Problem-solving Example 2

Use a Born-Haber cycle and the following data to calculate oxygen's second electron affinity.

ΔH°_{vap} of Mg = +148 kJmol^{-1}

$\Delta H^{\circ}_{IE_1}$ of Mg = 738 kJmol^{-1}

$\Delta H^{\circ}_{IE_2}$ of Mg = 1451 kJmol^{-1}

$\Delta H^{\circ}_{EA_1}$ of O = −142 kJmol^{-1}

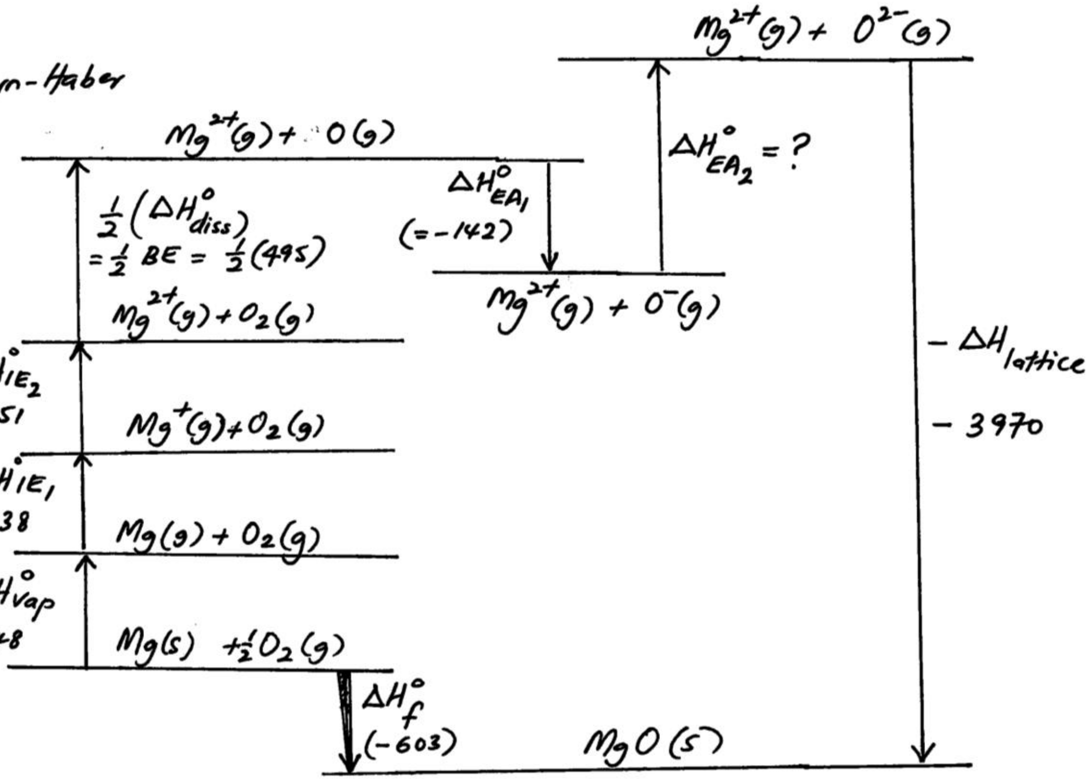
$\Delta H^{\circ}_{lattice}$ of Mg = +3970 kJmol^{-1}

ΔH°_{f} of MgO = −603 kJmol^{-1}

ΔH^{o}_{diss} = BE = 495 kJmol^{-1} (of oxygen)

SOLUTION

Using Born-Haber Cycle:



Solution:

* We are asked to find the second electron affinity of oxygen:

$$O^-(g) + e^- \longrightarrow O^{2-}(g)\ ;\ \Delta H_{EA_2} = ?$$

(* Note) * Second electron affinities are all large and positive!

* The overall reaction consumes $\frac{1}{2}$ mole of O_2 for each mole of Mg. So we require ½ the Bond energy of O_2

$$\tfrac{1}{2}\,O_2(g) \longrightarrow O(g)\ ;\ \Delta H = \tfrac{1}{2} \times BE$$

Using Hess's Law:

find this value

$$\Delta H^\circ_f = \Delta H^\circ_{vap} + \Delta H^\circ_{IE_1} + \Delta H^\circ_{IE_2} + \tfrac{1}{2}BE + \Delta H^\circ_{EA_1} + \boxed{\Delta H^\circ_{EA_2}} + (-\Delta H_{lattice})$$

$$(-603) = (+148) + (+738) + (+1451) + (\tfrac{1}{2} \times 495) + (-142) + \Delta H^\circ_{EA_2} + (-3970)$$

$\therefore \Delta H^\circ_{EA_2} = +924 \text{ kJmol}^{-1}$ (Ans)

↑ large positive value

$O^-(g) + e^- \longrightarrow O^{2-}(g) \; ; \; \Delta H_{EA_2} = +924 \text{ kJmol}^{-1}$

↑ very unstable

* A large positive value of 2nd electron affinity reflects the fact that an isolated $O^{2-}(g)$ is very unstable (means very reactive).

ALTERNATIVE METHOD SOLUTION:

Alternative Method (without using Born-Haber Cycle)

$$Mg(s) \longrightarrow Mg(g) \; ; \; \Delta H^\circ_{vap} = 148 \text{ kJ}$$
$$Mg(g) \longrightarrow Mg^+(g) + e^- \; ; \; \Delta H^\circ_{IE_1} = 738 \text{ kJ}$$
$$Mg^+(g) \longrightarrow Mg^{2+}(g) + e^- \; ; \; \Delta H^\circ_{IE_2} = 1451 \text{ kJ}$$
$$\tfrac{1}{2}O_2(g) \longrightarrow O(g) \; ; \; \tfrac{1}{2}\Delta H^\circ_{diss} = \tfrac{1}{2} BE = \tfrac{1}{2}(495) \text{ kJ}$$
$$e^- + O(g) \longrightarrow O^-(g) \; ; \; \Delta H_{EA_1} = -142 \text{ kJ}$$
$$O^-(g) + e^- \longrightarrow O^{2-}(g) \; ; \; \Delta H_{EA_2} = x \text{ kJ}$$
$$Mg^{2+}(g) + O^{2-}(g) \longrightarrow MgO(s) \; ; \; -\Delta H_{lattice} = -3970 \text{ kJ}$$

(+)

$$Mg(s) + \tfrac{1}{2}O_2 \longrightarrow MgO(s) \; ; \; \Delta H^\circ_f = -603 \text{ kJ}$$
$$= (148 + 738 + 1451 + \tfrac{1}{2}(495) - 142 + x - 3970) \text{ kJ}$$

$$\therefore x = 924 \text{ kJmol}^{-1} \text{ (Ans)}.$$

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