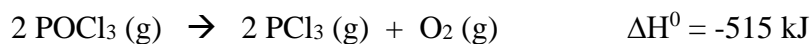
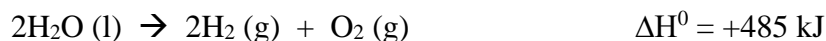
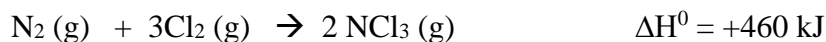
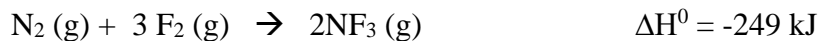


**Part I** (Multiple Choice) (3pts each)

- 1) For which of the following processes would  $\Delta S$  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  $\Delta S$  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  $\Delta S$ ?
  - a)  $3 \text{NO}(\text{g}) \rightarrow \text{NO}_2(\text{g}) + \text{N}_2\text{O}(\text{g})$
  - b)  $2 \text{CO}_2(\text{g}) \rightarrow 2 \text{CO}(\text{g}) + \text{O}_2(\text{g})$
  - c)  $2 \text{I}(\text{g}) \rightarrow \text{I}_2(\text{g})$
  - d)  $\text{NH}_3(\text{g}) \rightarrow \text{NH}_3(\text{l})$
  - e) None of these rxns would have a positive  $\Delta S$ .
  
- 4) Under which one of the following conditions will the following reaction be spontaneous as written?  $2 \text{CO}(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2 \text{CO}_2(\text{g})$   
 $\Delta H^\circ = -565.97 \text{ kJ/mol}$        $\Delta S^\circ = -173.0 \text{ J/mol K}$ 
  - 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)  $\Delta G^\circ = 1$
  - b)  $k = 1$
  - c)  $\Delta G = \Delta G^\circ$
  - d)  $\Delta G = 0$
  - e)  $\ln k = 0$

**Part II** Problems:

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

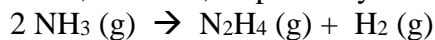


- 2) The standard molar enthalpies of formation of  $\text{KClO}_3(\text{s})$ ,  $\text{KCl}(\text{s})$ , and  $\text{O}_2(\text{g})$  are  $-391 \text{ kJ}$ ,  $-435.9 \text{ kJ}$ , and  $0 \text{ kJ}$  respectively.  $\Delta S^0$  for the reaction is  $+0.4944 \text{ kJ/K}$ .



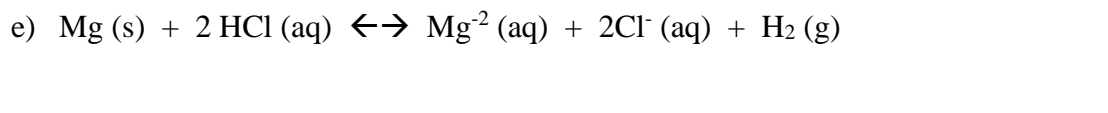
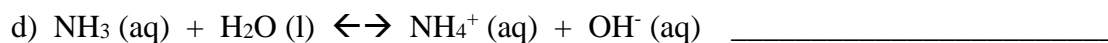
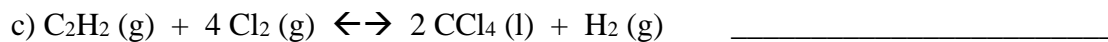
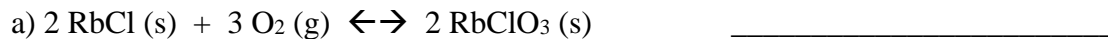
What is the  $\Delta H^0$  and the  $\Delta G^0$  for this reaction at  $298 \text{ K}$ ? Is it spontaneous? Why?

- 3) The standard molar free energies of formation ( $\Delta G^0_f$  of  $\text{NH}_3$ ,  $\text{N}_2\text{H}_4$ , and  $\text{H}_2$ ) are  $-16.66 \text{ kJ}$ ,  $+159.4 \text{ kJ}$ , and  $0 \text{ kJ}$ , respectively. What is the  $\Delta G^0$  of the reaction



Is it spontaneous? Why?

4) Write the thermodynamic equilibrium constant for the following reversible reactions and tell if the constant is  $K_p$ ,  $K_c$ , or  $K$ .

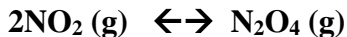


5) In the chemical reaction  $\text{N}_2\text{H}_4 \text{(g)} \rightarrow \text{N}_2 \text{(g)} + 2\text{H}_2 \text{(g)}$ , the partial pressures of the gases are 6.0 atm, 0.001 atm, and 0.0002 atm respectively. What is the equilibrium  $K_p$  for the reaction and what is the  $\Delta G^0$  of the reaction at 298 K? Is the reaction spontaneous? Why?

6) Given the following data at 298 K,

	$\Delta S^0_f$ ( J/mol-K)	$\Delta H^0_f$ ( kJ/mol)
NO <sub>2</sub> (g)	240.45	33.8
N <sub>2</sub> O <sub>4</sub> (G)	304.33	9.66

a) Calculate the  $\Delta H^0$ ,  $\Delta S^0$ , and then the  $\Delta G^0$  (use Free Energy equation) for the following reaction:



$$\Delta H^0 = \underline{\hspace{2cm}}$$

$$\Delta S^0 = \underline{\hspace{2cm}}$$

$$\Delta G^0 = \underline{\hspace{2cm}}$$

b) Is the formation of N<sub>2</sub>O<sub>4</sub> (g) spontaneous? \_\_\_\_\_

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

$$K_p = \underline{\hspace{2cm}}$$

7) For the reaction  $\text{PCl}_5(\text{g}) \leftrightarrow \text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g})$  at 298 K,  $k_p = 1.87 \times 10^{-7}$ ,  $\Delta S^0 = 181.92$  J/mol-K.

- Is this reaction spontaneous at 298K? Explain why or why not.
- Compute the value of  $\Delta H^0$  for the reaction.
- Compute  $\Delta G^0$  for this reaction at 344 K.

a) \_\_\_\_\_

b)  $\Delta H^0 =$  \_\_\_\_\_

c)  $\Delta G^0$  at 46°C = \_\_\_\_\_

### Needed Information

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

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

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

$k$  = Products/Reactants (power of coefficient)

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

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

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