## Exercise 4.52 – Born Haber cycles

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Q452-01 For which of the following is $\Delta H^{\ominus}$ positive?

A. $O^{+}(g) + e^{-} \longrightarrow O(g)$
B. $O(g) + e \longrightarrow O^{-}(g)$
C. $O^{-}(g) + e \longrightarrow O^{2-}(g)$
D. $O(g) + O(g) \longrightarrow O_2(g)$

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Q452-02 The first ionization energy for a mole of magnesium atoms is the energy required for which of the following processes?

A. $Mg(s) \longrightarrow Mg(g)$
B. $Mg(g) \longrightarrow Mg^{+}(g) + 2e$
C. $Mg^{+}(g) \longrightarrow Mg^{2+}(g) + e$
D. $Mg(g) \longrightarrow Mg^{+}(g) + e$

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Q452-03 The formation of an ionic compound from its elements can be understood in terms of steps, each involving a certain energy input or output. Which energy step usually dominates all others in the formation of a stable ionic compound?

A. ionization energy
B. electron affinity
C. lattice energy
D. dissociation energy

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Q452-04 The following enthalpy changes (in kJ $mol^{-1}$) refer to sodium chloride and its constituent elements:

| | |
|---|---|
| ΔHº formation of sodium chloride | -411 kJ |
| ΔHº atomisation sodium | +109 kJ |
| ΔHº atomisation chlorine | +121 kJ |
| 1st ionisation energy sodium | +494 kJ |
| 1st electron affinity chlorine | -364 kJ |

a) State the meaning of the + and - signs in the enthalpy values [1]
Explain the meaning of the symbol 'º'. [1]
b) The given values can be used to calculate the lattice enthalpy of sodium chloride.
Define the term 'lattice enthalpy' [1]
Construct a Born-Haber cycle and hence calculate the lattice enthalpy of sodium chloride [4]

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Q452-05 Using the following thermodynamic data, calculate the lattice enthalpy of lithium oxide:

| | |
|---|---|
| $Li(g) \longrightarrow Li^{+}(g) + e$ | +540 kJ |
| $Li(s) \longrightarrow Li(g)$ | +146 kJ |
| $O_2(s) \longrightarrow 2O(g)$ | +488 kJ |
| $O(g) + 2e \longrightarrow O^{2-}(g)$ | +598 kJ |
| $2Li(s) + ½O_2(g) \longrightarrow Li_2O(s)$ | -586 kJ |

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Q452-06 Use the following thermodynamic data to calculate the lattice enthalpy of barium iodide:

| | |
|---|---|
| $Ba(g) \longrightarrow Ba^{2+}(g) + 2e$ | +1440 kJ |
| $Ba(s) \longrightarrow Ba(g)$ | +142 kJ |
| $I_2(g) \longrightarrow 2I(g)$ | +144 kJ |

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| | |
|---|---|
| $I(g) + e \longrightarrow I^-(g)$ | -288 kJ |
| $Ba(s) + I_2(s) \longrightarrow BaI_2(s)$ | -608 kJ |
| $I_2(s) \longrightarrow I_2(g)$ | + 38 kJ |

Q452-07 Use the following thermodynamic data to calculate the enthalpy of atomisation of zinc:

| | |
|---|---|
| $Zn(g) \longrightarrow Zn^{2+}(g) + 2e$ | +2680 kJ |
| $Zn^{2+}(g) + O^{2-}(g) \longrightarrow ZnO(s)$ | -3980 kJ |
| $O_2(g) \longrightarrow 2O(g)$ | +488 kJ |
| $O(g) + 2e \longrightarrow O^{2-}(g)$ | +598 kJ |
| $Zn(s) + ½O_2(s) \longrightarrow ZnO(s)$ | -342 kJ |

Q452-08 Use the following thermodynamic data to calculate the sum of the first two ionisation energies of calcium:

| | |
|---|---|
| $O_2(g) \longrightarrow 2O(g)$ | +488 kJ |
| $Ca(s) \longrightarrow Ca(g)$ | +158 kJ |
| $O(g) + 2e \longrightarrow O^{2-}(g)$ | +598 kJ |
| $Ca^{2+}(g) + O^{2-}(g) \longrightarrow CaO(s)$ | -3328 kJ |
| $Ca(s) + ½O_2(s) \longrightarrow CaO(s)$ | -628 kJ |

Q452-09 Use the following thermodynamic data to calculate the bond dissociation enthalpy of fluorine:

| | |
|---|---|
| $Na(g) \longrightarrow Na^+(g) + e$ | +486 kJ |
| $Na(s) \longrightarrow Na(g)$ | +98 kJ |
| $Na^+(g) + F^-(g) \longrightarrow NaF(s)$ | -906 kJ |
| $F(g) + e \longrightarrow F^-(g)$ | -318 kJ |
| $Na(s) + ½F_2(g) \longrightarrow NaF(s)$ | -564 kJ |

Q452-10 Use the following thermodynamic data to calculate the enthalpy of atomisation of manganese:

| | |
|---|---|
| $Mn(g) \longrightarrow Mn^{2+}(g) + 2e$ | +2230 kJ |
| $Br_2(l) \longrightarrow Br_2(g)$ | +18 kJ |
| $Br_2(g) \longrightarrow 2Br(g)$ | +186 kJ |
| $Br(g) + e \longrightarrow Br^-(g)$ | -322 kJ |
| $Mn^{2+}(g) + 2Br^-(g) \longrightarrow MnBr_2(s)$ | -2386 kJ |
| $Mn(s) + Br_2(l) \longrightarrow MnBr_2(s)$ | -372 kJ |