15.1 Energy Cycles

Question Paper

Course	DP IB Chemistry
Section	15. Energetics/Thermochemistry (HL only)
Topic	15.1 Energy Cycles
Difficulty	Medium

Time allowed: 70

Score: /56

Percentage: /100

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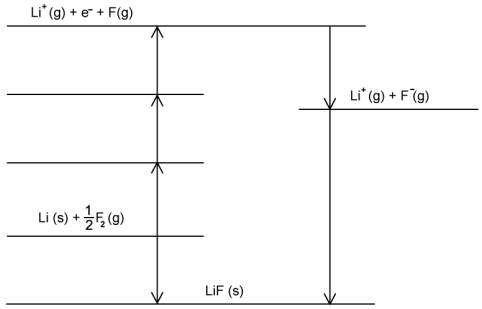
Question 1a

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]

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Question 1b

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.

[5 marks]

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Question 1c

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

[3 marks]

Question 1d

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

[2 marks]

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Question 2a

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

[5 marks]

Question 2b

b)
Describe the structure and bonding in calcium chloride.

[2 marks]

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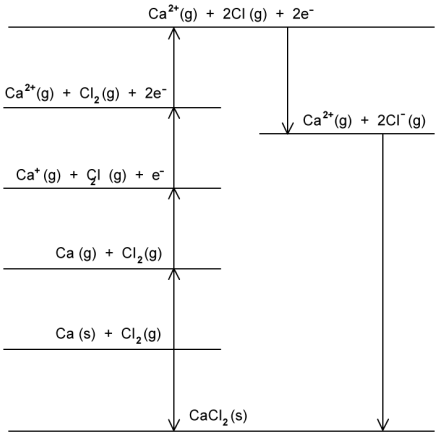
Question 2c

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]

Question 2d

d)
Using Section 18 of the Data Booklet, calculate the value for the enthalpy of formation for calcium chloride, ΔH^{θ}_f $CaCl_2$.

[2 marks]

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Question 3a

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]

Question 3b

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]

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Question 3c

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]

Question 3d

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.

[1 mark]

Question 4a

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, ΔH^{θ}_{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

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[5 marks]

Question 4b

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

[2 marks]

Question 4c

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).

[3 marks]

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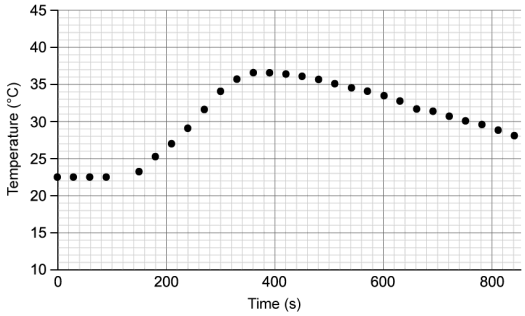
Question 4d

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

[1 mark]

Question 5a

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

[1 mark]

Question 5b

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

[4 marks]

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Question 5c

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.

[1 mark]

Question 5d

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

[3 marks]

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