Review #4: Thermochemistry

1. Know the meanings of, and be able to apply, the following terms:

enthalpy	thermochemical equation	standard enthalpy (heat) of formation
endothermic reaction	calorimetry	standard state
exothermic reaction	specific heat capacity	Hess's Law

2. A hot piece of metal is placed in 30.0 mL of water in a coffee cup calorimeter. As the metal cools, the water warms from 20.0 °C to 24.0°C. How much heat does the water absorb? (0.502 kJ)

3. What are the standard states of the following elements (give both the chemical formula and state)?

sulfur: ________, carbon: __________, hydrogen: __________, iodine: _________, neon: _________,

phosphorus: ________, lead: _________, mercury: __________, chlorine: _________, bromine; _________

4. Write formation equations for the following substances:

a) $NaNO_3$ (s)
c) Hg_2SO_3 (s)
b) $(NH_4)_2CO_3$ (s)
d) CH_2O (l)

5. Use standard enthalpies of formation ($\Delta H°f$) to calculate the heat of reaction (ΔH) for the following:

a) $C_2H_4\ (g) + 2\ O_2\ (g) \rightarrow 2\ CO_2\ (g) + 2\ H_2O\ (g)$
b) $N_2H_4\ (l) + 2\ H_2O_2\ (l) \rightarrow N_2\ (g) + 4\ H_2O\ (g)$
c) $NH_3\ (g) + HCl\ (g) \rightarrow NH_4Cl\ (s)$

6. Use Hess's Law to calculate the heat of reaction (ΔH) for the reaction: (-648 kJ)

$$N_2H_4\ (l) + 2\ H_2O_2\ (l) \rightarrow N_2\ (g) + 4\ H_2O\ (g)$$

Given:

$N_2H_4\ (l) + 3\ O_2\ (g) \rightarrow 2\ NO_2\ (g) + 2\ H_2O\ (g)$ $\Delta H = -\ 466$ kJ
$H_2O\ (l) + \frac{1}{2}\ O_2\ (g) \rightarrow H_2O_2\ (l)$ $\Delta H = +\ 98$ kJ
$\frac{1}{2}\ N_2\ (g) + O_2\ (g) \rightarrow NO_2\ (g)$ $\Delta H = +\ 34$ kJ
$H_2O\ (l) \rightarrow H_2O\ (g)$ $\Delta H = +\ 41$ kJ

7. A 1.00 gram sample of the rocket fuel hydrazine, N_2H_4, is burned in a calorimeter containing 1200.0 g of water. The temperature of the water rises from 24.62 to 28.16°C. The reaction is:

$$N_2H_4\ (l) + 3\ O_2\ (g) \rightarrow 2\ NO_2\ (g) + 2\ H_2O\ (g)$$

a) Calculate the amount of heat (Q) absorbed by the water when 1.000 g of hydrazine burns. (17.8 kJ)
b) Calculate the heat of reaction (ΔH) per mole of hydrazine burned. (-570. kJ/mol N_2H_4)

8. For the reaction: $Fe_2O_{3(s)} + 3\ CO_{(g)} \rightarrow 2\ Fe_{(s)} + 3\ CO_{2(g)}$ $\Delta H° = -25.0$ kJ
Calculate the amount of energy required/released when 100.0 grams of pure iron are formed. (-22.4 kJ)

9. Given:

$MnO_2\ (s) \rightarrow MnO\ (s) + \frac{1}{2}\ O_2\ (g)$ $\Delta H = +\ 134.8$ kJ
$MnO_2\ (s) + Mn(s) \rightarrow 2\ MnO\ (s)$ $\Delta H = -\ 250.1$ kJ

Calculate the heat of formation of MnO_2 (s). (-519.7 kJl)

10. When one mole of CH_4 (g) burns in a bomb calorimeter containing 21.00 kg of water, the temperature of the water rises by 9.140 °C.

a) Write the balanced reaction for the complete combustion of methane.

b) Use heats of formation to calculate the ΔH for the combustion per mole of methane (-802.5 kJ/mol)

c) Use the calorimetry data above to calculate the heat of combustion (ΔH) per mole of CH_4 (-803.1 kJ)

11. If a reaction is endothermic, which is higher, the enthalpy of the reactants or of the products?

12. In an experiment, 3.116 g of solid lithium hydroxide is mixed with 200.0 mL of 0.750 M solution of nitric acid in a coffee cup calorimeter. A neutralization (double displacement) reaction occurs and the temperature of the nitric acid goes from 24.5 °C to 31.4 °C.

a) Write the balanced chemical reaction for the reaction that occurs. Include the states of all reactants and products.

b) Calculate the molar enthalpy of reaction (ΔH) per mole of lithium hydroxide. (–44.4 kJ/mol LiOH)

c) State three assumptions that should not significantly affect the accuracy of the results.

13. Consider the following equations:

(1) $Fe_2O_{3(s)} + 3\ CO_{(g)} \rightarrow 2\ Fe_{(s)} + 3\ CO_{2(g)}$ $\Delta H^\circ = -25$ kJ

(2) $3\ Fe_2O_{3(s)} + CO_{(g)} \rightarrow 2\ Fe_3O_{4(s)} + CO_{2(g)}$ $\Delta H^\circ = -47$ kJ

(3) $Fe_3O_{4(s)} + CO_{(g)} \rightarrow 3\ FeO_{(s)} + CO_{2(g)}$ $\Delta H^\circ = +38$ kJ

Calculate ΔH for the reaction: $FeO_{(s)} + CO_{(g)} \rightarrow Fe_{(s)} + CO_{2(g)}$ (– 17 kJ)