Practice - Hess's Law

1) Find ΔH_{rxn} for the reaction below:

$$PCl_{5(g)} \rightarrow PCl_{3(g)} + Cl_{2(g)}$$

given the steps:

(1) $\cancel{P_4(s)} + \cancel{6\,Cl_2(g)} \rightarrow 4PCl_{3(g)}$ $\Delta H_1 = -2439\,kJ$

(2) $4PCl_{5(g)} \rightarrow \cancel{P_4(s)} + \cancel{10\,Cl_2(g)} + 4Cl_{2(g)}$ $+\Delta H_2 = 3438\,kJ$

$4PCl_{5(g)} \rightarrow 4PCl_{3(g)} + 4Cl_{2(g)}$ $\Delta H_{rxn} = 999\,kJ$

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$$PCl_{5(g)} \rightarrow PCl_{3(g)} + Cl_{2(g)} \quad \Delta H_{rxn} = 249.75\,kJ$$

2) Find ΔH_{rxn} for the reaction below:

$$2\,CO_{2(g)} + H_2O_{(g)} \rightarrow C_2H_{2(g)} + \tfrac{5}{2}\,O_{2(g)}$$

given the steps:

(1) $C_2H_{2(g)} + 2H_{2(g)} \rightarrow C_2H_{6(g)}$ reverse $\Delta H_1 = +94.5\,kJ$

(2) $H_2O_{(g)} \rightarrow H_{2(g)} + \tfrac{1}{2}O_{2(g)}$ reverse $\Delta H_2 = -71.2\,kJ$

(3) $C_2H_{6(g)} + \tfrac{7}{2}O_{2(g)} \rightarrow 2CO_{2(g)} + 3H_2O_{(g)}$ reverse $\Delta H_3 = +283\,kJ$

$\cancel{C_2H_{6(g)}} \rightarrow C_2H_{2(g)} + \cancel{2H_{2(g)}}$ $\Delta H_1 = +94.5\,kJ$

$\cancel{2H_{2(g)}} + \cancel{\tfrac{2}{2}O_{2(g)}} \rightarrow \cancel{2H_2O_{(g)}}$ $2(\Delta H_2 = -71.2\,kJ)$

$2CO_{2(g)} + \cancel{3H_2O_{(g)}} \rightarrow \cancel{C_2H_{6(g)}} + \cancel{\tfrac{7}{2}O_{2(g)}}$ $\Delta H_3 = +283\,kJ$

$-2H_2O$

$1H_2O_{(g)}$

$\tfrac{5}{2}O_{2(g)}$

$$2CO_{2(g)} + H_2O_{(g)} \rightarrow C_2H_{2(g)} + \tfrac{5}{2}O_{2(g)} \quad \Delta H_{rxn} = 235.1\,kJ$$

3) Find ΔH_{rxn} for the reaction below:

$$N_2H_4(l) + H_2(g) \rightarrow 2NH_3(g)$$

given the steps:

(1) $N_2H_4(l) + CH_4O(l) \rightarrow CH_2O(g) + N_2(g) + 3H_2(g)$ $\Delta H_1 = -37\,kJ$

(2) $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$ $\Delta H_2 = -46\,kJ$

(3) $CH_4O(l) \rightarrow CH_2O(g) + H_2(g)$ reverse $\Delta H_3 = -65\,kJ$

$N_2H_4(l) + \cancel{CH_4O(l)} \rightarrow \cancel{CH_2O(g)} + \cancel{N_2(g)} + \cancel{3H_2(g)}$ $\Delta H_1 = -37\,kJ$

$+ \quad \cancel{N_2(g)} + \cancel{3H_2(g)} \rightarrow 2NH_3(g)$ $\Delta H_2 = -46\,kJ$

$\cancel{CH_2O(g)} + H_2(g) \rightarrow \cancel{CH_4O(l)}$ $+ \quad \Delta H_3 = +65\,kJ$

$N_2H_4(l) + H_2(g) \rightarrow 2NH_3(g)$ $\Delta H_{rxn} = -18\,kJ$

4) Find ΔH_{rxn} for the reaction below:

$$H_2SO_4(l) \rightarrow SO_3(g) + H_2O(g)$$

given the steps:

(1) $H_2S(g) + 2O_2(g) \rightarrow H_2SO_4(l)$ reverse $\Delta H_1 = -235.5\,kJ$

(2) $H_2S(g) + 2O_2(g) \rightarrow SO_3(g) + H_2O(l)$ $\Delta H_2 = -207\,kJ$

(3) $H_2O(l) \rightarrow H_2O(g)$ $\Delta H_3 = 44\,kJ$

$H_2SO_4(l) \rightarrow \cancel{H_2S(g)} + \cancel{2O_2(g)}$ $\Delta H_1 = +235.5\,kJ$

$+ \quad \cancel{H_2S(g)} + \cancel{2O_2(g)} \rightarrow SO_3(g) + \cancel{H_2O(l)}$ $\Delta H_2 = -207\,kJ$

$\cancel{H_2O(l)} \rightarrow H_2O(g)$ $+ \quad \Delta H_3 = 44\,kJ$

$H_2SO_4(l) \rightarrow SO_3(g) + H_2O(g)$ $\Delta H_{rxn} = 72.5\,kJ$

AP Chemistry Thermo Unit	**Hess' Law**

Objectives:

I can…

- Use Hess' Law to determine the heat of a reaction. 1 2 3

Enthalpy

- Amount of heat released or absorbed in a chemical reaction
- State function → depends only upon the *initial and final state* of reactants/products and **NOT** the specific pathway to get from products to reactants.

Hess' Law

- If a reaction is carried out in a series of steps, ΔH for the reaction will be equal to the sum of the enthalpy changes for the individual steps.
- Rearranging stepwise reactions in order to find the overall enthalpy of a reaction

Examples:

1. Calculate the ΔH_{rxn} of $\mathbf{N_{2\,(g)} + 2O_{2\,(g)} \rightarrow 2NO_{2\,(g)}}$ based on the following reactions:

A.) $N_{2\,(g)} + O_{2\,(g)} \rightarrow 2NO_{(g)}$ $\Delta H = +180$ kJ
B.) $2NO_{(g)} + O_{2\,(g)} \rightarrow 2NO_{2\,(g)}$ $\Delta H = -112$ kJ

2. Calculate the ΔH_{rxn} of $\mathbf{C_{(graphite)} \rightarrow C_{(diamond)}}$ based on the following reactions:

A.) $C_{(graphite)} + O_{2\,(g)} \rightarrow CO_{2\,(g)}$ $\Delta H = -394$ kJ
B.) $C_{(diamond)} + O_{2\,(g)} \rightarrow CO_{2\,(g)}$ $\Delta H = -396$ kJ

3. Calculate the ΔH_{rxn} of $\mathbf{2C_2H_{6\,(g)} + 7O_{2\,(g)} \rightarrow 4CO_{2\,(g)} + 6H_2O_{(g)}}$ based on the following reactions:

A.) $2\,C_{(s)} + 3H_{2\,(g)} \rightarrow C_2H_{6\,(g)}$ reverse $\Delta H = -84.7$ kJ
B.) $C_{(s)} + O_{2\,(g)} \rightarrow CO_{2\,(g)}$ $\Delta H = -393.5$ kJ
C.) $H_{2\,(g)} + \frac{1}{2}\,O_{2\,(g)} \rightarrow H_2O_{(g)}$ $\Delta H = -242$ kJ

$2\,C_2H_6(g) \rightarrow \cancel{4\,C(s)} + \cancel{6\,H_2(g)}$ $2(\Delta H_a = +84.7\,kJ)$
$\cancel{4\,C(s)} + 4\,O_2(g) \rightarrow 4\,CO_2(g)$ $4(\Delta H_b = -393.5\,kJ)$
$+\ \cancel{6\,H_2(g)} + 3\,O_2(g) \rightarrow 6\,H_2O(g)$ $+\ 6(\Delta H_c = -242\,kJ)$

$2\,C_2H_6(g) + 7\,O_2(g) \rightarrow 4\,CO_2(g) + 6\,H_2O(g)$

$\Delta H_{rxn} = -2856.6\,kJ$