Problem Set Chapter 8 Part 2

Michael Brodskiy
Instructor: Mr. Morgan

January 11, 2020

1. Using the enthalpies of formation, calculate the enthalpy change in the following:

   (a) $C_2H_5OH\,(l) + O_2(g) \longrightarrow CH_3CHO\,(g) + H_2O\,(l)$, where $CH_3CHO\,(g)$ has an enthalpy of formation of $-166\left[\frac{\text{kJ}}{\text{mol}}\right]$

$$\begin{aligned} C_2H_5OH\,(l) &\longrightarrow -277.7\left[\frac{\text{kJ}}{\text{mol}}\right] \\ O_2(g) &\longrightarrow 0\left[\frac{\text{kJ}}{\text{mol}}\right] \\ H_2O\,(l) &\longrightarrow -285.8\left[\frac{\text{kJ}}{\text{mol}}\right] \end{aligned} \tag{1}$$

$$-285.8 - 166 - (-277.7) = -174.1[\text{kJ}]$$

   (b) $2\,Al^{3+}(aq) + 3\,Zn\,(s) \longrightarrow 3\,Zn^{2+}(aq) + 2\,Al\,(s)$

$$\begin{aligned} 2\,Al^{3+}(aq) &\longrightarrow 2(-531)\left[\frac{\text{kJ}}{\text{mol}}\right] \\ 3\,Zn\,(s) &\longrightarrow 0\left[\frac{\text{kJ}}{\text{mol}}\right] \\ 3\,Zn^{2+}(aq) &\longrightarrow 3(-153.9)\left[\frac{\text{kJ}}{\text{mol}}\right] \\ 2\,Al\,(s) &\longrightarrow 0\left[\frac{\text{kJ}}{\text{mol}}\right] \end{aligned} \tag{2}$$

$$3(-153.9) - 2(-531) = 600.3[\text{kJ}]$$

2. Using enthalpies of formation the enthalpy of the reaction, calculate the enthalpy of formation for $Cr_2O_7{}^{2-}$; $\Delta H = -1855[\text{kJ}]$

(a) $8\,H^+(aq) + Cr_2O_7{}^{2-}(aq) + 2\,Al(s) \longrightarrow 2\,Al^{3+}(aq) + Cr_2O_3(s) + 4\,H_2O(l)$

$$\begin{aligned}
8\,H^+(aq) &\longrightarrow 8(0)\left[\frac{kJ}{mol}\right] \\
2\,Al(s) &\longrightarrow 2(0)\left[\frac{kJ}{mol}\right] \\
2\,Al^{3+}(aq) &\longrightarrow 2(-531)\left[\frac{kJ}{mol}\right] \\
Cr_2O_3(s) &\longrightarrow -1139.7\left[\frac{kJ}{mol}\right] \\
4\,H_2O(l) &\longrightarrow 4(-285.8)\left[\frac{kJ}{mol}\right] \\
Cr_2O_7{}^{2-}(aq) &\longrightarrow ?\left[\frac{kJ}{mol}\right]
\end{aligned} \tag{3}$$

$$\begin{aligned}
2(-531) + (-1139.7) + 4(-285.8) - x &= -1855 \\
x &= -1489.9[kJ]
\end{aligned}$$

3. Using bond energies, calculate the enthalpy of the following reactions:

(a) $N_2H_4 + H_2 \longrightarrow 2\,NH_3$

$$\begin{aligned}
&\text{Broken:} \\
N\text{——}N &= 159[kJ] \\
4\cdot N\text{——}H &= 4(389)[kJ] \\
H\text{——}H &= 436[kJ] \\
&\text{Made:} \\
6\cdot N\text{——}H &= 6(389)[kJ]
\end{aligned} \tag{4}$$

$$159 + 4(389) + 436 - 6(389) = 183[kJ]$$

(b) $CH_4 + Cl_2 \longrightarrow CH_3Cl + HCl$

$$\begin{aligned}
&\text{Broken:}\\
4\cdot \mathrm{C}\text{---}\mathrm{H} &= 4(414)[\mathrm{kJ}]\\
\mathrm{Cl}\text{---}\mathrm{Cl} &= 243[\mathrm{kJ}]\\
&\text{Made:}\\
3\cdot \mathrm{C}\text{---}\mathrm{H} &= 3(414)[\mathrm{kJ}]\\
\mathrm{C}\text{---}\mathrm{Cl} &= 331[\mathrm{kJ}]\\
\mathrm{H}\text{---}\mathrm{Cl} &= 431[\mathrm{kJ}]
\end{aligned} \tag{5}$$

$$4(414) + 243 - 3(414) - 331 - 431 = -105[\mathrm{kJ}]$$

(c) $\mathrm{C_2H_2} + 2\,\mathrm{Br_2} \longrightarrow \mathrm{C_2H_2Br_4}$

$$\begin{aligned}
&\text{Broken:}\\
\mathrm{C}\equiv\mathrm{C} &= 820[\mathrm{kJ}]\\
2\cdot \mathrm{C}\text{---}\mathrm{H} &= 2(414)[\mathrm{kJ}]\\
2\cdot \mathrm{Br}\text{---}\mathrm{Br} &= 2(193)[\mathrm{kJ}]\\
&\text{Made:}\\
4\cdot \mathrm{C}\text{---}\mathrm{Br} &= 4(276)[\mathrm{kJ}]\\
2\cdot \mathrm{C}\text{---}\mathrm{H} &= 2(414)[\mathrm{kJ}]\\
\mathrm{C}\text{---}\mathrm{C} &= 347[\mathrm{kJ}]
\end{aligned} \tag{6}$$

$$820 + 2(414) + 2(193) - 4(276) - 2(414) - 347 = -245[\mathrm{kJ}]$$

4. Calculate the ΔH for the formation of 45.7[g] of oxygen in the following; $\Delta H = 286[\mathrm{kJ}]$

   (a) $2\,\mathrm{H_2} + \mathrm{O_2} \longrightarrow 2\,\mathrm{H_2O}$

$$\begin{aligned}
\frac{45.7}{32} &= 1.425[\mathrm{mol}]\\
1.425 \cdot 286 &= 408[\mathrm{kJ}]
\end{aligned} \tag{7}$$

5. The heat evolved on combustion of $\mathrm{C_2H_6}$ is 3120[kJ] and $\mathrm{C_2H_4}$ is 1411[kJ]. If the heat of formation of $\mathrm{CO_2}$ is -394[kJ] and $\mathrm{H_2O}$ is -286[kJ], calculate the ΔH for the following reaction:

   (a) $\mathrm{C_2H_4} + \mathrm{H_2} \longrightarrow \mathrm{C_2H_6}$

$$
\begin{aligned}
2\,C_2H_4 + 6\,O_2 &\longrightarrow 4\,CO_2 + 4\,H_2O \\
4(-394) + 4(-286) - 2(1411) &= -5542[\mathrm{kJ}] \\
2\,C_2H_6 + 7\,O_2 &\longrightarrow 4\,CO_2 + 6\,H_2O \\
4(-394) + 6(-286) - 2(3120) &= -9532[\mathrm{kJ}] \\
4\,CO_2 + 6\,H_2O &\longrightarrow 2\,C_2H_6 + 7\,O_2 \\
\underline{-[4(-394) + 6(-286) - 2(3120)] = 9532[\mathrm{kJ}]} & \qquad (8) \\
2\,C_2H_4 + 6\,O_2 &\longrightarrow 4\,CO_2 + 4\,H_2O \\
\underline{4\,CO_2 + 6\,H_2O \longrightarrow 2\,C_2H_6 + 7\,O_2} & \\
2\,C_2H_4 + 2\,H_2O &\longrightarrow 2\,C_2H_6 + O_2 \\
\Delta H = 9532 - 5542 &= 3990[\mathrm{kJ}] \\
2\,H_2 + O_2 \longrightarrow 2\,H_2O2(-286) &= -572[\mathrm{J}]
\end{aligned}
$$