A-Level Chemistry

Born-Haber Cycles

Question Paper

Time available: 61 minutes
Marks available: 56 marks

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

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

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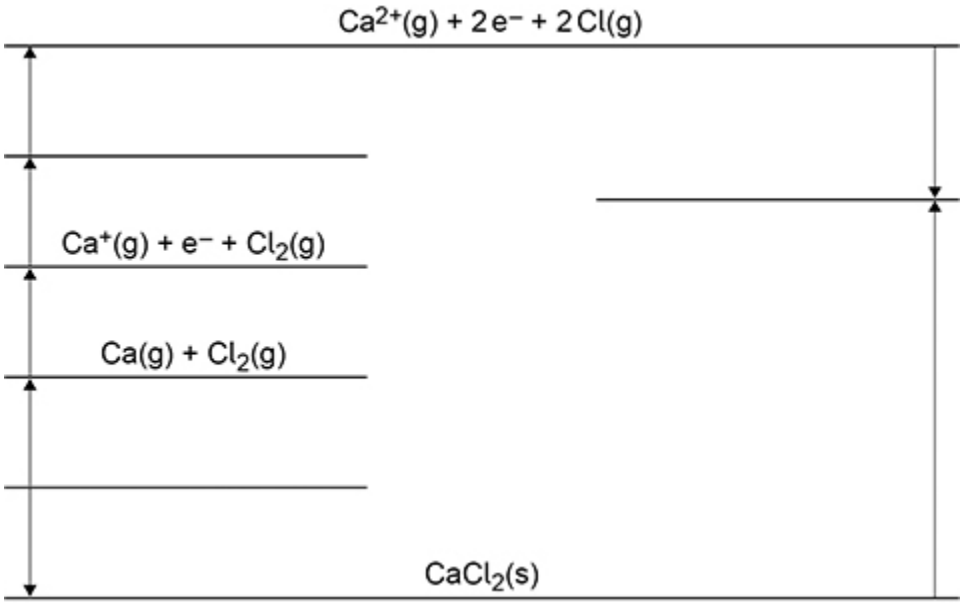
(1)

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.

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(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 $Mg^{2+}(g)$

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(2)

(Total 11 marks)

2. This question is about enthalpy changes.

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

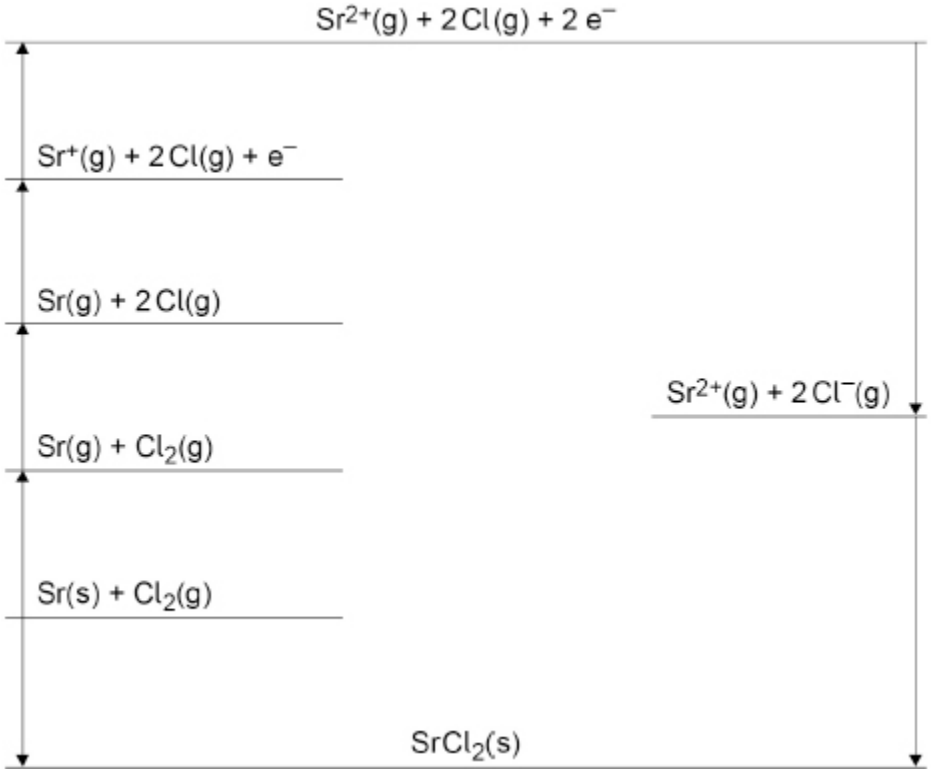

Table 1 shows some thermodynamic data.

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.

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(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^+

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(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)

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

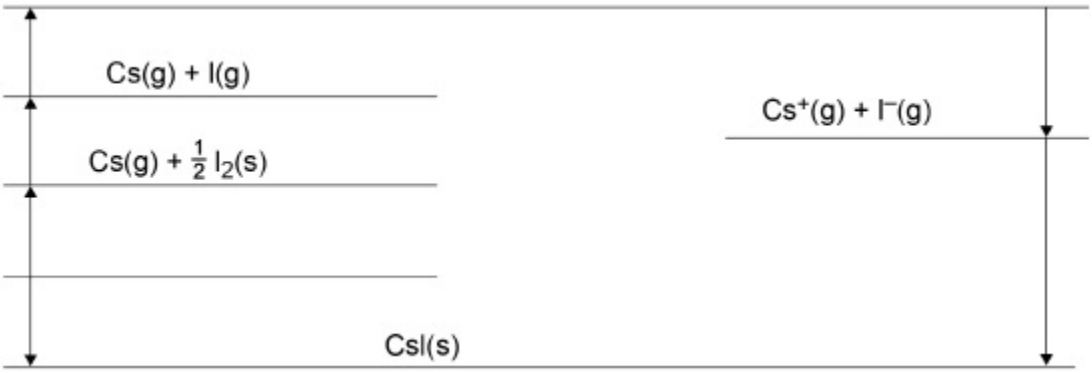

Table 1 gives values of some standard enthalpy changes.

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.

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(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

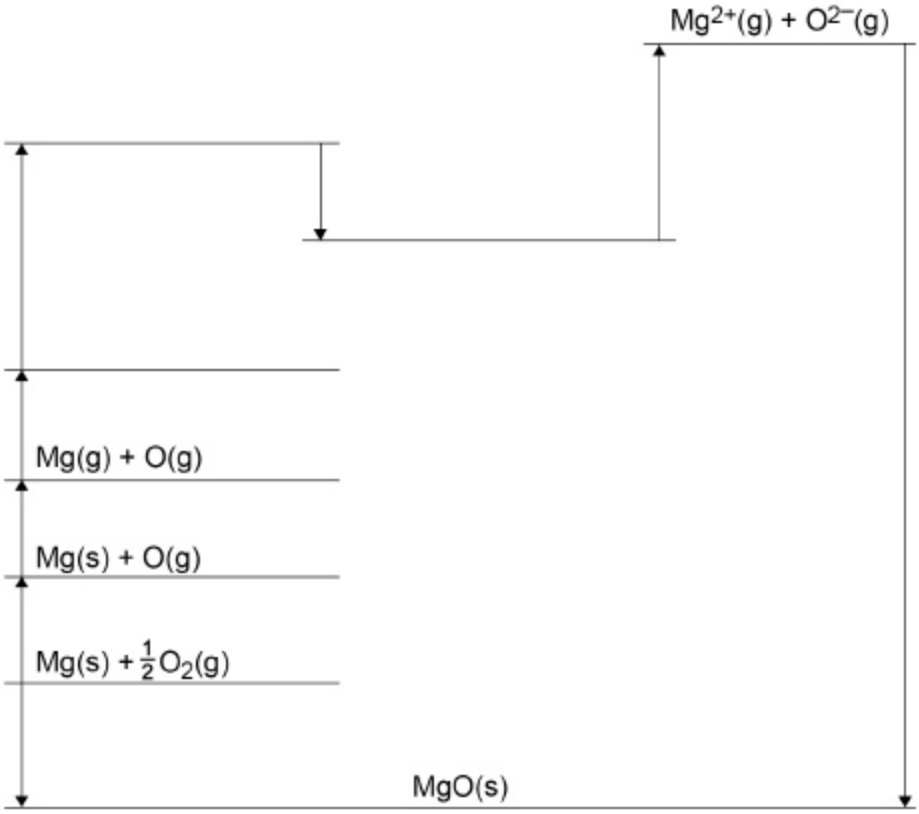
	CsI(s)	**Cs(s)**	**I_2(s)**
$S^{\ominus}$ / J K^{-1} mol^{-1}	130	82.8	117

(4)
(Total 9 marks)

4. 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.

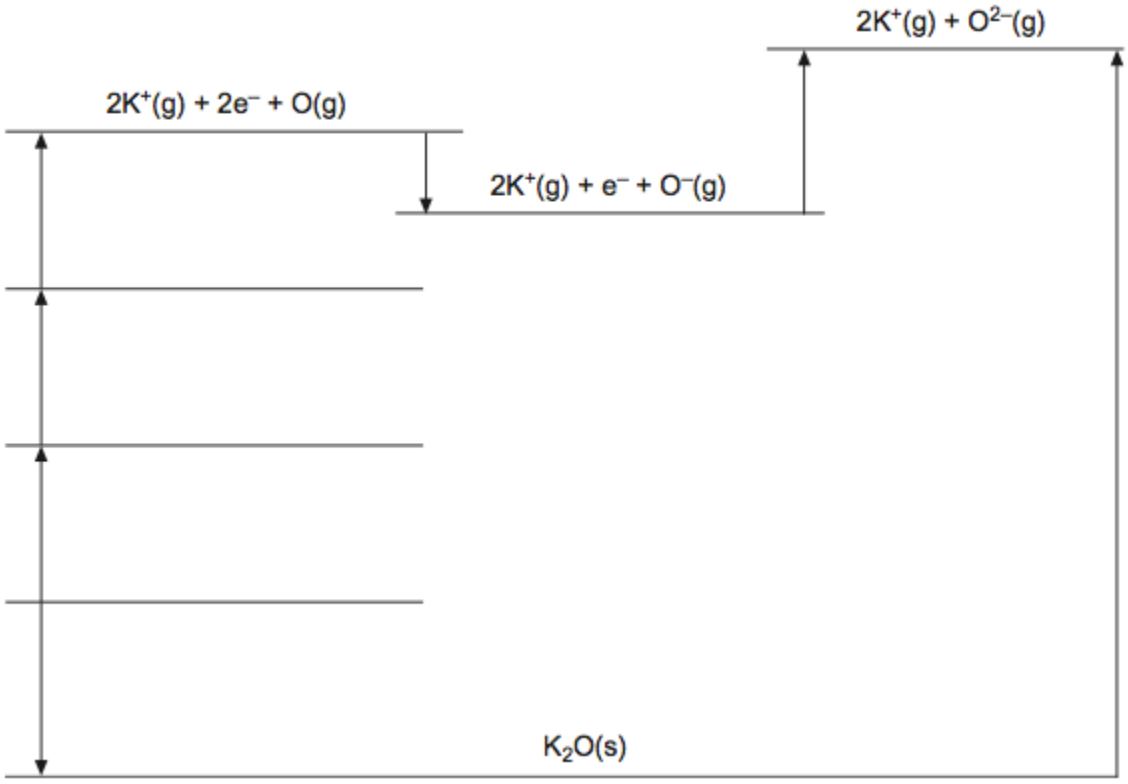
Enthalpy of lattice formation _____ kJ mol^{-1}

(3)

(Total 6 marks)

5. (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.

(3)

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

(2)

(Total 8 marks)

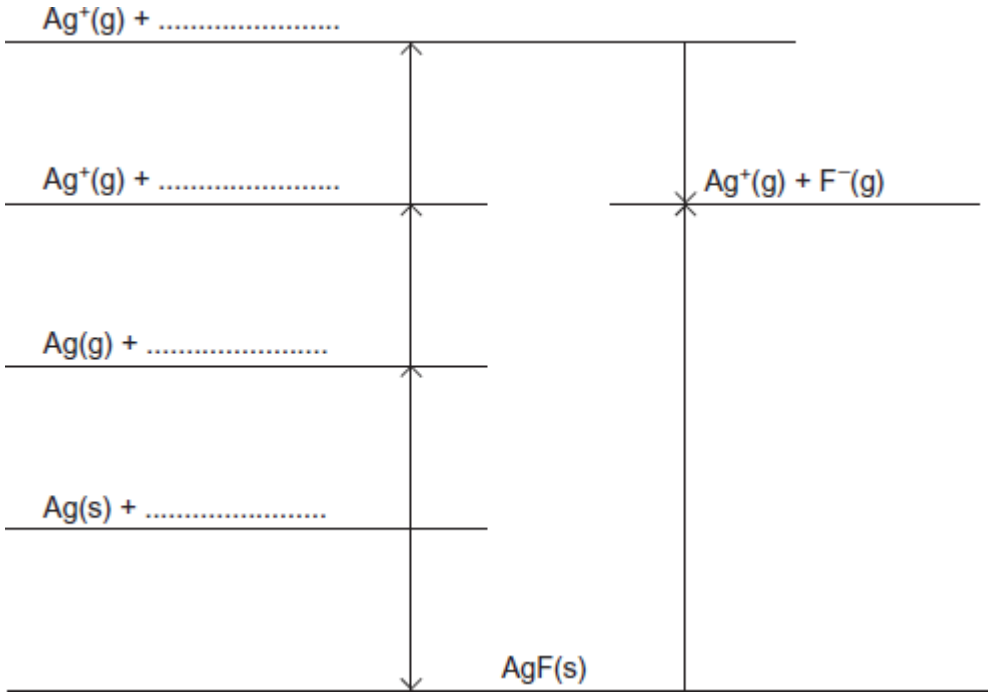
6. (a) Write an equation for the process that has an enthalpy change equal to the electron affinity of chlorine.

(1)

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

(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

(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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(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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(2)

(Total 12 marks)