Thermodynamics Test for College Chemistry II **Name___________________**

Part I (Multiple Choice) (3pts each)

1) For which of the following processes would ΔS be negative?
    a) the melting of ice
    b) the freezing of water
    c) the evaporation of a liquid
    d) the breakup of a large molecule into smaller molecules
    e) these all have positive ΔS values

2) If a reaction is spontaneous, what can be said about the reverse reaction under the same conditions?
    a) The reverse rxn is non-spontaneous.
    b) The reverse rxn is spontaneous also.
    c) The reverse rxn is at equilibrium.
    d) This cannot be determined.

3) Which of the following reactions would have a positive value for ΔS?
    a) $3\ NO(g) \rightarrow NO_2(g) + N_2O(g)$
    b) $2\ CO_2(g) \rightarrow 2\ CO(g) + O_2(g)$
    c) $2\ I(g) \rightarrow I_2(g)$
    d) $NH_3(g) \rightarrow NH_3(l)$
    e) None of these rxns would have a positive ΔS.

4) Under which one of the following conditions will the following reaction be spontaneous as written? $2\ CO(g) + O_2(g) \rightarrow 2\ CO_2(g)$
   $\Delta H^o = -565.97$ kJ/mol $\Delta S^o = -173.0$ J/mol K

    a) spontaneous at all temperatures
    b) spontaneous at high temperatures
    c) spontaneous at low temperatures
    d) not spontaneous at any temperature

5) The Second Law of Thermodynamics states that:
    a) the entropy of a perfect crystal is zero at a temperature of 0 K.
    b) a reaction is spontaneous when $k_c = k_p$
    c) the energy in a reaction may not be created or destroyed.
    d) Exothermic reactions tend to be spontaneous.
    e) The entropy of the universe must increase for a process to occur spontaneously.

6) Which of the following correctly describes a reaction at equilibrium?
    a) $\Delta G^o = 1$ d) $\Delta G = 0$
    b) $k = 1$ e) $\ln k = 0$
    c) $\Delta G = \Delta G^o$

Part II Problems:

1) Would you expect the following reactions to be spontaneous at **low, high, all, or no** temperatures?

$N_2 (g) + 3 F_2 (g) \rightarrow 2NF_3 (g)$ $\Delta H^0 = -249$ kJ

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$N_2 (g) + 3Cl_2 (g) \rightarrow 2 NCl_3 (g)$ $\Delta H^0 = +460$ kJ

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$2 NF_2 (g) \rightarrow N_2F_4 (g)$ $\Delta H^0 = -85$ kJ

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$2H_2O (l) \rightarrow 2H_2 (g) + O_2 (g)$ $\Delta H^0 = +485$ kJ

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$2 POCl_3 (g) \rightarrow 2 PCl_3 (g) + O_2 (g)$ $\Delta H^0 = -515$ kJ

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2) The standard molar enthalpies of formation of $KClO_3$ (s), KCl (s), and O_2 (g) are -391 kJ, -435.9 kJ, and 0 kJ respectively. ΔS^0 for the reaction is +0.4944 kJ/K.

$$2KClO_3 (s) \rightarrow 2KCl (s) + 3 O_2 (g)$$

What is the ΔH^0 and the ΔG^0 for this reaction at 298 K ? Is it spontaneous? Why?

3) The standard molar free energies of formation (ΔG^0_f of NH_3, N_2H_4, and H_2) are -16.66 kJ, +159.4 kJ, and 0 kJ, respectively. What is the ΔG^0 of the reaction

$$2 NH_3 (g) \rightarrow N_2H_4 (g) + H_2 (g)$$

Is it spontaneous? Why?

4) Write the thermodynamic equilibrium constant for 5the following reversible reactions and tell if the constant is k_p, k_c, or k.

a) $2\ RbCl\ (s) + 3\ O_2\ (g) \leftrightarrow 2\ RbClO_3\ (s)$ ______________________

b) $2\ CH_4\ (g) \leftrightarrow C_2H_6\ (g) + H_2\ (g)$ ______________________

c) $C_2H_2\ (g) + 4\ Cl_2\ (g) \leftrightarrow 2\ CCl_4\ (l) + H_2\ (g)$ ______________________

d) $NH_3\ (aq) + H_2O\ (l) \leftrightarrow NH_4^+\ (aq) + OH^-\ (aq)$ ______________________

e) $Mg\ (s) + 2\ HCl\ (aq) \leftrightarrow Mg^{-2}\ (aq) + 2Cl^-\ (aq) + H_2\ (g)$

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5) In the chemical reaction $N_2H_4\ (g) \rightarrow N_2\ (g) + 2H_2\ (g)$, the partial pressures of the gases are 6.0 atm, 0.001 atm, and 0.0002 atm respectively. What is the equilibrium K_p for the reaction and what is the ΔG^0 of the reaction at 298 K? Is the reaction spontaneous? Why?

6) Given the following data at 298 K,

	ΔS^0_f (J/mol-K)	ΔH^0_f (kJ/mol)
NO_2 (g)	240.45	33.8
N_2O_4 (G)	304.33	9.66

a) Calculate the ΔH^0, ΔS^0, and then the ΔG^0 (use Free Energy equation) for the following reaction:

ΔH^0 =____________________

ΔS^0 = ____________________

$2NO_2$ (g) $\leftrightarrow$ N_2O_4 (g) ΔG^0 = ____________________

b) Is the formation of N_2O_4 (g) spontaneous? ___________________________

c) What is the value of the equilibrium constant for this reaction? K_p =______________________

7) For the reaction **PCl_5 (g) $\leftrightarrow$ PCl_3 (g) + Cl_2 (g)** at 298 K, $k_p = 1.87 \times 10^{-7}$, $\Delta S^0 = 181.92$ J/mol-K.

a) Is this reaction spontaneous at 298K? Explain why or why not.
b) Compute the value of ΔH^0 for the reaction.
c) Compute ΔG^0 for this reaction at 344 K.

a) ____
b) ΔH^0 = __________________
c) ΔG^0 at 46^0C =____________________

Needed Information

$\Delta G^0 = -RT \ln k$

$\Delta G^0 = \Delta H^0 - T\,\Delta S^0$

$R = 8.314 \times 10^{-3}$ **(units in kJ)**

k = Products/Reactants (power of coefficient)

$\Delta H^0_{rxn} = \sum n\Delta H_{f(prod)} - \sum m\Delta H_{f(react)}$

$\Delta S^0_{rxn} = \sum n\Delta S_{f(ptod)} - \sum m\Delta S_{f(react)}$

$\Delta G^0_{rxn} = \sum n\Delta G_{f(prod)} - \sum m\Delta G_{f(react)}$