$2B_{(s)} + \frac{3}{2}O_{2(g)} \rightarrow B_2O_{3(s)}$ $\Delta H_r = ?$

① $B_2O_{3(s)} + 3H_2O_{(g)} \rightarrow 3O_{2(g)} + B_2H_{6(g)}$ $\Delta H = +2035\,kJ$

② $H_2O_{(e)} \rightarrow H_2O_{(g)}$ $\Delta H = 44\,kJ$

③ $2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(e)}$ $\Delta H = -572\,kJ$

④ $2B_{(s)} + 3H_{2(g)} \rightarrow B_2H_{6(g)}$ $\Delta H = 36\,kJ$

Rev①

⑤ $\frac{3O_{2(g)}}{2} + B_2H_{6(g)} \rightarrow B_2O_{3(g)} + 3H_2O_{(g)}$ $\Delta H = -2035\,kJ$

Rev③ x 3/2

⑥ $3H_2O_{(e)} \rightarrow 3H_{2(g)} + \frac{3}{2}O_{2(g)}$ $\Delta H = 858\,kJ$

Rev② x 3

⑦ $3H_2O_{(g)} \rightarrow 3H_2O_{(e)}$ $\Delta H = -132\,kJ$

④ + ⑤ + ⑥ + ⑦

$2B_{(s)} + \frac{3}{2}O_{2(g)} \rightarrow B_2O_{3(s)}$ $\Delta H_r = -1273\,kJ$

Predicting ΔH_r Using Formation Reactions

The Standard Enthalpy Change (ΔH^o_r) for a reaction can be found by writing the formation equation and corresponding standard enthalpy change for each compound in the given equation and then applying Hess' Law.

Ex. $CaO_{(s)} + H_2O_{(l)} \longrightarrow Ca(OH)_{2(s)}$ $\Delta H_r = ?$

Step 1: Write formation equations (with standard enthalpy change) each compound in the given equation.

① $Ca_{(s)} + \frac{1}{2}O_{2(g)} \rightarrow CaO_{(s)}$ $\Delta H_f = -634.9\ kJ$

② $H_{2(g)} + \frac{1}{2}O_{2(g)} \rightarrow H_2O_{(\ell)}$ $\Delta H_f = -285.8\ kJ$

③ $Ca_{(s)} + O_{2(g)} + H_{2(g)} \rightarrow Ca(OH)_{2(s)}$ $\Delta H_f = -986.1\ kJ$

Step 2: Apply Hess' Law

Rev①

④ $CaO_{(s)} \rightarrow Ca_{(s)} + \frac{1}{2}O_{2(g)}$ $\Delta H_r = +634.9\ kJ$

Rev②

⑤ $H_2O_{(\ell)} \rightarrow H_{2(g)} + \frac{1}{2}O_{2(g)}$ $\Delta H_r = 285.8\ kJ$

$\Delta H_r = -65.4\ kJ$

Enthalpies of Formation to Predict ΔH_r

$$\Delta H_r = \Delta H_f + (-\Delta H_f) + (-\Delta H_f)$$

ΔH_f of $Ca(OH)_2$ *

$-\Delta H_f$ of CaO Rev.

$-\Delta H_f$ of H_2O Rev.

$$\Delta H_r = \Delta H_f - (\Delta H_f + \Delta H_f)$$

ΔH_f of $Ca(OH)_2$

ΔH_f of CaO

ΔH_f of H_2O

$$\Delta H_r = \Delta H_{fp} - \Delta H_{fr}$$

products reactants

$$\Delta H_r = \Sigma n H_{fp} - \Sigma n H_{fr}$$

$$CaO_{(s)} + H_2O_{(e)} \rightarrow Ca(OH)_{2(s)}$$

$\Delta H_r = \Sigma n H_{fp} - \Sigma n H_{fr}$

$\Delta H_r = [(1\,mol)(-986.1\,\frac{kJ}{mol})] -$

$[(1\,mol)(-634.9\,\frac{kJ}{mol}) + (1\,mol)(-285.8\,\frac{kJ}{mol})]$

$\Delta H_r = (-986.1\,kJ) - (-920.7\,kJ)$

$\Delta H_r = -65.4\,kJ$

Ex. What is the standard molar enthalpy of combustion of methane fuel?

$$CH_{4(g)} + 2O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(g)}$$

$\Delta H_r = \sum n H_{f_p} - \sum n H_{f_r}$

$\Delta H_r = \left[(1\,mol)\left(-393.5\frac{kJ}{mol}\right) + (2\,mol)\left(-241.8\frac{kJ}{mol}\right)\right] - \left[(1\,mol)\left(-74.4\frac{kJ}{mol}\right) + (2\,mol)\left(0\frac{kJ}{mol}\right)\right]$

$\Delta H_r = (-877.1\,kJ) - (-74.4\,kJ)$

$\Delta H_r = -802.7\,kJ$

$\Delta H_r = nH_r$

$H_r = \frac{\Delta H_r}{n} = \frac{-802.7\,kJ}{1\,mol} = -802.7\,kJ/mol$

Homework

Worksheet