More Ch.6 AP Questions

1. Liquid hydrazine, N_2H_4, is sometimes used as a rocket propellant.
a. Write an equation for the formation of hydrazine from its elements and use the combustion equations below to derive an equation in which $\Delta H_f°$ for liquid hydrazine is expressed in terms of ΔH_1, ΔH_2 and ΔH_3.

$\frac{1}{2} N_{2(g)} + O_{2(g)} \rightarrow NO_{2(g)}$	ΔH_1
$H_{2(g)} + \frac{1}{2} O_{2(g)} \rightarrow H_2O_{(g)}$	ΔH_2
$N_2H_{4(l)} + 3O_{2(g)} \rightarrow 2NO_{2(g)} + 2H_2O_{(g)}$	ΔH_3

$N_2 + 2H_2 \rightarrow N_2H_4 \quad \Delta H =$

$N_2 + 2O_2 \rightarrow 2NO_2 \quad \Delta H_1 \cdot 2$

$2H_2 + O_2 \rightarrow 2H_2O \quad \Delta H_2 \cdot 2$

$2NO_2 + 2H_2O \rightarrow N_2H_4 + 3O_2 \quad -\Delta H_3$

$\Delta H_f^0 = (2 \cdot \Delta H_1) + (2 \cdot \Delta H_2) - \Delta H_3$

b. In a rocket, liquid hydrazine is reacted with liquid hydrogen peroxide to produce nitrogen and water vapor. Write a balanced equation for this reaction.

$N_2H_4 + 2H_2O_2 \rightarrow N_2 + 4H_2O$

H–N–N–H (H, H) 2 H–O–O–H N≡N 4 H–O–H

c. Calculate $\Delta H°_{rxn}$ for the reaction represented in 2b.

	$\Delta H_f°$ kJ/mol
$N_2H_{4(l)}$	50.6
$H_2O_{2(l)}$	–187.8
$H_2O_{(g)}$	–285.8

$\Delta H = [\Delta H_{N_2} + 4\Delta H_{H_2O}] - [\Delta H_{N_2H_4} + 2\Delta H_{H_2O_2}]$

$\Delta H = [0 + 4 \cdot -285.8] - [50.6 + 2 \cdot -187.8]$

$\Delta H = -1{,}143.2 - (-325) = -818.2 \frac{kJ}{mol}$

d. Calculate $\Delta H°_{rxn}$ for the reaction in 2b using bond dissociation energies.

Bond Dissociation Energy kJ/mol

N–N 167	O–O 142
N=N 418	O=O 494
N≡N 942	O–H 459
N-H 386	

$\Delta H = [4 \cdot N\text{-}H + N\text{-}N + 4 \cdot H\text{-}O + 2 O\text{-}O] - [N{\equiv}N + 4 \cdot O\text{-}H]$

$\Delta H = [4 \cdot 386 + 167 + 2 \cdot 142] - [942 + 4 \cdot 459]$

$1995 - 2778$

$\Delta H = -783 \frac{kJ}{mol}$

e. Which value of ΔH°_{rxn} (that calculated in part c or part d) is likely to be more accurate? Justify your answer.

ΔH_f values are probably more accurate they take into account the influence of the whole molecule

f. Calculate the maximum temperature of the combustion gases if all the energy generated in the reaction goes into raising the temperature of those gases. [The heat capacities of $N_{2(g)}$ and $H_2O_{(g)}$ are 29.1 J/(mol.°C) and 33.6 J/(mol.°C), respectively.]

$q = -818.2 \frac{kJ}{mol}$ assume 1 mol $N_2H_4 \rightarrow$ 1 mol N_2, 4 mol H_2O

$-818.2\ kJ = q_{H_2O} + q_{N_2}$

$q_{H_2O} = 4mol\ 33.6\ J \cdot \Delta T$

$q_{N_2} = 1mol \cdot 29.1\ J \cdot \Delta T$

$818.2 \cdot 10^3 J = (4mol \cdot 33.6 \cdot \Delta T) + (29.1\ \Delta T)$

$818.2 \cdot 10^3 J = 163.5\ T$

$\Delta T = 5.00 \cdot 10^3\ °C$

More Ch 6 APQs

(3) Ai) $C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$

Aii) 2 moles of CO_2 for each C_2H_4

Bi) $H_3PO_4 + OH^- \rightarrow H_2O + H_2PO_4^-$

Bii) Basic $H_2PO_4^-$ would act as a Base

Ci) $3Mg + N_2 \rightarrow Mg_3N_2$

Cii) Green

2. Coffee cup calorimetry experiments can be used to obtain $\Delta H_f°$ for magnesium oxide.

a. Write a balanced equation for the formation of magnesium oxide, whose enthalpy change is $\Delta H_f°$.

$$Mg + \frac{1}{2}O_2 \rightarrow MgO$$

b. To determine the heat capacity of the calorimeter, 49.6 mL of 1.01 M HCl are reacted with 50.1 mL of 0.998 M NaOH. The solution's temperature increases by 6.40°C. Determine the heat capacity of the calorimeter. You may assume the solution's specific heat capacity is 4.025 $J \cdot g^{-1} \cdot °C^{-1}$, the enthalpy of neutralization is –55.9 kJ per mole of H_2O and the solutions have a density of 1.0 g/mL

$$HCl + NaOH \rightarrow$$

$$0.050096 \quad 0.049998$$

$$q_{rxn} = q_{H_2O} + q_{cal}$$

$$q_{rxn} = 55.9 \frac{kJ}{mol} \cdot 0.05000 = -2.795 \cdot 10^3 J$$

$$q_{H_2O} = 99.7g \cdot 4.025 \cdot 6.40°C = 2.568 \cdot 10^3 J$$

$$q_{cal} = 2.795 \cdot 10^3 - 2.568 \cdot 10^3 = 226.7 J$$

$$C_{cal} = \frac{226.7}{6.40} = 35.4 \frac{J}{°C}$$

c. When 0.221 g of magnesium turnings are added to 49.9 mL of 1.01 M HCl and 49.7 mL of H_2O in the same calorimeter, the temperature increases by 9.67°C. Write a balanced equation for the reaction that occurs and calculate the ΔH per mole magnesium. (Assume the solution's specific heat capacity is 3.862 $J \cdot g^{-1} \cdot {}^\circ C^{-1}$ and the heat capacity of the calorimeter is the value obtained in b.).

0.00909 0.050

$Mg + 2HCl \rightarrow MgCl_2 + H_2$

$-q_{rxn} = q_{H_2O} + q_{cal} = 2205$ ~~2212.8~~ 1,720 J

$q_{H_2O} = 49.9\,g \cdot 3.862 \cdot 9.67 =$ ~~1865.5 J~~

$50.12 \cdot 3.862 \cdot 9.67 =$ ~~1,871.8 J~~

$q_{cal} = 35.45 \frac{J}{°C} \cdot 9.67°C = 342.3\,J$

$\Delta H = \frac{4,060\,J \;\; -2205}{.00909} =$ ~~242 kJ/mol~~

$\frac{-2212}{0.00909} = -243.\,kJ/mol$

$-447\,kJ/mol$

d. When 0.576 g of MgO react with 51.0 mL of 1.01 M HCl and 50.1 mL of H_2O in the same calorimeter the temperature rises 4.72°C. Write a balanced equation for this reaction and calculate its ΔH per mole of MgO using the same assumptions as in part c.

$MgO + 2HCl \rightarrow MgCl_2 + H_2O$

.0143 mol .05 mol

$q_{H_2O} = 101.1\,g \cdot 3.862 \cdot 4.72 =$ ~~1724.9 J~~ 1853 J -2020

$q_{cal} = 35.4 \cdot 4.72 = 167.1\,J$

$\Delta H = \frac{-1892\,J}{.014\,mol} =$ ~~99.6 kJ/mol~~

$-144\,kJ/mol$

e. Use the above results and ΔH_f° of $H_2O_{(l)}$ ($-285.8\ kJ \cdot mol^{-1}$) to calculate ΔH_f° of magnesium oxide.

$Mg + \frac{1}{2}O_2 \rightarrow MgO$

$Mg + 2HCl \rightarrow MgCl_2 + H_2 \quad \Delta H =$ ~~-242 kJ/mol~~ -447

$MgCl_2 + H_2O \rightarrow MgO + 2HCl \quad \Delta H = -($~~-99.6~~ 144 kJ/mol$)$

$H_2 + \frac{1}{2}O_2 \rightarrow H_2O \quad \Delta H = -285.8\,kJ/mol$

$\Delta H = -$~~242~~ 447 $+$ ~~99.6~~ 144 $- 285.8$

$\Delta H = -$~~428.2~~ kJ/mol / $-588\,kJ/mol$