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

   b) cleaning your room

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

   d) Building a house of cards

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

   a) a lake freezing

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

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

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

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

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) $+ 2 H_2(g)$

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

   c) $NH_3(g) + 5 O_2(g) \rightarrow 4 NO(g) + 6 H_2O(g)$

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

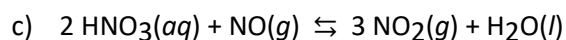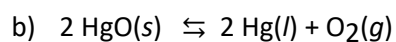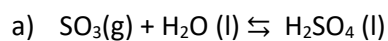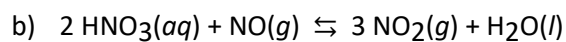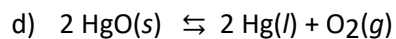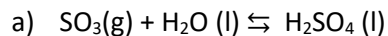5.   Above what temperature does the following reaction become nonspontaneous?

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

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) ?
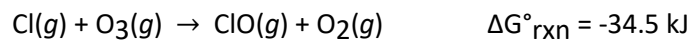
7. Using the data in the appendix of your text book, calculate the standard Gibbs free energy change ($\Delta G°$) for the following reactions at 25.0°C. **In each case, indicate whether the reaction is spontaneous or not**

       a) $SO_3(g) + H_2O (l) \leftrightarrows H_2SO_4 (l)$

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

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

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)

   d) $2 HgO(s) \leftrightarrows 2 Hg(l) + O_2(g)$

   b) $2 HNO_3(aq) + NO(g) \leftrightarrows 3 NO_2(g) + H_2O(l)$

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

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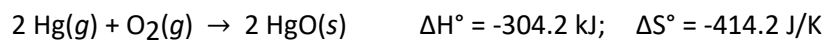
11. Calculate ΔG_{rxn} at 298 K under the conditions shown below for the following reaction.

   $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$ $\Delta G° = +131.1$ kJ
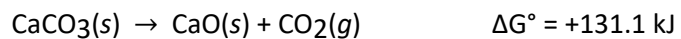
   $P(CO_2) = 0.00100$ atm

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.

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

   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.

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?)

The following are multiple choice questions

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

(A) ΔH, ΔS, and ΔG are positive at all temperatures.　　　　(B) ΔH and ΔS are positive.

(C) ΔG is negative at low temperatures, positive at high temperatures.　　(D) $\Delta H = \Delta S$

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 ΔS are both positive.　　　(B) ΔH and ΔS are both negative.

(C) ΔH is positive and ΔS is negative.　　(D) ΔH is negative and ΔS is positive.