WS 11.3 Hess's Law Name:______________________ p.___

1. Given the following data:

$SO_{2(g)}$ -------> $S_{(s)}$ + $O_{2(g)}$ ΔH = 296.8 kJ ×2

$2\ SO_{3(g)}$ ---------> $2\ S_{(s)} + 3\ O_{2(g)}$ ΔH = 791.4 kJ ×−1

Use Hess's Law to calculate ΔH for this reaction: $\boxed{2\ SO_{2(g)} + O_{2(g)} \text{ -------> } 2\ SO_{3(g)}}$

$2\ SO_2 \rightarrow \cancel{2S} + \cancel{2O_2}$ ΔH = 593.6 kJ

$\cancel{2S} + \cancel{3}^{1}O_2 \rightarrow 2\ SO_3$ ΔH = −791.4 kJ

$2SO_2 + 1O_2 \rightarrow 2\ SO_3$ $\boxed{\Delta H = -197.8 \text{ kJ}}$

2. Given the following data:

$2\ P_{(s)} + 5\ Cl_{2(g)}$ -------> $2\ PCl_{5(s)}$ ΔH = -886 kJ × ½

$2\ P_{(s)} + 3\ Cl_{2(g)}$ -------> $2\ PCl_{3(l)}$ ΔH = -640. kJ × −½

Use Hess's Law to calculate ΔH for this reaction: $PCl_{3(l)} + Cl_{2(g)}$ -------> $PCl_{5(s)}$

$\cancel{P} + \frac{5}{2}Cl_2 \rightarrow PCl_5$ ΔH = −443 kJ

$PCl_3 \rightarrow \cancel{P} + \frac{3}{2}Cl_2$ ΔH = +320. kJ

$PCl_3 + Cl_2 \rightarrow PCl_5$ $\boxed{\Delta H = -123 \text{ kJ}}$

3. Given the following data:

$H_{2(g)} + F_{2(g)}$ -------> $2\ HF_{(g)}$ ΔH = -537.2 kJ × 2

$2\ H_{2(g)} + O_{2(g)}$ -------> $2\ H_2O_{(g)}$ ΔH = -483.6 kJ × −1 (reverse)

$H_2O_{(g)}$ -------> $H_2O_{(l)}$ ΔH = -44.0 kJ × −2

Use Hess's Law to calculate ΔH for this rxn: $2\ F_{2(g)} + 2\ H_2O_{(l)}$ -------> $4\ HF_{(g)} + O_{2(g)}$

$\cancel{2H_2} + 2F_2 \rightarrow 4HF$ ΔH = −1074.4 kJ

$2H_2O_{(g)} \rightarrow \cancel{2H_2} + O_2$ ΔH = 483.6 kJ

$2H_2O_{(l)} \rightarrow \cancel{2H_2O_{(g)}}$ ΔH = 88.0 kJ

$2H_2O_{(l)} + 2F_2 \rightarrow 4HF + O_2$ $\boxed{\Delta H = -502.8 \text{ kJ}}$

4. Given the following data:

$CaCO_{3(s)} + 2\ HCl_{(aq)}$ -------> $CaCl_2(aq) + H_2O_{(l)} + CO_{2(g)}$ ΔH = -15.41 kJ ×(1)

$2\ CaO_{(s)} + 2\ H_{2(g)} + 2\ Cl_{2(g)}$ ------> $2\ CaCl_2(aq) + 2\ H_2O_{(g)}$ ΔH = -968.4 kJ × (−1/2)

$2\ HCl_{(aq)}$ -------> $H_{2(g)} + Cl_{2(g)}$ ΔH = 334.9 kJ ×(−1)

$H_2O_{(l)}$ -------> $H_2O_{(g)}$ ΔH = 44.0 kJ ×(1)

Use Hess's Law to calculate ΔH for this rxn: $CaCO_{3(s)}$ -------> $CaO_{(s)} + CO_{2(g)}$

$CaCO_3 + \cancel{2HCl} \rightarrow \cancel{CaCl_2} + \cancel{H_2O_{(l)}} + CO_2$ ΔH = −15.41 kJ

$\cancel{CaCl_2} + \cancel{H_2O_{(g)}} \rightarrow CaO + \cancel{H_2} + \cancel{Cl_2}$ ΔH = 484.2 kJ

$\cancel{H_2} + \cancel{Cl_2} \rightarrow \cancel{2HCl}$ ΔH = −334.9 kJ

$\cancel{H_2O_{(l)}} \rightarrow \cancel{H_2O_{(g)}}$ ΔH = 44.0 kJ

$CaCO_3 \rightarrow CaO + CO_2$ $\boxed{\Delta H_{rxn} = 177.9 \text{ kJ}}$

5. Olive oil contains many types of fat molecules. A typical molecular formula for olive oil is $C_{57}H_{104}O_6$, which has a molecular weight of 885.4 amu. When you metabolize ("burn") olive oil in your body, the following reaction occurs:

$$C_{57}H_{104}O_{6\,(l)} + 80\ O_{2\,(g)} \text{ ------> } 57\ CO_{2(g)} + 52\ H_2O_{(l)} \quad \Delta H_{rxn} = -33429 \text{ kJ}$$

a. Calculate the energy (in kilojoules) produced when 1.00 gram of $C_{57}H_{104}O_6$ is metabolized.

$$(1.00\text{g } C_{57}H_{104}O_6)\left(\frac{1 \text{ mole fat}}{885.4\text{g}}\right)\left(\frac{33429 \text{ kJ}}{1 \text{ mole fat}}\right) = 37.7558 \rightarrow \boxed{37.8 \text{ kJ}}$$

b. Convert the answer in (b) to kilocalories (1 kcal = 4.184 kJ)

$$(37.7558 \text{ kJ})\left(\frac{1 \text{ kcal}}{4.184 \text{ kJ}}\right) = \boxed{9.02 \text{ kcal}}$$ (or 9.02 "food calories")

c. 1 gram of fat typically contains about 9 dietary calories. How does olive oil compare?

It has the same "energy content" as a typical fat.

d. If 1.00 grams of $C_{57}H_{104}O_6$ react, how many grams of carbon dioxide gas would be produced (exhaled!)?

$$(1.00\text{g } C_{57}H_{104}O_6)\left(\frac{1 \text{ mole}}{885.4\text{ g}}\right)\left(\frac{57 \text{ mole } CO_2}{1 \text{ mole } C_{57}H_{104}O_6}\right)\left(\frac{44.0098\text{ g}}{1 \text{ mole}}\right) = \boxed{2.83\text{g } CO_2}$$

6. Ethanol (ethyl alcohol) has the formula $C_2H_5OH_{(l)}$.

a. Write a chemical equation for ethanol burning. Balance and include phase subscripts.

$$C_2H_5OH_{(l)} + 3\,O_{2\,(g)} \rightarrow 2\,CO_{2(g)} + 3\,H_2O_{(l)} + \underline{1230 \text{ kJ}}$$

b. Without looking at any numbers, predict whether the above reaction will be exo- or endo-thermic, and explain your answer.

It should be <u>exo</u>thermic since it is a <u>combustion</u> rxn.

When 10.00 grams of ethanol are combusted under constant pressure conditions, the heat released is enough to increase the temperature of 2000. g of water from 10.0°C to 42.0°C.

c. Determine the heat energy absorbed/released (which is it?) by the water, in calories.

$$q = mc\Delta T = (2000.\text{g})\left(1.000 \tfrac{\text{cal}}{\text{g°C}}\right)(32.0\text{°C}) = 64000 \rightarrow \boxed{6.40\times10^4 \text{ cal}}$$

d. Convert your answer in (c) to kiloJoules.

$$(64000 \text{ cal})\left(\frac{4.184\text{J}}{1 \text{ cal}}\right)\left(\frac{1 \text{ kJ}}{1000\text{J}}\right) = 267.776 \text{ kJ} \rightarrow \boxed{268 \text{ kJ}}$$

e. Determine how many moles of ethanol burned in the experiment.

$$(10.00\text{g})\left(\frac{1 \text{ mole}}{46.0688 \text{ g}}\right) = 0.2170666 \rightarrow \boxed{0.2171 \text{ moles ethanol}}$$

f. Determine ΔH_{rxn} for the combustion of ethanol in kJ/mole.

$$267.776 \text{ kJ} / .2170666 \text{ mole} = 1233.61 \frac{\text{kJ}}{\text{mole}} \rightarrow \boxed{-1230 \frac{\text{kJ}}{\text{mole}}}$$

must be negative since the rxn caused H_2O to gain heat so rxn is exo and it is combustion!

g. Write the heat term into the equation in (a).

Cont'd, next page!