Name _____ Date _____ Period _____

Thermochemistry Review

1. Glucose, $C_6H_{12}O_6(s)$, is converted into ethyl alcohol, $C_2H_5OH(l)$, in the fermentation of fruit juice to produce wine: $C_6H_{12}O_6(s) \rightarrow 2C_2H_5OH(l) + 2CO_2(g)$ $\Delta H = -67.0kJ$ What quantity of heat is liberated when a liter of wine containing 95.0 g of $C_2H_5OH(l)$, is produced?

2. Hydrazine, $N_2H_4(l)$, is used in rocket fuels. When combusted it yields nitrogen gas and liquid water.

a) Write the balanced equation for the combustion of hydrazine.

b) When one mole of hydrazine is combusted, the enthalpy is $\Delta H = -622.4$ kJ What quantity of heat is liberated by the combustion of 230.0 g of $N_2H_4(l)$?

3. Calculate the heat capacity of an aluminum block that must absorb 629 J of heat from its surroundings for its temperature to rise from 22.00C to 145.00C.

4. What will be the final temperature if a 5.00g silver ring at 37.00C gives off 25.0 J of heat to its surroundings? (specific heat of silver = 0.235 J/g0C)

5. A 15.5g sample of a metal alloy is heated to 98.90C and then dropped into 25.0g of water in a calorimeter. The temperature of the water rises from 22.50C to 25.70C. Calculate the specific heat of the alloy.

6. A 50.0 mL sample of 0.250 M HCl is added to 50.0 mL of 0.250 M NaOH at 19.500C in a styrofoam calorimeter. After mixing, the solution temperature rises to 21.210C.Calculate the heat of the reaction.

7. When 1.050g of diethylene glycol, $C_4H_{10}O_3$, undergoes complete combustion, it gives off 23.50 kJ of heat to the surroundings. Calculate the standard enthalpy of formation of liquid diethylene glycol. Assume the initial reactants and products of the combustion are at 250C and 1 atm pressure. (standard heats of formation of CO_2 (g) and H_2O (l) are –393.5 and –285.8 kJ/mol respectively)

8. PCl_3 is a compound used to manufacture pesticides. A reaction requires that 96.7 g of PCl_3 be raised from 31.7 oC to 69.2oC. How much energy will this require given that the specific heat of PCl_3 is 0.874 J/g oC?

9. A quantity of water is heated from 25.0 oC to 36.4 oC by absorbing 325 J of heat energy. What is the mass of the water?

10. A 29.5 g sample of methanol at 208.9 K is mixed with 54.3 g of methanol at 302.3 K. Calculate the final temperature of the mixture assuming no heat is lost to the containers and surroundings. The specific heat of methanol is 2.53 $J\ g^{-1}\ K^{-1}$

11. Using the standard enthalpies, calculate the standard change in enthalpy for the thermite reaction: powdered aluminum metal and solid iron (III) oxide produces solid aluminum oxide and iron metal. This reaction occurs when a mixture of powdered aluminum and iron (III) oxide is ignited with a magnesium fuse. (If you need any other $\Delta H°f$ values use the appendix in the text.)

12. The "thermite reaction" above is one in which molten iron is made from the reaction of aluminum powder and iron oxide. A variation on that reaction was described in October 1984 Journal of Chemical Education. The reaction is:

$$2Al(s) + Cr2O3(s) \rightarrow Al2O3(s) + 2Cr(s)$$

(a) Calculate ΔH for this reaction.

(b) Which reaction yields more energy per gram of metal formed, the thermite reaction in #11 above, or this one?

13. Use the following equations

$C3H8\ (g) + 5\ O2\ (g) \rightarrow 3\ CO2\ (g) + 4\ H2O\ (l)$ $\Delta H = -2219.9$ kJ

$CO\ (g) + ½\ O2\ (g) \rightarrow CO2\ (g)$ $\Delta H = -283.0$ kJ

to calculate the enthalpy change for the reaction

$C3H8\ (g) + 7/2\ O2 \rightarrow 3\ CO\ (g) + 4\ H2O\ (l)$ $\Delta H = ?$

14. Use the following equations

$N2H4\ (l) + O2\ (g) \rightarrow N2\ (g) + 2\ H2O\ (l)$ $\Delta H = -622.2$ kJ

$H2\ (g) + ½\ O2\ (g) \rightarrow H2O\ (l)$ $\Delta H = -285.8$ kJ

$H2\ (g) + O2\ (g) \rightarrow H2O2\ (l)$ $\Delta H = -187.8$ kJ

to calculate the following

$N2H4\ (l) + 2\ H2O2\ (l) \rightarrow N2\ (g) + 4\ H2O\ (l)$ $\Delta H = ?$

Enropy and Free Energy Review

1. When solid potassium iodide is dissolved in water, a cooling of the mixture occurs because the solution process is endothermic for these substances. Explain, in terms of what happens to the molecules and ions, why this mixing occurs spontaneously?

2. Which of the following are spontaneous and which are nonspontaneous?
   a. The melting of ice cubes at -5°C and 1 atm of pressure
   b. Dissolution of sugar in a cup of hot coffee.
   c. The reaction of nitrogen atoms to form N_2 molecules at 25°C and 1 atm
   d. The bursting of an inflated balloon

3. Determine whether the following reactions show an increase or decrease in entropy and write $+\Delta S$ or $-\Delta S$ to indicate this.

a) $2KClO_3(s) \rightarrow 2KCl(s) + 2O_2(g)$ _____

b) $H_2O(l) \rightarrow H_2O(s)$ _____

c) $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$ _____

d) $NaCl(s) \rightarrow Na^+(aq) + Cl^-(aq)$ _____

e) $KCl(s) \rightarrow KCl(l)$ _____

f) $CO_2(s) \rightarrow CO_2(g)$ _____

4. Why is the increase in entropy of the system greater for the vaporization of a substance than for its melting?

5. For each of the following pairs, indicate which substance has the larger entropy:
   a. 1 mol of $P_4(g)$ at 300°C and 0.01 atm, or mol of As_4 (g) at 300°C and 0.01 atm.
   b. 0.5 mol of $N_2(g)$ at 298 K, 20-L volume, or 0.5 mole CH_4 (g) at 298 K, 20-L volume

6. Solid elemental sulfur can be produced, along with liquid water, by the reaction of hydrogen sulfide and sulfur dioxide gases. Calculate the standard free energy change for this reaction.

7. Nitrogen monoxide gas spontaneously decomposes into dinitrogen oxide and nitrogen dioxide gases. What is the standard entropy change for the decompositionof 3.0 mol of nitrogen monoxide?

8. What is the meaning of ΔG^o as compared with ΔG?

9. When does $\Delta G=O$?

10. For each of the following reactions determine if ΔG would be

11. For the Haber process : $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$
   a. what do you expect the sign on ΔS^o_{rxn} to be?
   b. calculate ΔS^o_{rxn} and compare it to the answer in a.

12. ΔH^o = -566.0 kJ and ΔS^o = -173.6 J/K for the reaction 2 CO (g) + O_2 (g) ↔ 2 CO_2 (g). Calculate ΔG^o at 298 K. Comment on spontaneity. What temperature is the system at equilibrium?

13. Consider the production of water from the elements. Do you expect ΔH to be positive or negative? Do you expect ΔS to be positive or negative? Do you expect ΔG to be positive or negative? Does a decrease or increase in T change spontaneity? Explain.

14. ΔH^o = + 167 kJ and ΔS^o = + 202 J/K for a process. Determine the temperature in which the system is at equilibrium?

15. For carbon disulfide, CS_2, the enthalpy and entropy for vaporization is 27.7 kJ/mol and 86.4 J/molK, respectively. What is the boiling point (°C) for CS_2? Will CS_2 boil above or below this temperature?

16. Calculate the temperature at which this reaction changes from being spontaneous to non spontaneous: Mg(s) + O_2(g) → MgO(s). Is the reaction spontaneous above or **below** this temperature?

17. What combination of signs for ΔH_{rxn} and ΔS_{rxn} lead to a reaction that is never favorable?

18. For the following reactions, decide comment on whether they are expected to be spontaneous or non-spontaneous and at what temperatures (high or low).

a. $N_2(g) + 3F_2(g) \rightarrow 2NF_3(g)$ $\Delta H^o = -249$ KJ $\Delta S^o = -278$ J/K

b. $N_2(g) + 3Cl_2(g) \rightarrow 2NCl_3(g)$ $\Delta H^o = -460$ KJ $\Delta S^o = -275$ J/K

c. $2POCl_3(g) \rightarrow 2PCl_3(g) + O_2(g)$ $\Delta H^o = 572$ KJ $\Delta S^o = 179$ J/K

19. a. Calculate the standard free energy change, ΔG°, for the following at 25 °C:

$$MgO(s) + C(graphite) \rightarrow Mg(s) + CO(g)$$

$\Delta H° = 491.18$ kJ $\Delta S° = 197.67$ J/K

b. is this reaction spontaneous at 25°C? If not, at what temperature can we make this reaction spontaneous?

20. Consider the reaction of nitrogen monoxide and chlorine to form nitrosyl chloride:

2 NO(g) + Cl2(g) → 2 NOCl(g)

a) Calculate ΔG° for the reaction.

b) Calculate ΔG when pNO = 0.30 atm, pC l2= 0.10 atm, and pNOCl = 0.45 atm.

c) Is this reaction favoring the product side or the reactant side?

21. Most of the direct energy needs of a cell are provided by the reaction of adenosine 5'-triphosphate (ATP) to form adenosine 5'-diphosphate (ADP) and hydrogen phosphate ion (Pi):

ATP → ADP + Pi

ΔG° = –30.0 kJ/mol for this reaction.

What is ΔG when the concentrations in a cell are [ATP] = 3.2 × 10–3 M, [ADP] = 1.4 × 10–3 M, and [Pi] = 5.0 × 10–3 M?

22. The value of Ksp for iron(II) hydroxide is 7.9×10^{-16}. Use the equation $\Delta G° = -RT \ln K$ to determine the value of ΔG° for the solution reaction of this slightly soluble solid. How does this value compare to the value determined by using ΔGf° values?

23. At 25ºC the equilibrium constant for this reaction $CO(g) + 2H_2(g) \rightarrow CH_3OH(g)$ has the value $K_p = 2.1 \times 10^4$. Calculate $\Delta G^º_{rxn}$ for this reaction at this temperature.

24. Calculate K for $MgCO_3(s) \rightarrow MgO(s) + CO_2(g)$