Enthalpy Stoichiometry Practice

1. Citric acid reacts with sodium bicarbonate according to the balanced equation below.

$H_3C_6H_5O_7(aq) + 3\ NaHCO_3(s) \rightarrow 3\ NaC_6H_5O_7(aq) + 3\ H_2O(l) + 3\ CO_2(g)$ $\Delta H = \cancel{20.}\ 70.0$ kJ/mol

   a. Calculate the quantity of heat, in joules, absorbed when 5.00 grams of sodium bicarbonate reacts with excess citric acid.

$$\frac{5.00\text{ g } NaHCO_3}{1} \times \frac{1\text{ mol } NaHCO_3}{84.01\text{ g}} \times \frac{1\text{ mol } H_3C_6H_5O_7}{3\text{ mol } NaHCO_3} \times \frac{70.\text{ kJ}}{1\text{ mol } H_3C_6H_5O_7} = 1.39\text{ kJ}$$

$$\frac{1.39\text{ kJ}}{1} \times \frac{1000\text{ J}}{1\text{ kJ}} = \boxed{1.39 \times 10^{-3}\text{ J}}$$

   b. Calculate the grams of carbon dioxide produced when 300. kj of heat are absorbed.

$$\frac{300\text{ kJ}}{1} \times \frac{3\text{ mol } CO_2}{70\text{ kJ}} \times \frac{44.01\text{ g } CO_2}{1\text{ mol } CO_2} = \boxed{566\text{ g } CO_2}$$

2. The combustion of benzene, $C_6H_6(l)$, in oxygen liberates heat according to the balanced equation below.

$$2\ C_6H_6(l) + 15\ O_2(g) \rightarrow 12\ CO_2(g) + 6\ H_2O(g) + 6.536 \times 10^3\text{ kJ}$$

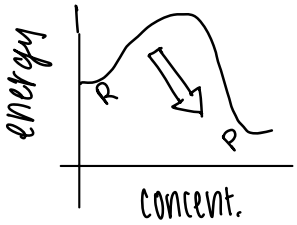
   a. Is the reaction endothermic or exothermic? Explain your reasoning.

Exothermic → reaction produced heat

   b. What is the value of ΔH?

$$\Delta H = \frac{-6.536 \times 10^3\text{ kJ}}{2\text{ mol } C_6H_6} \Rightarrow \boxed{-3268\text{ kJ/mol } C_6H_6}$$

   c. Draw the potential energy diagram for this reaction.



   d. Calculate the quantity of heat released when 10.00 g of benzene is burned in excess oxygen.

$$\frac{10.00\text{ g } C_6H_6}{1} \times \frac{1\text{ mol } C_6H_6}{78.11\text{ g}} \times \frac{-3268\text{ kJ}}{1\text{ mol } C_6H_6} = \boxed{-418\text{ kJ}}$$

   e. How many grams of benzene must be burned to evolve 1.00 kJ of heat?

$$\frac{1.00\text{ kJ}}{1} \times \frac{1\text{ mol } C_6H_6}{3268\text{ kJ}} \times \frac{78.11\text{ g}}{1\text{ mol } C_6H_6} = \boxed{0.0239\text{ g } C_6H_6}$$

Hess's Law

1. Calculate ΔH for the reaction: $N_2(g) + 2\,O_2(g) \rightarrow 2\,NO_2(g)$.

   Given: $N_2(g) + O_2(g) \rightarrow 2\,NO(g)$ $\quad \Delta H = 180\ kJ/mol_{rxn}$

   $2\,NO(g) + O_2(g) \rightarrow 2\,NO_2(g)$ $\quad \Delta H = -112\ kJ/mol_{rxn}$

   $N_2(g) + 2\,O_2(g) \rightarrow 2\,NO_2(g)$ $\quad \Delta H = 180 + -112 = \boxed{68\ kJ/mol}$

2. Calculate ΔH for the reaction: $C_{graphite}(s) \rightarrow C_{diamond}(s)$

   Given: $C_{graphite}(s) + O_2(g) \rightarrow CO_2(g)$ $\quad \Delta H = -394\ kJ/mol_{rxn}$

   ~~$C_{diamond}(s) + O_2(g) \rightarrow CO_2(g)$ $\quad \Delta H = -396\ kJ/mol_{rxn}$~~ reverse!

   $CO_2(g) \rightarrow C_{diamond}(s) + O_2(g)$ $\quad \Delta H = 396\ kJ/mol$

   $C_{graph}(s) \rightarrow C_{diam}(s)$ $\quad \Delta H = -394 + 396 = \boxed{2\ kJ/mol}$

3. Calculate ΔH for the reaction: $2\,H_3BO_3(aq) \rightarrow B_2O_3(s) + 3\,H_2O(l)$

   Given: ~~$H_3BO_3(aq) \rightarrow HBO_2(aq) + H_2O(l)$ $\quad \Delta H = -0.02\ kJ/mol_{rxn}$~~ $\times 2$

   ~~$H_2B_4O_7(aq) + H_2O(l) \rightarrow 4\,HBO_2(aq)$ $\quad \Delta H = -11.3\ kJ/mol_{rxn}$~~ $\times \frac{1}{2}$ and reverse!

   ~~$H_2B_4O_7(aq) \rightarrow 2\,B_2O_3(s) + H_2O(l)$ $\quad \Delta H = 17.5\ kJ/mol_{rxn}$~~ $\times \frac{1}{2}$

   $2\,H_3BO_3(aq) \rightarrow 2\,HBO_2(aq) + 2\,H_2O(l)$ $\quad \Delta H = -0.04\ kJ/mol$

   $\frac{1}{2}\,H_2B_4O_7(aq) \rightarrow B_2O_3(s) + \frac{1}{2}\,H_2O(l)$ $\quad \Delta H = 8.75\ kJ/mol$

   $2\,HBO_2(aq) \rightarrow \frac{1}{2}\,H_2B_4O_7 + \frac{1}{2}\,H_2O(l)$ $\quad \Delta H = 5.65\ kJ/mol$

   $2\,H_3BO_3(aq) \rightarrow B_2O_3(s) + 3\,H_2O(l)$ $\quad \Delta H = -0.04 + 8.75 + 5.65 = \boxed{14.4\ kJ/mol}$

Stoich WU:

25.00 mL of CH_3COOH is titrated to its endpoint with 32.45 mL of 0.1000 M NaOH. What is the molarity of the acetic acid?

25.00 mL Acetic acid ⇒ .0250 L
32.45 mL NaOH ⇒ .03245 L

$M = \frac{mol}{L}$

$mol = M \cdot L$

$CH_3COOH + NaOH \longrightarrow CH_3OH + NaCOOH$

$.03245\ L\ (0.1000\ M) = .003245\ mol\ NaOH \times \frac{1\ mol\ CH_3COOH}{1\ mol\ NaOH} \times \frac{1}{.0250\ L\ CH_3COOH} = \boxed{0.1298\ M\ CH_3COOH}$

Enthalpy (H) - heat content of a system at constant pressure

ΔH = heat exchanged w/ surroundings during a chem. reaction

(+) exothermic: system released heat

(-) endothermic: system absorbed heat

ΔH = J, KJ, $\frac{KJ}{mol}$

more specific to the substances of a reaction

All enthalpy is energy but not all energy is enthalpy.