoms/molecules

Ignore electronegativity

1

(d) **M1** $\Delta S = [(82.8 + \frac{1}{2} \times 117) - 130] = \underline{11.3}$ (J K^{-1} mol^{-1})

M1 *Correct entropy change value*

1

M2 $\Delta G = \Delta H - T\Delta S$

M2 *equation or equation with numbers*

1

M3 $\Delta G = 337 - 298 \times 11.3 \times 10^{-3}$ OR $337000 - 298 \times 11.3$

M3 *for converting units:*

ΔS into kJK^{-1} mol^{-1} or ΔH into J mol^{-1}

1

M4 ΔG = (+)334 <u>kJ mol</u>$^{-1}$ or 334000 <u>J mol</u>$^{-1}$

M4 *answer with correct units*

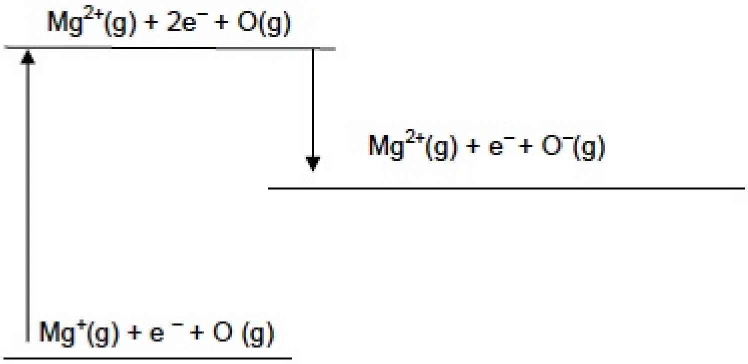
Any negative answer loses ***M4***

1

[9]

Q6.

(a)



One mark for each level with correct state symbols

1
1
1

(b) $\Delta_f H = \Delta_a H$ (Mg) + ½ $\Delta_{BD} H$ (O_2) + $\Delta_{1st\ IE} H$ (Mg) + $\Delta_{2nd\ IE} H$ (Mg) + 1

$\Delta_{1st\ EA} H$ (O) + $\Delta_{2nd\ EA} H$(O) + $\Delta_{LE} H$ (MgO)

- 602 = 150 + (½ × 496) + 736 +1450 – 142 + 844 + $\Delta_{LE} H$ (MgO) 1

$\Delta_{LE} H$ (MgO) = -3888 / -3890 (kJ mol^{-1})

Allow answers to 2sf or more

1 mark for +3888 or +3890

1 mark for -4136 or -4140 (not 496 × ½)

1

[6]