IB · DP · Chemistry

2 hours 14 questions

Structured Questions: Paper 2

15.1 Energy Cycles

Easy (5 questions)	/42
Medium (5 questions)	/56
Hard (4 questions)	/38
Total Marks	**/136**

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Easy Questions

1 (a) Write one equation to represent each the following changes:

Atomisation of sodium ....

First ionisation energy of magnesium ....

First electron affinity of chlorine ....

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(3 marks)

(b) Give the definition of the term *enthalpy of lattice formation.*

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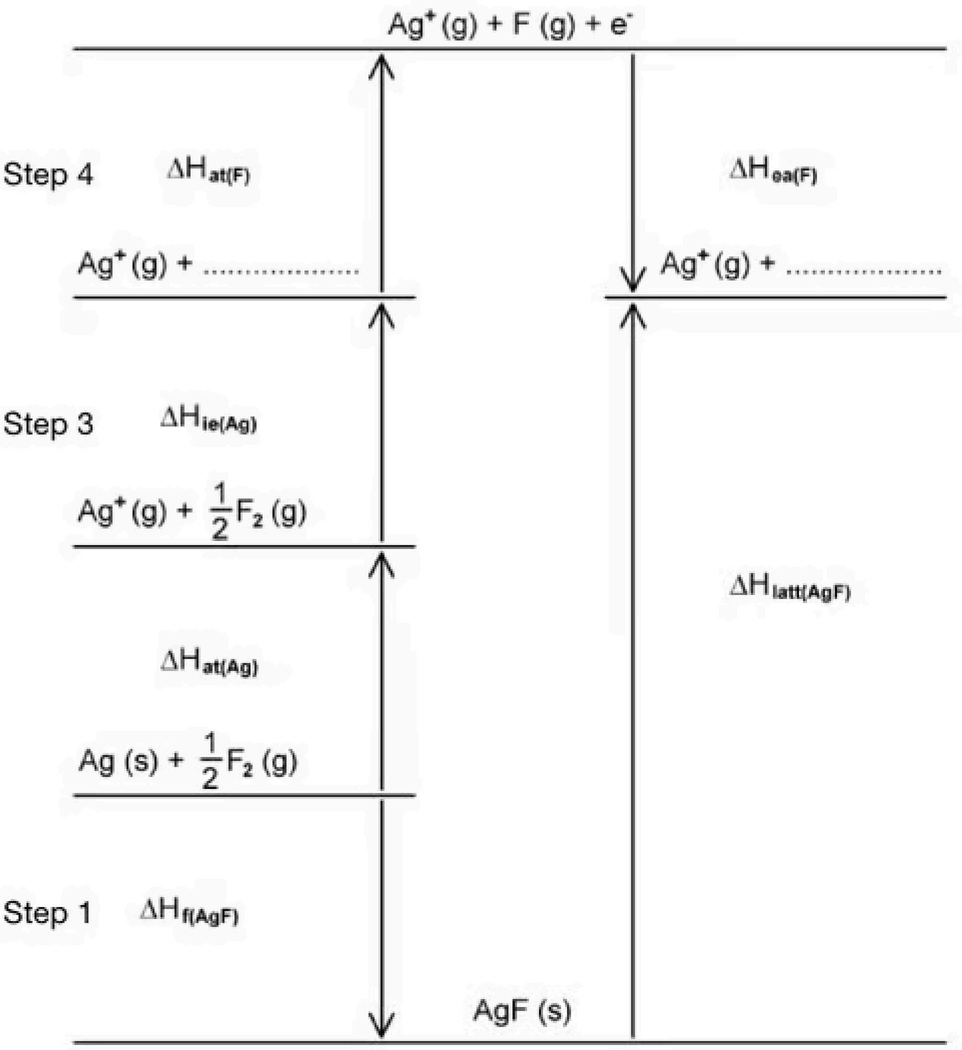
(2 marks)

(c) Study the following Born-Haber cycle.



State the enthalpy changes for the following steps:

Step 1 ....

Step 3 ....

Step 4 ....

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(3 marks)

(d) The enthalpy of lattice formation of potassium fluoride and caesium fluoride is -829 kJ mol^{-1} and -759 kJ mol^{-1} respectively.

With reference to the ions in the structure, explain why the enthalpy of lattice formation is more exothermic for potassium fluoride.

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(3 marks)

2 (a) State the equation to determine the standard enthalpy change of solution, ΔH_{sol}.

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(1 mark)

(b) Use sections 18 and 20 in the data booklet to determine the enthalpy change of solution, ΔH_{sol}, in kJ mol^{-1}, of sodium chloride, NaCl.

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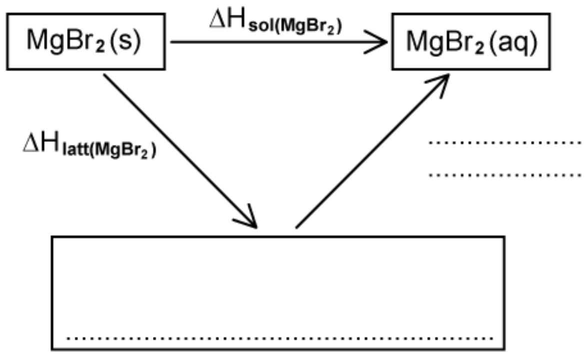
(2 marks)

(c) Part of the dissolution cycle for magnesium bromide is shown below. Complete the cycle.



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(3 marks)

(d) The lattice enthalpy ΔH_{latt} , of magnesium bromide is 2421 kJ mol^{-1}. Using section 20 of the data booklet and your answer to part c), determine the enthalpy of solution, ΔH_{sol} , in kJ mol^{-1} of magnesium bromide.

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(2 marks)

(e) The enthalpy of hydration for the calcium ion , $\Delta H_{hyd(Ca^{2+})}$, is 1616 kJ mol^{-1} . Explain why this value is less exothermic than the value for the enthalpy of hydration for the magnesium ion , $\Delta H_{hyd(Mg^{2+})}$.

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(2 marks)

3 (a) State the definition of electron affinity, ΔH_{ea}.

(3 marks)

(b) Electron affinities can be represented using equations.

i) State the equation which represents the first electron affinity of oxygen. [1]

ii) State the equation which represents the second electron affinity of oxygen. [1]

(2 marks)

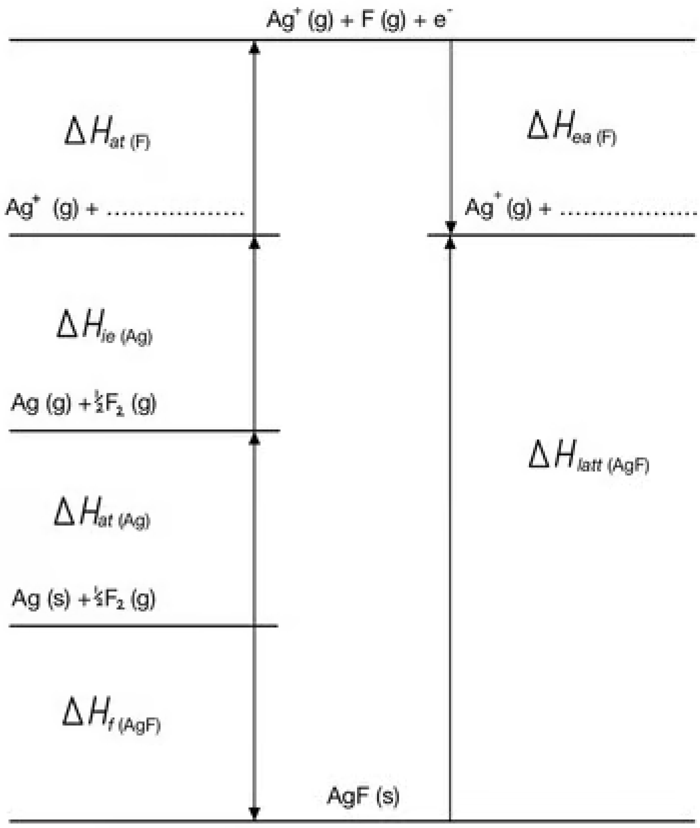
(c) The first and second electron affinities of oxygen are shown in the table below.

First electron affinity of O	-141 kJ mol^{-1}	Exothermic
Second electron affinity of O	+844 kJ mol^{-1}	Endothermic

State why the second electron affinity of oxygen is an endothermic process.

(2 marks)

4 (a) The incomplete Born-Haber cycle for silver fluoride, AgF, is shown below.



Complete the Born Haber cycle.

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(2 marks)

(b) Use the Born-Haber cycle in part a) and sections 8 and 11 in the data booklet to determine the enthalpy changes, in kJ mol^{-1}, of the following.

The enthalpy of atomisation of silver, $\Delta H_{at(Ag)}$, is +289 kJ mol^{-1}

The enthalpy of atomisation of fluorine, $\Delta H_{at(F)}$, is +79 kJ mol^{-1}

$\Delta H_{at(Ag)} + \Delta H_{ie(Ag)}$ ....

$\Delta H_{at(F)} + \Delta H_{ea(F)}$ ....

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(2 marks)

(c) Use your answer to part b) and the lattice enthalpy of silver fluoride, $\Delta H_{latt(AgF)}$, in section 18 in the data booklet to determine the enthalpy of formation of silver fluoride, $\Delta H_{f(AgF)}$, in kJ mol^{-1}.

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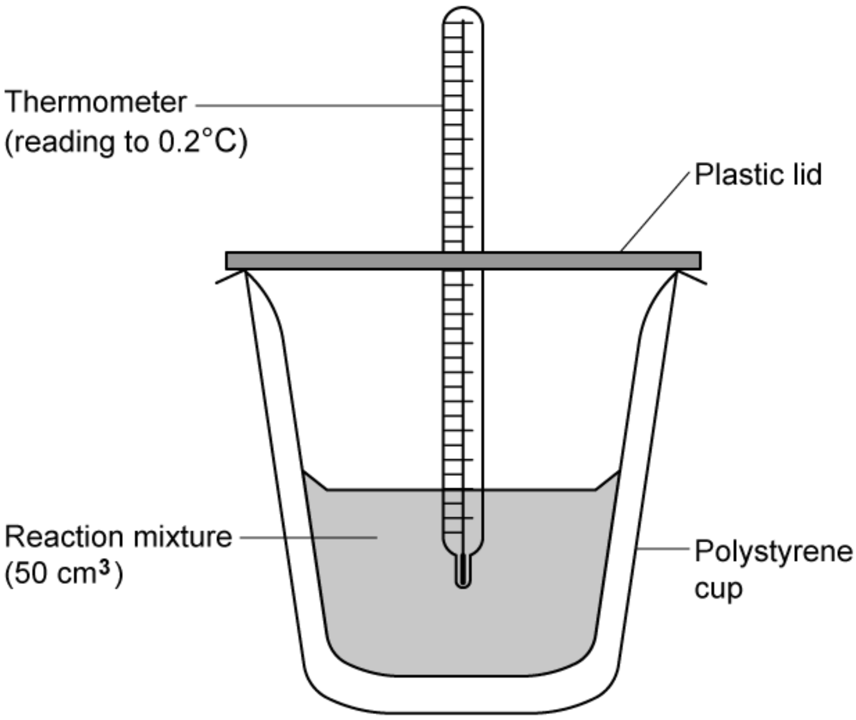
(3 marks)

5 (a) The equipment set up below is used to measure the enthalpy change for a reaction.



Suggest why a polystyrene cup is used for this experiment.

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(1 mark)

(b) A student added 50.00 cm^3 of 1.50 mol dm^{-3} copper sulfate solution, $CuSO_4$ (aq), to the polystyrene cup. They recorded the temperature every minute for 3 minutes. On the fourth minute, 6.00 g of powdered zinc was added. They then recorded the temperature of the reaction mixture every minute for a further 7 minutes. The maximum temperature change was estimated to be 29.0 °C.

Use section 6 of the data booklet to answer the following questions.

i) Determine the amount, in moles, of copper sulfate used in the reaction.

[1]

ii) Determine the amount, in moles, of powdered zinc used in the reaction.

[1]

iii) Determine the limiting reagent in the reaction.

[1]

(3 marks)

(c) Use the information in part b) and sections 1 and 2 in the data booklet to determine the following.

i) The energy change, in J, for the reaction.

[1]

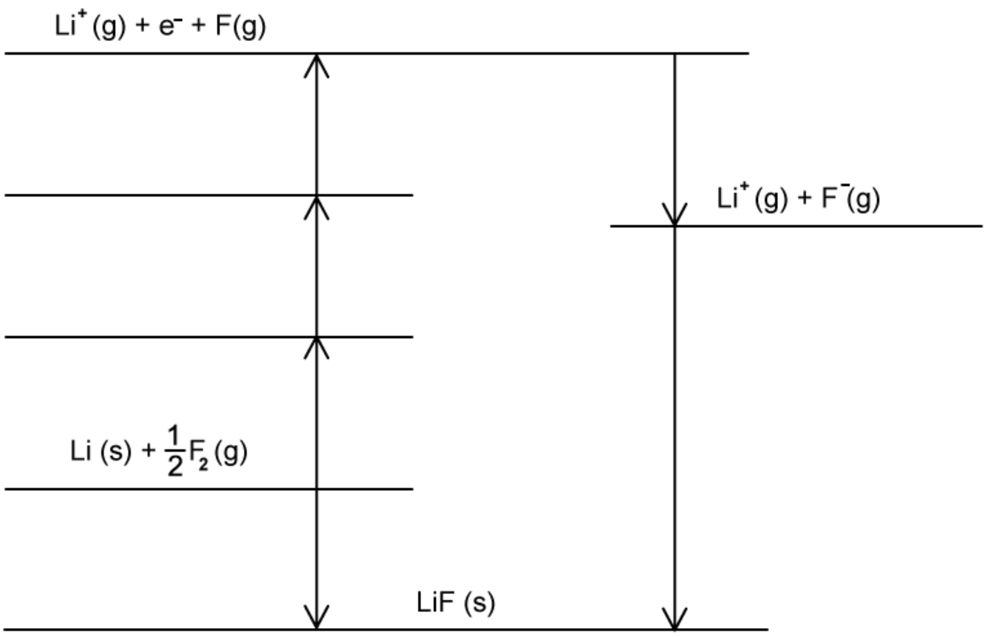
ii) The enthalpy change, in kJ mol^{-1}, for the reaction between copper sulfate and zinc.

[2]

(3 marks)

Medium Questions

1 (a) Pure crystals of lithium fluoride are used in X-ray monochromators.



i) Define the term enthalpy of atomisation

ii) Explain why the enthalpy of atomisation of fluorine is positive

iii) Complete the Born–Haber cycle for lithium fluoride by adding the missing species on the lines

(4 marks)

(b) Use the data in the following table and your completed Born–Haber cycle from part (a) to answer the questions below.

Name of enthalpy change	**Energy change / kJ mol^{-1}**
$Li (s) \rightarrow Li (g)$	+216
$Li (g) \rightarrow Li^{+} (g) + e^{-}$	+520
$F_2 (g) \rightarrow 2F (g)$	+158
$F (g) + e^{-} \rightarrow F^{-} (g)$	-348
$Li (s) + 1/2F_2 (g) \rightarrow LiF (s)$	-594

i) Calculate the enthalpy of lattice formation of lithium fluoride.

ii) Explain and justify how the enthalpy of lattice formation of LiBr compares with that of LiF. You must refer to the size of the ions in your answer.

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(5 marks)

(c) This question is about enthalpy changes in solution.

i) Write the equation for the process showing the enthalpy of solution of potassium fluoride. Include state symbols in your answer.

ii)

Use the data in the following table to calculate the standard enthalpy of solution of potassium fluoride.

Name of enthalpy change in solution	**Enthalpy change (kJ mol^{-1})**
Enthalpy of lattice dissociation potassium fluoride	+829
Enthalpy of hydration of potassium ions	-340
Enthalpy of hydration of fluoride ions	-504

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(3 marks)

(d) Explain the decrease why the value for the enthalpy of hydration, ΔH^{θ}_{hyd}, of group 1 ions increases from lithium to caesium.

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(2 marks)

2 (a) Calcium chloride has many uses including as an agent to lower the freezing point of water. It is very effective for preventing ice formation on road surfaces and as a deicer.

i) Define the term ionisation energy

ii) Explain why the second ionisation energy of calcium is greater than the first ionisation energy

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(5 marks)

(b) Describe the structure and bonding in calcium chloride.

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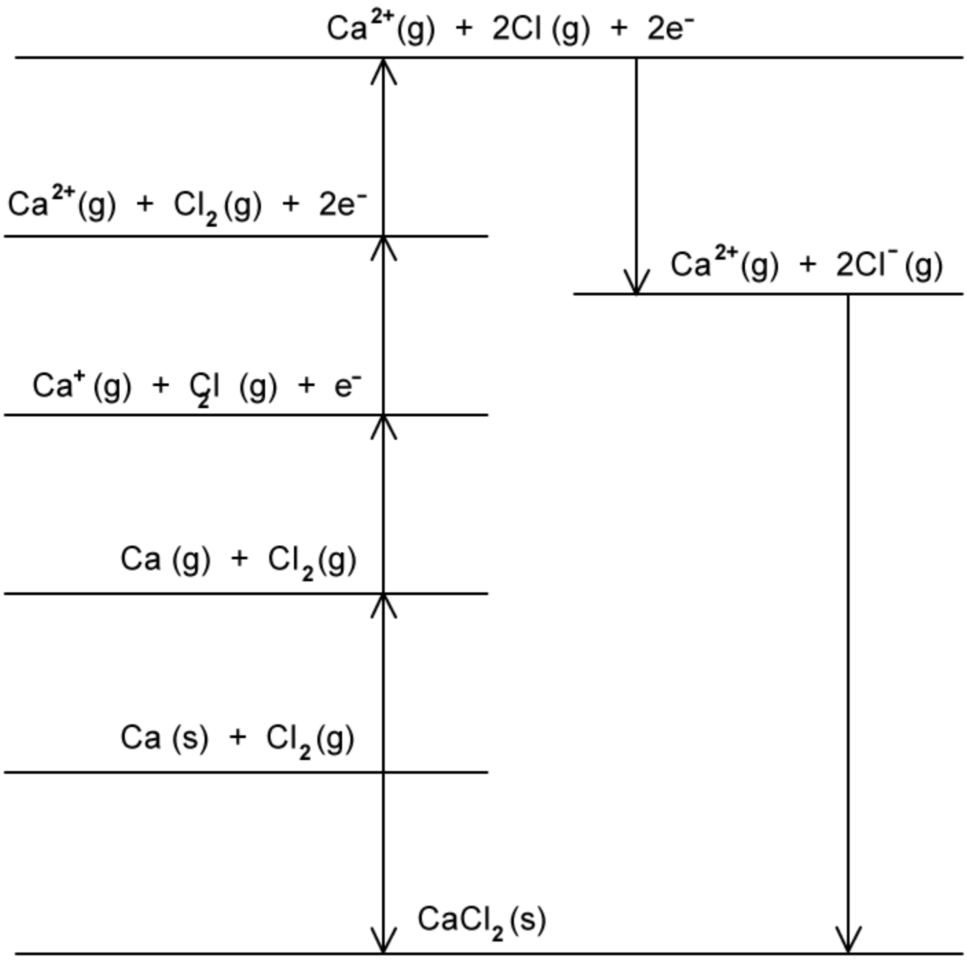
(2 marks)

(c) The Born-Haber cycle for $CaCl_2$ is shown:



Using Section 8 in the Data Booklet and the following information, calculate the enthalpy change for the following conversions.

ΔH^{θ}_{IE2} Ca = 1145 kJ mol^{-1}

ΔH^{θ}_{at} Ca = 178 kJ mol^{-1}

ΔH^{θ}_{BE} Cl_2 = 242 kJ mol^{-1}

i) Ca (s) $\rightarrow$ Ca^{2+} (g) + $2e^-$ ii)

Cl_2 (g) + $2e^-$ $\rightarrow$ $2Cl^-$ (g)

(2 marks)

(d) Using Section 18 of the Data Booklet, calculate the value for the enthalpy of formation for calcium chloride, $\Delta H^{\theta}{}_{f}\ CaCl_2$.

(2 marks)

3 (a) Magnesium chloride supplements are commonly found in tablet and capsule forms and are used to help increase magnesium levels in the body. Magnesium is an important nutrient and is responsible for many processes in the body including regulation of blood sugar and blood pressure.

i) Define the term enthalpy of hydration in relation to a chloride ion.

ii) State whether the hydration of a chloride ion is an exothermic or endothermic process. Justify your answer.

(4 marks)

(b) Using Section 20 in the Data Booklet, explain why the value for the enthalpy of hydration for the fluoride ion is more negative than that for the chloride ion.

(3 marks)

(c) The enthalpy of solution for magnesium chloride was measured in a lab as -73 kJ mol^{-1} Using Sections 18 and 20 in the Data Booklet and showing your working, determine the enthalpy of hydration of magnesium ions, $\Delta H^{\theta}{}_{hyd}$ Mg^{2+}

(3 marks)

(d) Calculate the percentage error for your value for the enthalpy of hydration of magnesium ions, $\Delta H^{\theta}{}_{hyd}$ Mg^{2+}, and the value given in section 18 in the Data Booklet.

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(1 mark)

4 (a) This question is about fluorine and the associated energy changes when it reacts with magnesium to form magnesium fluoride.

i) Define the term electron affinity.

ii) Using Sections 8 and 11 in the Data Booklet and showing your working, determine the electron affinity of a fluorine atom, $\Delta H^{\theta}{}_{EA}$

Name of enthalpy change	Energy change (kJ mol^{-1})
Enthalpy of atomisation of magnesium	+150
Second ionisation energy of magnesium	+1450
Enthalpy of formation of magnesium fluoride	-642
Lattice enthalpy of formation of magnesium fluoride	-2493

(5 marks)

(b) Suggest why the first electron affinity of fluorine is an exothermic change.

(2 marks)

(c) The enthalpy of hydration of anhydrous magnesium sulfate, $MgSO_4$ (s), is difficult to determine experimentally, but can be determined by using a Hess's Law cycle.

A group of students decided to measure the enthalpy of hydration of anhydrous magnesium sulfate, $MgSO_4$ (s), by dissolving 3.05 g into 50.0 cm^3 of water and recording the maximum temperature change. They calculated the value to be -85 kJ mol^{-1}.

The same group of students repeated the experiment using hydrated magnesium sulfate, $MgSO_4.7H_2O$ (s), and calculated the enthalpy change to be +16 kJ mol^{-1}.

Using the student's data, draw a Hess's Law cycle to determine the enthalpy of hydration of solid anhydrous magnesium sulfate, $MgSO_4$ (s).

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(3 marks)

(d) Determine a value for the enthalpy of hydration of anhydrous magnesium sulfate $MgSO_4$ (s).

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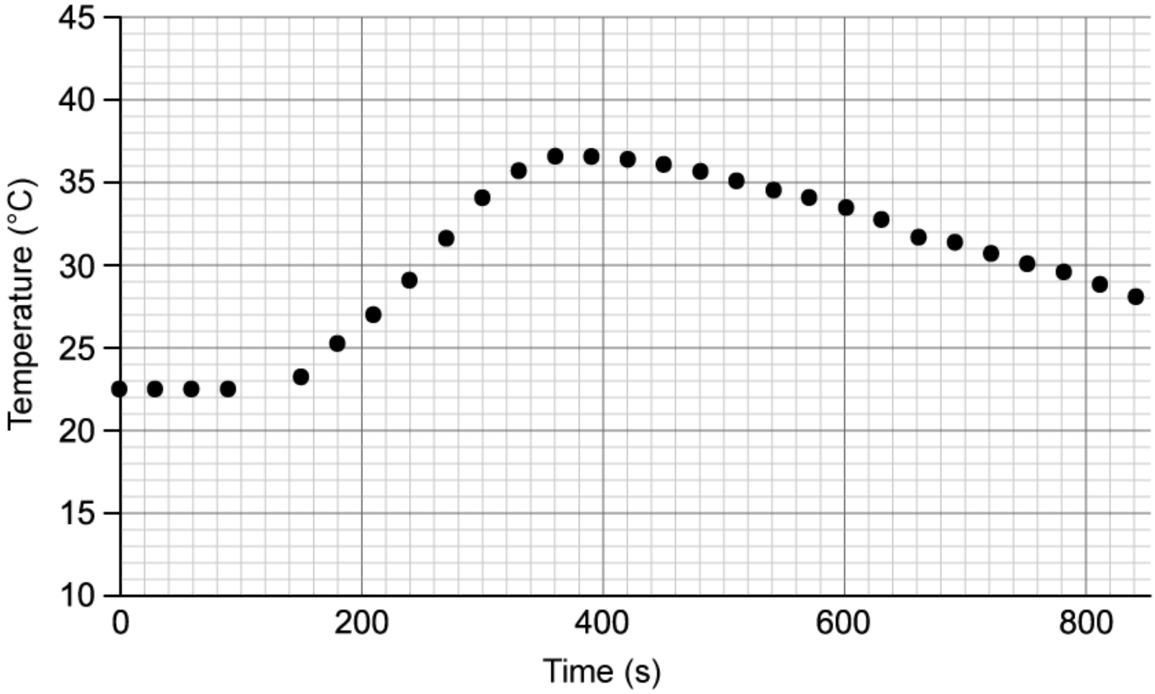
(1 mark)

5 (a) A student measured the energy change when 1.35 g of zinc was added to 50 cm^3 of 0.5 mol dm^{-3} copper sulfate, $CuSO_4$ (aq), solution. The initial temperature of 21 ^oC was recorded before the addition of the zinc and a temperature reading was taken every 30 seconds.



Use the graph to determine the overall temperature change for the reaction

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(1 mark)

(b) Calculate the enthalpy change for the reaction in kJ mol^{-1}.

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(4 marks)

(c) Calculate the percentage error between your value for the enthalpy change of reaction and the literature value of -217 kJ mol^{-1}. Give your answer to two significant figures.

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(1 mark)

(d) Explain why your calculated value for the enthalpy change of reaction is different from the literature value of -271 kJ mol^{-1}.

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(3 marks)

Hard Questions

1 (a) Lattice enthalpies can be determined experimentally using a Born–Haber cycle and theoretically using calculations based on electrostatic principles.

The experimental lattice enthalpies of magnesium chloride, $MgCl_2$, calcium chloride, $CaCl_2$, strontium chloride, $SrCl_2$, and barium chloride, $BaCl_2$ are given in section 18 of the data booklet. Explain the trend in the values.

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(2 marks)

(b) Explain why strontium chloride, $SrCl_2$, has a much greater lattice enthalpy than rubidium chloride, RbCl.

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(2 marks)

(c) Strontium is used as a red colouring agent in fireworks as it provides a very intense red colour. Use section 8 and 18 to calculate the enthalpy of atomisation for chlorine in strontium chloride.

Enthalpy change	Enthalpy change (kJ mol^{-1})
$Sr (s) \longrightarrow Sr (g)$	164.0
$Sr (s) + Cl_2(g) \longrightarrow SrCl_2(s)$	-828.9
$Sr^+(g) \longrightarrow Sr^{2+} (g) + e^-$	1064.3

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(3 marks)

2 (a) The enthalpy of hydration becomes less exothermic as you go down Group 1. Explain why the enthalpy of hydration of Group 1 ions is negative.

(3 marks)

(b) Explain why the enthalpies of hydration become less negative as you go down Group 1.

(2 marks)

(c) A Group 1 bromide has an enthalpy of solution, $\Delta H^{\ominus}_{sol}$, of 19.87 kJ mol^{-1} and the lattice enthalpy, $\Delta H^{\ominus}_{latt}$, is 691 kJ mol^{-1} . Use section 20 of the data booklet to identify the Group 1 ion, showing your working.

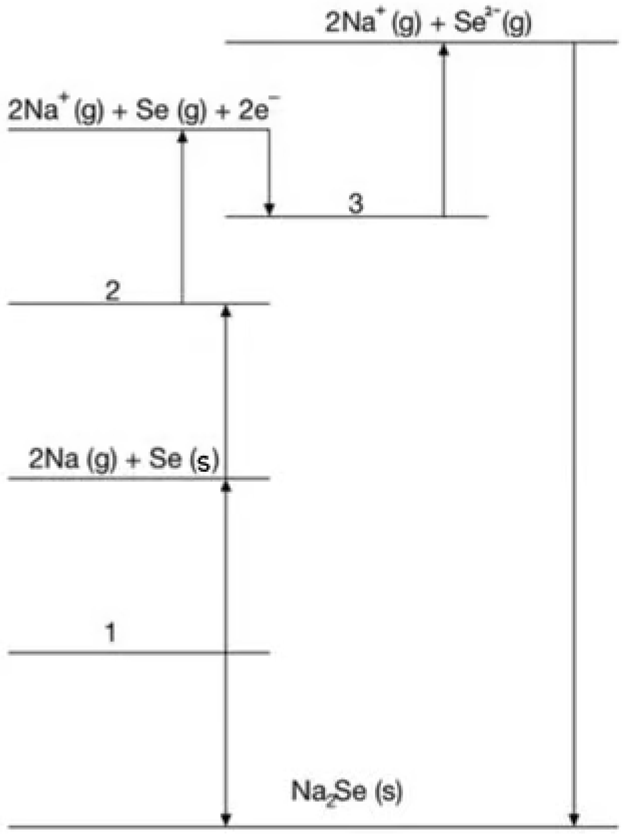
(3 marks)

(d) The same Group 1 metal from part c) forms an ionic lattice with another halide ion. This new ionic compound has a larger value for lattice enthalpy, ΔH^{θ}_{latt}. Suggest a formula for the new ionic lattice and justify your answer.

(4 marks)

3 (a) The incomplete Born-Haber cycle for sodium selenide is shown below.

State the equations for processes 1, 2 and 3.



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(3 marks)

(b) If sulfur is used as opposed to selenium in the lattice, what would you expect to happen to the value of the enthalpy of lattice dissociation. Explain your answer.

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(3 marks)

(c) Use section 8 in the data booklet and the information in the table to calculate the lattice enthalpy of aluminium oxide.

Enthalpy change	Energy change (kJ mol^{-1})
Atomisation of aluminium	+326
Atomisation of oxygen	+249
Second ionisation energy of aluminium	+1817
Third ionisation energy of aluminium	+2745
Formation of aluminium oxide	-1670

(3 marks)

(d) Aluminium oxide is insoluble in water, but sodium oxide is soluble. Explain why there is no enthalpy of solution data for sodium oxide.

(1 mark)

4 (a) A student carried out a calorimetry experiment using 12.41 g of ammonium chloride and 12.50 cm^3 of water. The temperature decreased from 23.7 °C to 17.3 °C. Construct a dissolution cycle for this reaction.

(3 marks)

(b) The enthalpy change for the hydration, ΔH^θ_{hyd} , of the ammonium ion is -331 kJ mol^{-1}. Use sections 19 and 20 and your answer to part a) to calculate the lattice enthalpy, ΔH^θ_{latt} , of ammonium chloride.

(2 marks)

(c) Use sections 1, 2 and 6 in the data booklet to determine the energy change, ΔH_r , in kJ mol^{-1} , for the calorimetry experiment outlined in part a).

(3 marks)

(d) Determine the percentage uncertainty in the student's temperature change using a thermometer with an uncertainty of ±0.1° C.

(1 mark)