Problem Set Chapter 8 Part 2

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

   (a) $2\,C_2H_5OH\,(l) + O_2(g) \longrightarrow 2\,CH_3CHO\,(g) + 2\,H_2O\,(l)$, where $CH_3CHO\,(g)$ has an enthalpy of formation of $-166\left[\frac{kJ}{mol}\right]$

$$\begin{aligned} C_2H_5OH\,(l) &\longrightarrow 2(-277.7)\left[\frac{kJ}{mol}\right] \\ O_2(g) &\longrightarrow 0\left[\frac{kJ}{mol}\right] \\ H_2O\,(l) &\longrightarrow 2(-285.8)\left[\frac{kJ}{mol}\right] \end{aligned} \tag{1}$$

$$2(-285.8) - 2(166) - 2(-277.7) = -348.2[kJ]$$

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

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

$$3(-153.9) - 2(-531) = 600.3[kJ]$$

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

(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:

$$C_2H_4 + H_2 \longrightarrow C_2H_6$$

$$\begin{aligned}
&C_2H_4 + H_2 \longrightarrow C_2H_6 \\
&\text{Broken:} \\
&4 \cdot C\text{—}H = 4(414) \\
&C{=}C = 612 \\
&H\text{—}H = 436 \\
&\text{Made:} \\
&6 \cdot C\text{—}H = 6(414) \\
&C\text{—}C = 347 \\
&\hline \\
&2704 - 2831 = -127[\text{kJ}]
\end{aligned} \tag{8}$$