# Assignment: Hess' Law

SCH4U- 2018-2019

1. One of the methods that the steel industry uses to obtain metallic iron is to react iron (III) oxide, $Fe_2O_3$, with carbon monoxide, CO, according to the following equation:

$$Fe_2O_{3(s)} + 3CO_{(g)} \longrightarrow 3CO_{2(g)} + 2Fe_{(s)} \qquad \Delta H^0 = ???$$

Determine the enthalpy change for the production of iron, given the following:

$$CO_{(g)} + \tfrac{1}{2} O_{2(g)} \longrightarrow CO_{2(g)} \qquad \Delta H^0 = -283.0 \text{ kJ}$$

$$2\,Fe_{(s)} + \tfrac{3}{2} O_{2(g)} \longrightarrow Fe_2O_{3(s)} \qquad \Delta H^0 = -822.3 \text{ kJ}$$

2. Given the following equations:

$$CH_3COCH_{3\,(l)} + 4O_{2\,(g)} \longrightarrow 3\,CO_{2(g)} + 3\,H_2O_{(g)} \qquad \Delta H^0 = -1787.0 \text{ kJ}$$

$$H_2O_{(l)} \longrightarrow H_2O_{(g)} \qquad \Delta H^0 = -44.1 \text{ kJ}$$

$$CH_3COOH_{(l)} + 2O_{2\,(g)} \longrightarrow 2\,CO_{2(g)} + 2\,H_2O_{(l)} \qquad \Delta H^0 = -1787.0 \text{ kJ}$$

Determine the enthalpy change, $\Delta H^0_{RXN,}$ for the following reaction using Hess's Law:

$$CH_3COCH_{3\,(l)} + 2O_{2\,(g)} \longrightarrow CH_3COOH_{(l)} + CO_{2(g)} + H_2O_{(g)}$$

3. Methane, $CH_{4\,(g)}$, undergoes an explosive substitution reaction with chlorine gas, $Cl_{2\,(g)}$, in the presence of ultra-violet light, a chain initiated by chlorine free radicals, according to:

$$CH_{4\,(g)} + 2\,Cl_{2\,(g)} \longrightarrow CH_2Cl_{2\,(g)} + 2\,HCl_{\,(g)}$$

Calculate the heat of this reaction, $\Delta H^0_{rxn}$, using the following data:

| Compound | $\Delta H^0_f$ (kJ mol$^{-1}$) |
|---|---|
| $CH_{4\,(g)}$ | -74.9 |
| $HCl_{\,(g)}$ | -92.5 |
| $CH_2Cl_{2\,(g)}$ | -110.5 |

4. Use the standard enthalpies of formation, $\Delta H^0_f$, given below:

| **Compound** | **$\Delta H^0_f$ (kJ mol$^{-1}$)** |
|---|---|
| $CO_{2(g)}$ | – 394 |
| $C_3H_7OH_{(l)}$ | – 304 |
| $H_2O_{(l)}$ | – 286 |

to calculate the standard enthalpy of combustion of an alcohol $C_3H_7OH$, as shown in the equation below:

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$$C_3H_7OH_{(l)} + 4\tfrac{1}{2} O_{2(g)} \longrightarrow 3CO_{2\,(g)} + 4H_2O_{(l)}$$

5. Determine the enthalpy of the following reaction using the Table of $\Delta H_f^0$ provided:

$$2\ NH_{3(g)} + 3\ Cl_{2(g)} \longrightarrow N_{2(g)} + 6\ HCl_{(g)} \qquad \Delta H_{rxn}{}^0 = ?$$

6. Methanol can be synthesized from carbon dioxide and hydrogen according to the following equation:

$$CO_{2\ (g)} + 3\ H_{2\ (g)} \longrightarrow CH_3OH_{(g)} + H_2O_{(g)}$$

Calculate the enthalpy for the above reaction, $\Delta H^0_{rxn.}$, using the Table of $\Delta H_f^0$ provided.

7. Calculate the $\Delta H$ for the following reaction using the Table of $\Delta H_f^0$ provided.

$$12\ NH_{3(g)} + 21\ O_{2(g)} \longrightarrow 14\ H_2O_{(g)} + 8\ HNO_{3(aq)} + 4\ NO_{(g)}$$

8. Ammonium nitrate ($NH_4NO_3$) is easily exploded in the presence of oxidizable impurities and was part of the Oklahoma City bomb and other terrorist attacks. It explodes according to the balanced equation below with a heat of reaction of $\Delta H = -3076.7$ kJ.
Calculate the standard heat of formation of ammonium nitrate.

$$2\ NH_4NO_{3\ (s)} \longrightarrow 2\ N_{2(g)} + O_{2\ (g)} + 4\ H_2O_{(g)}$$

9. Stearin, with formula $C_{57}H_{110}O_6$, is a typical fat and its oxidation is an important source of energy in the body. The standard enthalpy change of combustion of stearin in oxygen to give carbon dioxide and liquid water is $-37.7 \times 10^6$ J mol$^{-1}$.

a. Write a balanced thermochemical equation for the combustion reaction of stearin.

b. Use data from the thermochemical tables to calculate the standard enthalpy change of formation of stearin.

10. Determine the $\Delta H$ for the reaction below,

$$N_2H_{4\ (l)} + CH_4O_{(l)} \longrightarrow CH_2O_{(g)} + N_{2\ (g)} + 3H_{2\ (g)}$$

given the following reactions and the subsequent $\Delta H$ values:

$2NH_{3\ (g)} \longrightarrow N_2H_{4\ (l)} + H_{2\ (g)}$ $\quad \Delta H = +22.5$ kJ
$2NH_{3\ (g)} \longrightarrow N_{2\ (g)} + 3H_{2\ (g)}$ $\quad \Delta H = +57.5$ kJ
$CH_2O_{(g)} + H_{2\ (g)} \longrightarrow CH_4O_{(l)}$ $\quad \Delta H = +81.2$ kJ

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