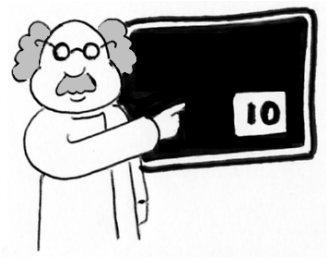

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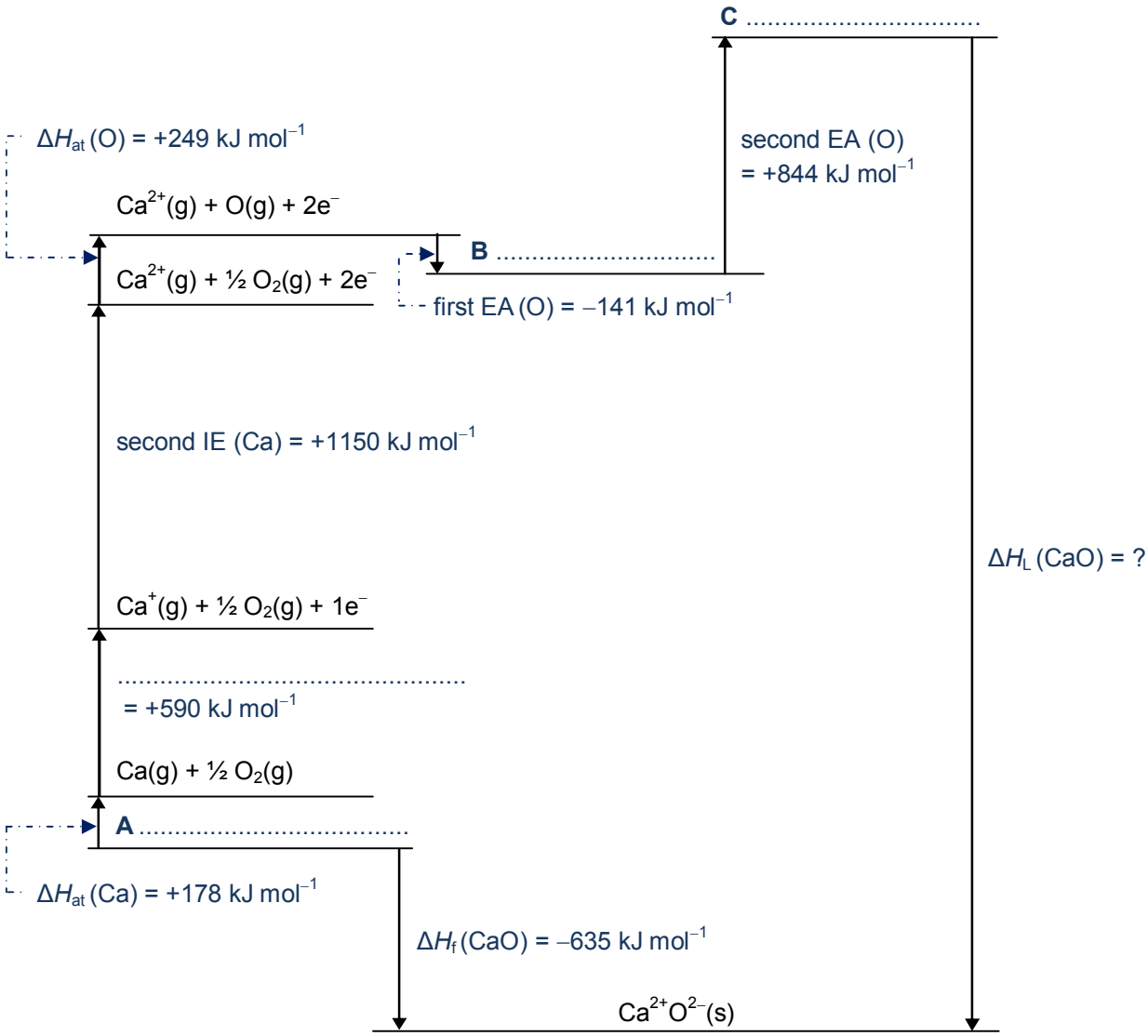
10.2. Born Haber cycles

In 1918, a chance meeting of two German scientists, Max Born and Fritz Haber led to a discussion of the manner in which an ionic compound is formed when a metal reacts with a non-metal. This resulted in the creation of what we know today as Born Haber cycles.

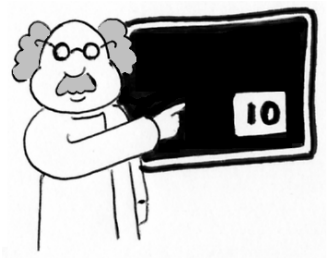
The Born Haber cycle for the formation of calcium oxide is shown in the diagram below;



1. Complete the cycle by adding suitable labels for the one missing enthalpy change and the missing intermediate species on the three stages labelled **A**-**C**. (7 marks)

2. Explain why the second electron affinity of oxygen is positive. (2 marks)

3. Use the values for the enthalpy changes given to calculate the lattice dissociation enthalpy for calcium oxide. (1 mark)



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10. Thermodynamics answers

10.1. Important definitions

1. $O^-(g) + 1\ e^-(g) \rightarrow O^{2-}(g)$

Name: Second electron affinity of oxygen *(1 mark)*

Definition: The enthalpy change when a mole of electrons is added to a mole of gaseous oxygen ions each with a single negative charge, forming one mole of gaseous ions each with a two negative charge. *(1 mark)*

2. $K^+(g) + aq \rightarrow K^+(aq)$

Name: Molar enthalpy of hydration *(1 mark)*

Definition: The enthalpy change when one mole of gaseous ions dissolve in sufficient water to give an infinitely dilute solution *(1 mark)*

3. $NaCl(s) + aq \rightarrow Na^+(aq) + Cl^-(aq)$

Name: Molar enthalpy change of solution *(1 mark)*

Definition: The enthalpy change when one mole of an ionic substance dissolves in sufficient water to give an infinitely dilute solution *(1 mark)*

4. $Mg^{2+}(g) + O^{2-}(g) \rightarrow MgO(s)$

Name: Lattice formation enthalpy *(1 mark)*

Definition: The enthalpy change when one mole of an ionic substance is formed from its gaseous ions under standard conditions *(1 mark)*

5. $HCl(g) \rightarrow H(g) + Cl(g)$

Name: The H-Cl bond enthalpy in hydrogen chloride *(1 mark)*

Definition: The enthalpy change when one mole of gaseous hydrogen chloride molecules breaks its covalent bond to form a gaseous hydrogen radical and a gaseous chlorine radical *(1 mark)*

10.2. Born Haber cycles

1. Missing enthalpy change is the first ionisation energy of calcium *(1 mark)*

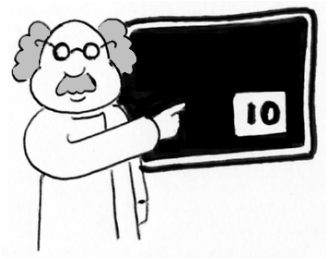
A: $Ca(s) + ½\ O_2(g)$

B: $Ca^{2+}(g) + O^-(g) + 1\ e^-$

C: $Ca^{2+}(g) + O^{2-}(g)$

(2 marks for each of A-C; 1 mark for correct species, 1 mark for correct state symbols)

2. The second electron affinity is positive as you are adding an electron to an already negative ion. Therefore energy is needed to overcome the repulsion. *(2 marks)*



STARTER FOR 10...

10. Thermodynamics answers

3. $\Delta H_L(CaO) = 178 + 590 + 1150 + 249 + (-141) + 844 - (-635)$
$= 2870 - (-635)$
$= \underline{3505 \text{ kJ mol}^{-1}}$ *(1 mark)*

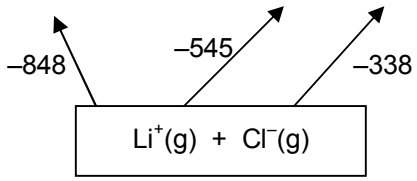
10.3. Enthalpy of solution

1. (a) As the ions increase in size, the enthalpy of hydration decreases. *(1 mark)*

As the ions increase in size the positive ions are less attractive (lower charge to size ratio) and so the attractions formed between the water molecules of the positive ion are weaker *(1 mark)* and hence less energy is produced when they form *(1 mark)*.

(b) As a bromide ion is bigger than a chloride ion, following the trend described above the enthalpy of hydration is smaller (less negative). The actual value is –304 kJ mol^{-1}.

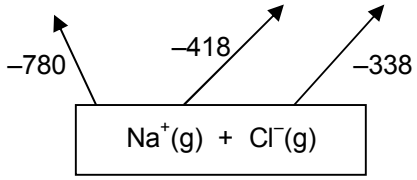
2. (a) $LiCl(s) \xrightarrow{?} Li^+(aq) + Cl^-(aq)$



ΔH_{sol} (LiCl) = –(–848) + –545 + –338 = $\underline{-35 \text{ kJ mol}^{-1}}$

(2 marks)

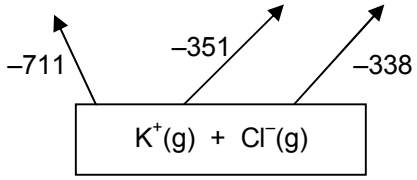
(b) $NaCl(s) \xrightarrow{?} Na^+(aq) + Cl^-(aq)$



ΔH_{sol} (NaCl) = –(–780) + –418 + –338 = $\underline{+24 \text{ kJ mol}^{-1}}$

(2 marks)

(c) $KCl(s) \xrightarrow{?} K^+(aq) + Cl^-(aq)$



ΔH_{sol} (KCl) = –(–711) + –351 + –338 = $\underline{+22 \text{ kJ mol}^{-1}}$

(2 marks)

10.4. Entropy

1. (a) The puddle of water *(1 mark)*

(b) The firework after it has exploded *(1 mark)*

2. (a) $H_2O_2(l) \rightarrow H_2O(l) + O_2(g)$ Positive entropy change *(1 mark)*

(b) $2\ Fe_2O_3(s) + 3\ C(s) \rightarrow 4\ Fe(s) + 3\ CO_2(g)$ Positive entropy change *(1 mark)*