Unit 4 Homework
Thermochemistry

Name: _____ Date: _____ Period: _____

Directions: Answer each question in the space provided. For problems with calculations, be sure to show all work, include units, round answers to the correct number of significant figures where appropriate, and place a box around your final answer.

1. Consider the following reaction:

$$2Mg(s) + O_2(g) \rightarrow 2MgO(s) \quad \Delta H = -1204 \text{ kJ}$$

   a. Is this reaction exothermic or endothermic?

   b. Calculate the amount of heat transferred when 2.4 g of Mg reacts.

   c. How many grams of MgO are produced during an enthalpy change of -96.0 kJ?

   d. How many kJ of heat are absorbed when 7.50 g of MgO are decomposed into Mg(s) and $O_2(g)$?

2. Consider the following reaction:

$$CH_3OH(g) \rightarrow CO(g) + 2H_2(g) \quad \Delta H = +90.7 \text{ kJ}$$

   a. Calculate the amount of heat transferred when 1.60 kg of $CH_3OH(g)$ are decomposed.

   b. How many grams of hydrogen are produced if there is an enthalpy change of 64.7 kJ?

   c. How many kJ of heat are released when 32.0 g of $CO(g)$ reacts completely with $H_2(g)$?

3. Two solid objects, A and B, with identical masses, are placed in boiling water and allowed to come to temperature there. Each item is then lifted out and placed in separate beakers containing 1000 g of water at 10°C. Object A increases the water temperature by 3.5°C; B increases it by 2.6°C. What can you say about the specific heats of A and B?

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4. The specific heat of liquid water is 4.184 J/g·K.
   a. What is the molar heat capacity of liquid water?

   b. How many kJ of heat are needed to raise the temperature of 10.00 kg of liquid water from 24.6°C to 46.2°C?

5. Phileas Fogg, the character who went around the world in 80 days, was very fussy about his bathwater temperature. It had to be exactly 38.0°C. You are his butler, and one morning while checking his bath temperature, you notice that it's 42.0°C. You plan to cool the 100.0 kg of water to the desired temperature by adding an aluminum ducky originally at freezer temperature (-24.0^{o}C). Of what mass should the ducky be? [Specific heat of Al = 0.900 J/(g·°C); density of water = 1.00 g/ml]. Assume that no heat is lost to the air.

6. The specific heat of toluene (C_7H_8) is 1.13 J/g·K. How many joules of heat are needed to raise the temperature of 62.0 g of toluene from 16.3°C to 38.8°C?

7. When a 3.88-g sample of solid ammonium nitrate dissolves in 60.0 g of water in a coffee-cup calorimeter, the temperature drops from 23°C to 18.4°C. Calculate ΔH for the dissolving process:

$$NH_4NO_3(s) \rightarrow NH_4^+(aq) + NO_3^-(aq)$$

   Assume the specific heat of the solution is the same as that of pure water.

8. Given the enthalpies of reaction:

$$P_4(s) + 3O_2(g) \rightarrow P_4O_6(s) \quad \Delta H = -1640.1 \text{ kJ}$$
$$P_4(s) + 5O_2(g) \rightarrow P_4O_{10}(s) \quad \Delta H = -2940.1 \text{ kJ}$$

   Calculate the enthalpy change for the reaction:

$$P_4O_6(s) + 2O_2(g) \rightarrow P_4O_{10}(s)$$

9. From the enthalpies of reaction:

$$H_2(g) + F_2(g) \rightarrow 2HF(g) \quad \Delta H = -537 \text{ kJ}$$
$$C(s) + 2F_2(g) \rightarrow CF_4(g) \quad \Delta H = -680 \text{ kJ}$$
$$2C(s) + 2H_2(g) \rightarrow C_2H_4(g) \quad \Delta H = +52.3 \text{ kJ}$$

Calculate ΔH for the following:

$$C_2H_4(g) + 6F_2(g) \rightarrow 2CF_4(g) + 4HF(g)$$

10. Given the data:

$$N_2(g) + O_2(g) \rightarrow 2NO(g) \quad \Delta H = +180.7 \text{ kJ}$$
$$2NO(g) + O_2(g) \rightarrow 2NO_2(g) \quad \Delta H = -113.1 \text{ kJ}$$
$$2N_2O(g) \rightarrow 2N_2(g) + O_2(g) \quad \Delta H = -163.2 \text{ kJ}$$

Use Hess's law to calculate ΔH for the reaction:

$$N_2O(g) + NO_2(g) \rightarrow 3NO(g)$$

11. The following is known as a thermite reaction:

$$2Al(s) + Fe_2O_3(s) \rightarrow Al_2O_3(s) + 2Fe(s)$$

This highly exothermic reaction is used for welding massive units, such as propellers for ships. Using enthalpies of formation, calculate $\Delta H°$ for this reaction.

12. Using enthalpies of formation, calculate the standard enthalpy change for each of the following reactions:
    a. $2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$

    b. $Mg(OH)_2(s) \rightarrow MgO(s) + H_2O(l)$

    c. $SiCl_4(l) + 2H_2O(l) \rightarrow SiO_2(s) + 4HCl(g)$

13. A sample of a hydrocarbon is combusted completely in $O_2(g)$ to produce 21.83 g $CO_2(g)$, 4.47 g $H_2O(g)$, and 311 kJ of heat.
    a. What is the empirical formula of the hydrocarbon?

b. Calculate the value of ΔH_f° per empirical-formula unit of the hydrocarbon.

c. Can you find this hydrocarbon listed in Appendix C of your textbook?

14. For each of the following pairs, indicate which possesses the larger entropy. Explain your reasoning.
    a. 1 mol of $P_4(g)$ at 300°C and 0.01 atm, or 1 mol of $As_4(s)$ at 300°C and 0.01 atm

    b. 1 mol of $H_2O(g)$ at 100°C and 1 atm, or 1 mol of $H_2O(l)$ at 100°C and 1 atm

    c. 0.5 mol $N_2(g)$ at 298 K and 20 L volume, or 0.5 mol $CH_4(g)$ at 298 K and 20 L volume

    d. 100 g $Na_2SO_4(s)$ at 30°C, or 100 g $Na_2SO_4(aq)$ at 30°C

15. Predict the sign of the entropy change of the system for each of the following reactions:
    a. $2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$

    b. $Ba(OH)_2(s) \rightarrow BaO(s) + H_2O(g)$

    c. $CO(g) + 2H_2(g) \rightarrow CH_3OH(l)$

    d. $FeCl_2(s) + H_2(g) \rightarrow Fe(s) + 2HCl(g)$

16. Predict the sign of ΔS for each of the following processes:
    a. Molten Fe solidifies

    b. $LiCl(s)$ is formed from $Li(s)$ and $Cl_2(g)$

    c. Zinc metal dissolves in hydrochloric acid, producing $ZnCl_2(aq)$ and $H_2(g)$

17. Using listed values, compare the standard entropies at 25°C for the following pairs of substances. In each case explain the difference in entropy values.
    a. $Sc(s)$ and $Sc(g)$

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    b. 1 mol $N_2O_4(g)$ and 2 mol $NO_2(g)$

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    _____

    c. $CH_3OH(g)$ and $CH_3OH(l)$

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    _____

    d. 1 mol $PbO(s)$ plus 1 mol $CO_2(g)$ and 1 mol $PbCO_3(s)$

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18. Calculate $\Delta S°$ values for the following reactions. In each case, explain the sign of $\Delta S°$.
    a. $N_2H_4(g) + H_2(g) \rightarrow 2NH_3(g)$

    b. $Al(s) + 3Cl_2(g) \rightarrow 2AlCl_3(s)$

    c. $Mg(OH)_2(s) + 2HCl(g) \rightarrow MgCl_2(s) + 2H_2O(l)$

19. For a certain chemical reaction, $\Delta H° = -35.4$ kJ and $\Delta S° = +42.7$ J/K. Calculate $\Delta G°$ for the reaction at 298 K. Is the reaction spontaneous at this temperature?

20. Use listed values to calculate $\Delta H°$, $\Delta S°$, and $\Delta G°$ at 25°C for each of the following reactions. In each case show that $\Delta G° = \Delta H° - T\Delta S°$.

    a. $Ni(s) + Cl_2(g) \rightarrow NiCl_2(s)$

    b. $CaCO_3(s, \text{calcite}) \rightarrow CaO(s) + CO_2(g)$

    c. $P_4O_{10}(s) + 6H_2O(l) \rightarrow 4H_3PO_4(aq)$

21. Calculate $\Delta G°$ for each of the following reactions at 298K. If the reaction is not spontaneous under standard conditions, at what temperatures (if any) would the reaction be spontaneous?

a. $2PbS(s) + 3O_2(g) \rightarrow 2PbO(s) + 2SO_2(g)$ $\Delta H° = -844$ kJ $\Delta S° = -165$ J/K

b. $2POCl3(g) \rightarrow 2PCl3(g) + O2(g)$ $\Delta H° = 572$ kJ $\Delta S° = 179$ J/K

22. Consider the following reaction between the oxides of nitrogen:

$$NO_2(g) + N_2O(g) \rightarrow 3NO(g)$$

a. Using listed values, calculate $\Delta G°$ at 800 K, assuming that $\Delta H°$ and $\Delta S°$ do not change with temperature. Is the reaction spontaneous at 800 K?

b. Is the reaction spontaneous at 1000 K?