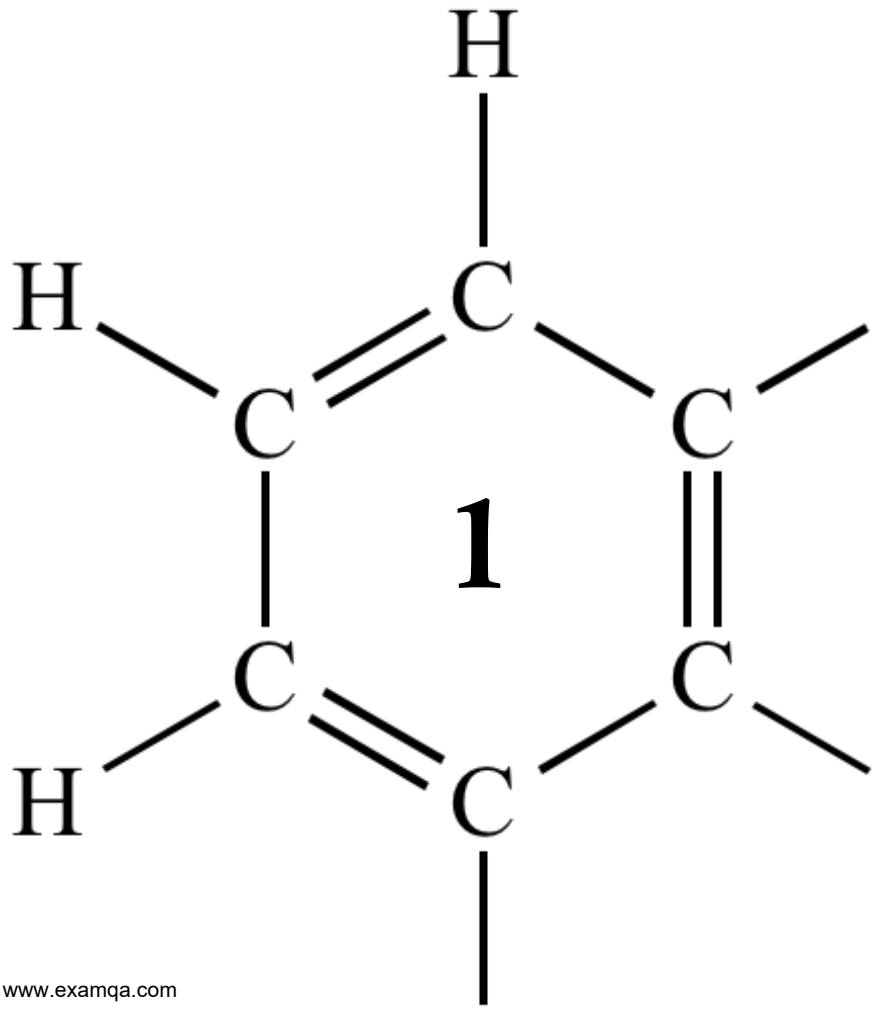
LONDON SCIENCE COLLEGE

OCR A2 CHEMISTRY

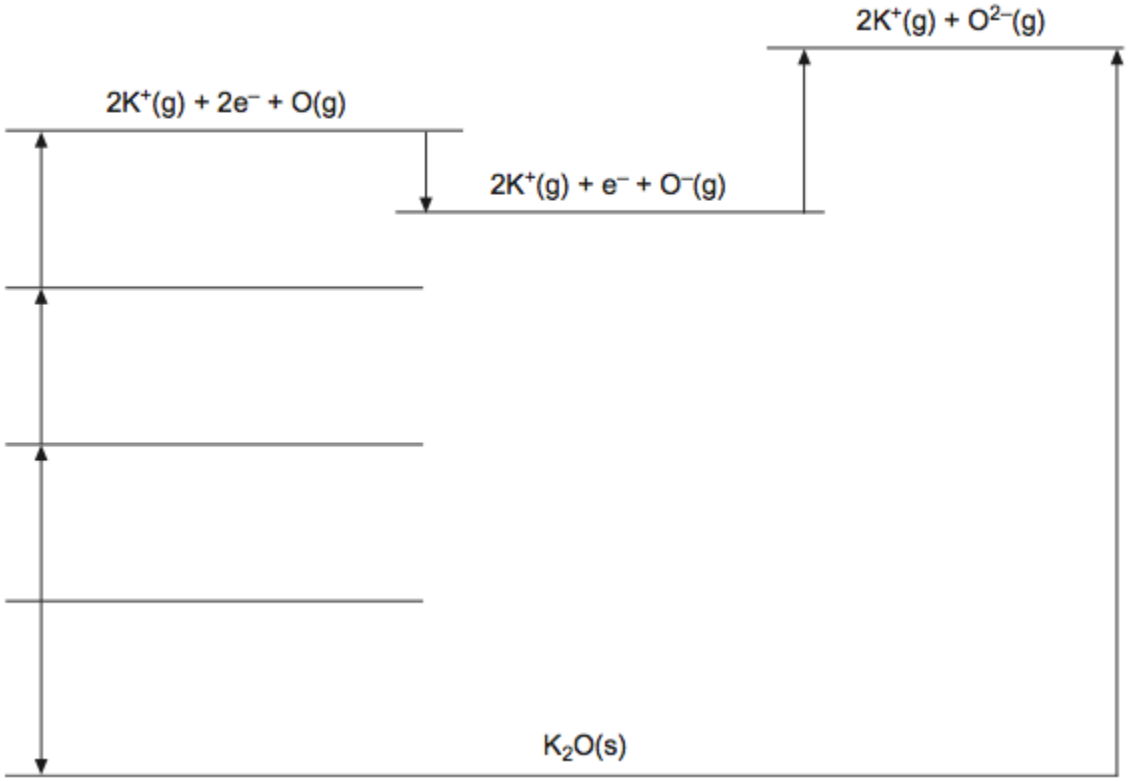
MODULE 5.4

THERMODYNAMICS



1 (a) The diagram is a Born–Haber cycle for potassium oxide, K_2O. The diagram is not to scale and not fully labelled.

(i) Complete the diagram by writing the formulae, including state symbols, of the appropriate species on each of the three blank lines.



(3)

(ii) The table shows some enthalpy data.

Enthalpy change	**$\Delta H^{\ominus}$/kJ mol^{-1}**
Enthalpy of atomisation of potassium	+90
First ionisation enthalpy of potassium	+418
Enthalpy of atomisation of oxygen	+248
First electron affinity of oxygen	-142
Second electron affinity of oxygen	+844
Enthalpy of formation of potassium oxide	-362

Use the data in the table to calculate the enthalpy of lattice dissociation of potassium oxide, K_2O.

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(3)

(b) Explain why the enthalpy of lattice dissociation of potassium oxide is less endothermic than that of sodium oxide.

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(2)
(Total 8 marks)

2 This question is about magnesium chloride.

(a) Write the equation, including state symbols, for the process corresponding to the enthalpy of solution of magnesium chloride.

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(1)

(b) Use these data to calculate the standard enthalpy of solution of magnesium chloride.

Enthalpy of lattice dissociation of $MgCl_2$	= +2493 kJ mol^{-1}
Enthalpy of hydration of magnesium ions	= –1920 kJ mol^{-1}
Enthalpy of hydration of chloride ions	= –364 kJ mol^{-1}

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(2)

(c) Solubility is the measure of how much of a substance can be dissolved in water to make a saturated solution. A salt solution is saturated when an undissolved solid is in equilibrium with its aqueous ions.

Use your answer to part **(b)** to deduce how the solubility of $MgCl_2$ changes as the temperature is increased.
Explain your answer.

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(3)
(Total 6 marks)

3 A 5.00 g sample of potassium chloride was added to 50.0 g of water initially at 20.0 °C. The mixture was stirred and as the potassium chloride dissolved, the temperature of the solution decreased.

(a) Describe the steps you would take to determine an accurate minimum temperature that is **not** influenced by heat from the surroundings.

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(4)

(b) The temperature of the water decreased to 14.6 °C.

Calculate a value, in kJ mol^{-1}, for the enthalpy of solution of potassium chloride.

You should assume that only the 50.0 g of water changes in temperature and that the specific heat capacity of water is 4.18 J K^{-1} g^{-1}.
Give your answer to the appropriate number of significant figures.

Enthalpy of solution = ... kJ mol^{-1}

(4)

(c) The enthalpy of solution of calcium chloride is −82.9 kJ mol^{-1}.
The enthalpies of hydration for calcium ions and chloride ions are −1650 and −364 kJ mol^{-1}, respectively.

Use these values to calculate a value for the lattice enthalpy of dissociation of calcium chloride.

Lattice enthalpy of dissociation = ... kJ mol^{-1}

(2)

(d) Explain why your answer to part **(c)** is different from the lattice enthalpy of dissociation for magnesium chloride.

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(2)
(Total 12 marks)

4 (a) Define the term **electron affinity** for chlorine.

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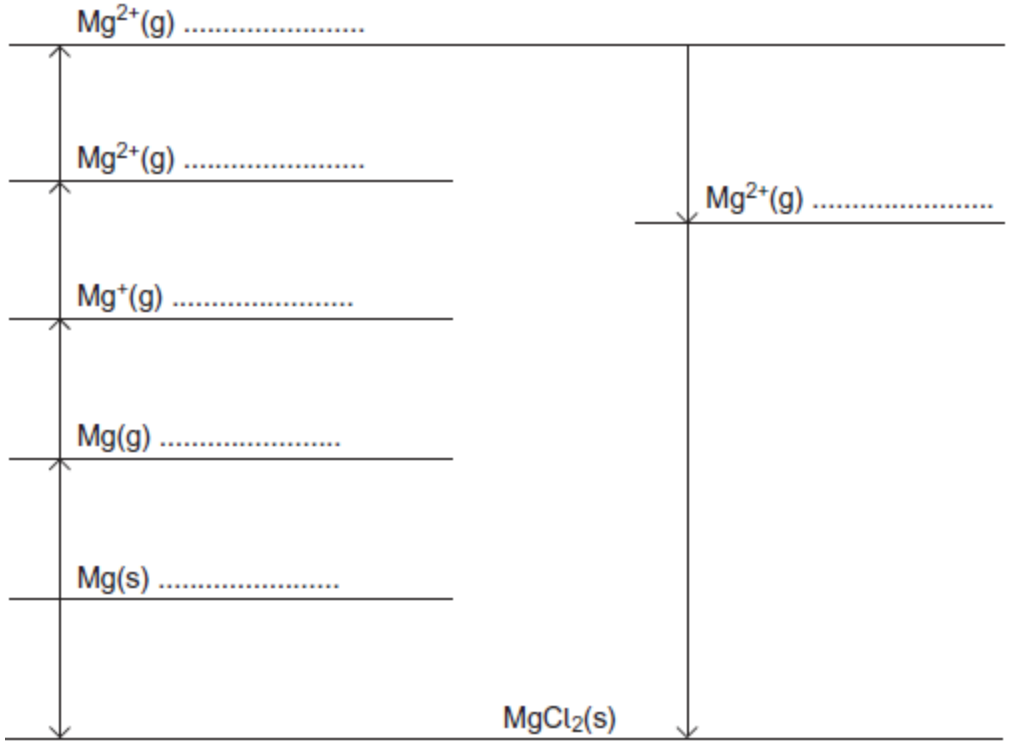
(2)

(b) Complete this Born−Haber cycle for magnesium chloride by giving the missing species on the dotted lines. Include state symbols where appropriate.

The energy levels are **not** drawn to scale.



(6)

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

Table 1

	Enthalpy change / kJ mol^{-1}
Enthalpy of atomisation of magnesium	+150
Enthalpy of atomisation of chlorine	+121
First ionisation energy of magnesium	+736
Second ionisation energy of magnesium	+1450
Enthalpy of formation of magnesium chloride	−642
Lattice enthalpy of formation of magnesium chloride	−2493

Use your Born−Haber cycle from part (b) and data from **Table 1** to calculate a value for the electron affinity of chlorine.

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(3)

(d) **Table 2** contains some more enthalpy data.

Table 2

	Enthalpy change / kJ mol^{-1}
Enthalpy of hydration of Mg^{2+} ions	−1920
Enthalpy of hydration of Na^{+} ions	−406
Enthalpy of hydration of Cl^{-} ions	−364

(i) Explain why there is a difference between the hydration enthalpies of the magnesium and sodium ions.

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(2)

(ii) Use data from **Table 1** and **Table 2** to calculate a value for the enthalpy change when one mole of magnesium chloride dissolves in water.

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(2)

(Total 15 marks)

5 (a) Write an equation for the process that has an enthalpy change equal to the electron affinity of chlorine.

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(1)

(b) In terms of electrostatic forces, suggest why the electron affinity of fluorine has a negative value.

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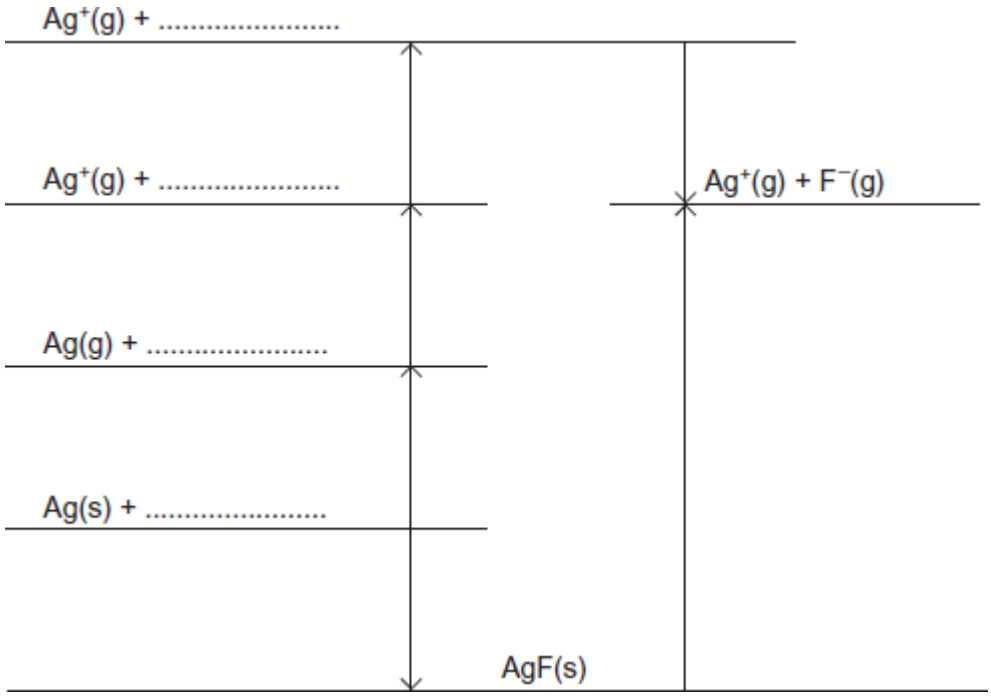
(2)

(c) (i) Complete the Born–Haber cycle for silver fluoride by adding the missing species on the dotted lines.



(3)

(ii) Use the cycle in part (i) and the data in the table to calculate a value, in kJ mol^{-1}, for the bond enthalpy of the fluorine–fluorine bond.

Enthalpy change	**Value / kJ mol^{-1}**
Enthalpy of atomisation for silver	+298
First ionisation energy for silver	+732
Electron affinity for fluorine	–348
Experimental enthalpy of lattice dissociation for silver fluoride	+955
Enthalpy of formation for silver fluoride	–203

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(2)

(d) A theoretical value for enthalpy of lattice dissociation can be calculated using a perfect ionic model.

The theoretical enthalpy of lattice dissociation for silver fluoride is +870 kJ mol^{-1}.

(i) Explain why the theoretical enthalpy of lattice dissociation for silver fluoride is different from the experimental value that can be calculated using a Born–Haber cycle.

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(Extra space) .....

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(2)

(ii) The theoretical enthalpy of lattice dissociation for silver chloride is +770 kJ mol^{-1}.

Explain why this value is less than the value for silver fluoride.

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(Extra space) .....

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(2)
(Total 12 marks)

6 The following table shows some enthalpy change and entropy change data.

	ΔH / kJ mol^{-1}	ΔS / J K^{-1} mol^{-1}
$AgCl(s) \longrightarrow Ag^+(g) + Cl^-(g)$	+905	
$AgCl(s) \longrightarrow Ag^+(aq) + Cl^-(aq)$	+77	+33
$AgF(s) \longrightarrow Ag^+(aq) + F^-(aq)$	–15	to be calculated
$Ag^+(g) \longrightarrow Ag^+(aq)$	–464	

(a) Define the term **enthalpy of hydration** of an ion.

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(2)

(b) Use data from the table to calculate a value for the enthalpy of hydration of the chloride ion.

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(2)

(c) Suggest why hydration of the chloride ion is an exothermic process.

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(2)

(d) Silver chloride is insoluble in water at room temperature.

Use data from the table to calculate the temperature at which the dissolving of silver chloride in water becomes feasible.
Comment on the significance of this temperature value.

Calculation of temperature .....

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Significance of temperature value .....

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(4)

(e) When silver fluoride dissolves in water at 25 °C, the free-energy change is –9 kJ mol^{-1}.

Use this information and data from the table to calculate a value, with units, for the entropy change when silver fluoride dissolves in water at 25 °C.

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(3)
(Total 13 marks)

7 (a) Define the term *lattice enthalpy of dissociation*.

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(2)

(b) Lattice enthalpy can be calculated theoretically using a **perfect ionic model**.

Explain the meaning of the term *perfect ionic model*.

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(Extra space) .....

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(1)

(c) Suggest **two** properties of ions that influence the value of a lattice enthalpy calculated using a perfect ionic model.

Property 1 .....

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Property 2 .....

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(2)

(d) Use the data in the table to calculate a value for the lattice enthalpy of dissociation for silver chloride.

Enthalpy change	**Value / kJ mol $^{-1}$**
Enthalpy of atomisation for silver	+289
First ionisation energy for silver	+732
Enthalpy of atomisation for chlorine	+121
Electron affinity for chlorine	−364
Enthalpy of formation for silver chloride	−127

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(3)

(e) Predict whether the magnitude of the lattice enthalpy of dissociation that you have calculated in part (d) will be less than, equal to or greater than the value that is obtained from a perfect ionic model. Explain your answer.

Prediction compared with ionic model .....

Explanation .....

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(2)
(Total 10 marks)