CHM 112 **Chapter 16 Extra Credit: Thermodynamics** **Name: _____**

1. Which of the following processes are spontaneous and which are nonspontaneous?

   a) spreading of the fragrance of perfume or air freshener in a room = Spontaneous

   b) cleaning your room = Nonspontaneous

   c) $2H_2O\ (l) \rightarrow 2H_2\ (g) + O_2\ (g)$ (at room temperature, 1 atm pressure) = Nonspontaneous

   d) Building a house of cards = Nonspontaneous

2. Predict the sign of entropy change (positive or negative) for the following processes/reactions

   a) a lake freezing negative

   b) $SO_2(g) + CaO(s) \rightarrow CaSO_3(s)$ negative

   c) $NH_3(g) + HCl(g) \rightarrow NH_4Cl\ (s)$ negative

   d) $4\ CO_2\ (g) + 2\ H_2O\ (g) \rightarrow 2\ C_2H_2\ (g) + 5\ O_2(g)$ Positive

   e) $N_2H_4\ (g) \rightarrow N_2(g) + 2\ H_2(g)$ Positive

3. Using the values for standard molar entropies (S°) from the Appendix in your text book, calculate ΔS° for the following reactions at 25°C.

   a) $CH_3OH\ (l) \rightarrow CO\ (g) + 2\ H_2(g)$ 332 J/K

   b) $N_2H_4(l) + H_2(g) \rightarrow 2\ NH_3(g)$ 133.8 J/K

   c) $NH_3(g) + 5\ O_2(g) \rightarrow 4\ NO(g) + 6\ H_2O(g)$ 757.2 J/K

4. Consider the following reaction at constant P. Use the information here to determine the value of ΔS_{surr} at 355 K. Predict whether or not this reaction will be spontaneous at this temperature.

   $2\ NO(g) + O_2(g) \rightarrow 2\ NO_2(g)$ ΔH = -114 kJ 321 J/K

5. Above what temperature does the following reaction become nonspontaneous?

   $2\ H_2S(g) + 3\ O_2(g) \rightarrow 2\ SO_2(g) + 2\ H_2O(g)$ Given: ΔH = -1036 kJ; ΔS = -153.2 J/K

   T<6760 K

6. What is the minimum temperature required for the spontaneous conversion of $CCl_4(l)$ to $CCl_4(g)$
   Given: $\Delta H°_{(vap)}$ is 57.3 kJ/mol and $\Delta S°_{(vap)}$ is 164 J/(mol K) ?

   T>349 K

7. Using the data in Sapling, calculate the standard Gibbs free energy change (ΔG°) for the following reactions at 25.0°C. **In each case, indicate whether the reaction is spontaneous or not.**

The ΔG° for $H_2SO_4(l)$ is -690 kJ/mole and is incorrect in the back of Openstax!

   a) $SO_3(g) + H_2O\ (l) \leftrightarrows H_2SO_4\ (l)$ -81.8 kJ spontaneous

   b) $2\ HgO(s) \leftrightarrows 2\ Hg(l) + O_2(g)$ +117 kJ nonspontaneous

   c) $2\ HNO_3(aq) + NO(g) \leftrightarrows 3\ NO_2(g) + H_2O(l)$ +51 kJ nonspontaneous

8. For each of the reactions listed in 7, calculate the value of the equilibrium constant K at 25.0°C.

a) $SO_3(g) + H_2O(l) \leftrightarrows H_2SO_4(l)$ $K = 2.2 \times 10^{14}$

b) $2\ HgO(s) \leftrightarrows 2\ Hg(l) + O_2(g)$ $K = 3.1 \times 10^{-21}$

c) $2\ HNO_3(aq) + NO(g) \leftrightarrows 3\ NO_2(g) + H_2O(l)$ $K = 1.1 \times 10^{-9}$

9. Use Hess's law to calculate $\Delta G°_{rxn}$ for: $ClO(g) + O_3(g) \rightarrow Cl(g) + 2\ O_2(g)$
using the following information.

$2\ O_3(g) \rightarrow 3\ O_2(g)$ $\Delta G°_{rxn} = +489.6$ kJ

$Cl(g) + O_3(g) \rightarrow ClO(g) + O_2(g)$ $\Delta G°_{rxn} = -34.5$ kJ

524.1 kJ

10. Estimate $\Delta G°_{rxn}$ for the following reaction at 775 K.

$2\ Hg(g) + O_2(g) \rightarrow 2\ HgO(s)$ $\Delta H° = -304.2$ kJ; $\Delta S° = -414.2$ J/K

16.8 kJ

11. Calculate ΔG_{rxn} at 298 K under the conditions shown below for the following reaction.

$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$ $\Delta G° = +131.1$ kJ

$P(CO_2) = 0.00100$ atm

114 kJ

12. Consider the reaction $N_2O_4(g) \rightleftarrows 2\ NO_2(g)$

a) Using the data in your textbook, calculate the Gibbs free energy change ($\Delta G°$) for the reaction at 298 K.

2.8 kJ

b) Calculate the value of K_{eq} at 298 K

K = .32

c) Calculate ΔG at 298 K when the partial pressures for N_2O_4 and NO_2 are 10.5 and 0.50 atm respectively.

-6.5 kJ

13. Consider the reaction $C(s) + 2\ H_2(g) \rightarrow CH_4(g)$

a) Using the data in your textbook, calculate $\Delta H°$ and $\Delta S°$ for the reaction at 298 K.

b) Estimate $\Delta G°$ for the reaction at 400K. (is the reaction more or less spontaneous at high temperature?)

-42.3 kJ (less spontaneous at high Temp)

The following are multiple choice questions

14. Melting of a solid is an example of a process for which

(A) ΔH, Δ S, and ΔG are positive at all temperatures.

(B) Δ H and Δ S are positive.

(C) ΔG is negative at low temperatures, positive at high temperatures.

(D) Δ H = ΔS

15. For the following process: $2Cl(g) \rightarrow Cl_2(s)$

(A) ΔH is + and ΔS is + for the reaction.

(B) ΔH is – and ΔS is – for the reaction.

(C) ΔH is + and ΔS is – for the reaction.

(D) ΔH is – and ΔS is + for the reaction.

(E) ΔG is + for all temperatures

16. A reaction is nonspontaneous at all temperatures if

(A) ΔH and Δ S are both positive.

(B) Δ H and Δ S are both negative.

(C) Δ H is positive and Δ S is negative.

(D) Δ H is negative and ΔS is positive.