

PRACTICE TEST QUESTIONS

See notes on taking practice test in the Preface

1. Which of the following processes are spontaneous?
- melting of ice at $-10\text{ }^\circ\text{C}$ and 1 atm pressure
 - evaporation of water at $30\text{ }^\circ\text{C}$ when the relative humidity is less than 100 percent
 - Water + NaCl(s) \rightarrow salt solution
2. Choose the substance that has the larger standard entropy at $25\text{ }^\circ\text{C}$ from each pair:
- $\text{H}_2\text{O}(l)$ or $\text{H}_2\text{O}(g)$
 - $\text{SiO}_2(s)$ or $\text{CO}_2(g)$
 - $\text{Ag}^+(g)$ or $\text{Ag}^+(aq)$
 - $\text{F}_2(g)$ or $\text{Cl}_2(g)$
 - $2\text{Cl}(g)$ or $\text{Cl}_2(g)$
3. Predict, using the intuitive ideas about entropy, whether ΔS_{sys} will be positive, negative, or essentially zero for each of the following:
- $\text{Ca}(\text{OH})_2(s) + \text{CO}_2(g) \rightarrow \text{CaCO}_3(s) + \text{H}_2\text{O}(g)$ ~ 0
 - $\text{CuSO}_4(s) \rightarrow \text{Cu}^{2+}(aq) + \text{SO}_4^{2-}(aq)$ $+$
 - $2\text{HCl}(g) + \text{Br}_2(l) \rightarrow 2\text{HBr}(g) + \text{Cl}_2(g)$ $+$
 - $3\text{H}_2(g) + \text{N}_2(g) \rightarrow 2\text{NH}_3(g)$ $-$
 - $\text{Cu}^{2+}(aq) + 4\text{NH}_3(aq) \rightarrow \text{Cu}(\text{NH}_3)_4^{2+}(aq)$ $-$

4. At the boiling point, $35\text{ }^\circ\text{C}$, the heat of vaporization of MoF_6 is 25 kJ/mol . Calculate ΔS for the vaporization of MoF_6 .

$$81 \frac{\text{J}}{\text{mol}\cdot\text{K}}$$

5. Calculate $\Delta G_{\text{rxn}}^\circ$ for the following reaction at 298 K : $\Delta G = -24.7 \frac{\text{kJ}}{\text{mol}}$
- $$2\text{H}_2(g) + \text{CO}(g) \rightleftharpoons \text{CH}_3\text{OH}(g)$$
- given that $\Delta H^\circ = -90.7\text{ kJ/mol}$ and $\Delta S^\circ = -221.5\text{ J/K}\cdot\text{mol}$ for this process.

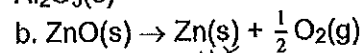
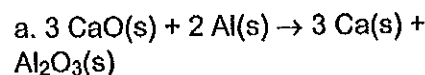
6. For the reaction at 298 K , $\Delta S = -111 \frac{\text{J}}{\text{K}\cdot\text{mol}}$
- $$\text{Mg}(s) + \frac{1}{2}\text{O}_2(g) \rightarrow \text{MgO}(s)$$
- $\Delta H^\circ = -602\text{ kJ/mol}$ and $\Delta G^\circ = -569\text{ kJ/mol}$. Calculate ΔS° .

8. Which of the following three reactions will have the largest equilibrium constant?

- $\text{N}_2 + \text{O}_2 \rightleftharpoons 2\text{NO}$
- $\text{N}_2 + 2\text{O}_2 \rightleftharpoons \text{N}_2\text{O}_4$
- $\text{N}_2 + \frac{1}{2}\text{O}_2 \rightleftharpoons \text{N}_2\text{O}$

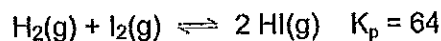
Given: $\Delta G_f^\circ(\text{NO}) = +86.7\text{ kJ/mol}$
 $\Delta G_f^\circ(\text{N}_2\text{O}_4) = +98.3\text{ kJ/mol}$
 $\Delta G_f^\circ(\text{N}_2\text{O}) = +103.6\text{ kJ/mol}$

7. Using Appendix 3 of the text, calculate ΔG° values for the following reactions:



$$\Delta G = -236 \frac{\text{kJ}}{\text{mol}} \quad \Delta S = 318.2 \frac{\text{J}}{\text{mol}\cdot\text{K}}$$

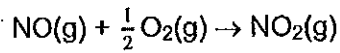
9. Given the equilibrium constant at $400\text{ }^\circ\text{C}$ for the reaction:



calculate the value of $\Delta G_{\text{rxn}}^\circ$ at this temperature.

$$-23.3 \frac{\text{kJ}}{\text{mol}}$$

10. Calculate ΔG_{rxn}° and K_p at 25 °C for the following reaction:



$$\Delta G = -34,35 \frac{\text{kJ}}{\text{mol}} \quad K_p = 1.28 \times 10^6$$

12. For the reaction: $\text{N}_2 + \text{O}_2 \rightarrow 2 \text{NO}$
the following are given:

$$\Delta H^\circ = 180.7 \text{ kJ/mol and } \Delta S^\circ = 24.7 \text{ J/K}\cdot\text{mol.}$$

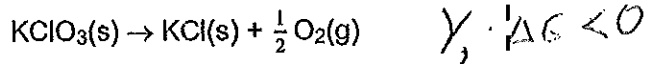
- Is this reaction spontaneous at 25 °C?
- Above what temperature will this reaction become spontaneous under standard conditions?

a. 0

$$\Delta G > 0$$

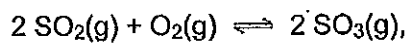
$$b. T = 7320 \text{ K}$$

11. The synthesis of $\text{O}_2\text{(g)}$ can be carried out by the decomposition of KClO_3 :



for which $\Delta H^\circ = -44.7 \text{ kJ/mol}$ and $\Delta S^\circ = +247.2 \text{ J/K}\cdot\text{mol}$. Is this reaction spontaneous at 25 °C under standard conditions?

13. For the reaction,



$K_p = 7.4 \times 10^4$ at 700 K. If, in a reaction vessel at 700 K, we have the following partial pressures, what is ΔG ?

$$P_{\text{SO}_2} = 1.2 \text{ atm} \quad P_{\text{O}_2} = 0.5 \text{ atm}$$

$$P_{\text{SO}_3} = 50 \text{ atm}$$

Predict the direction of reaction.

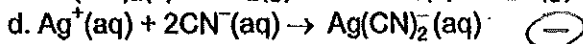
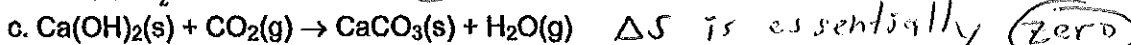
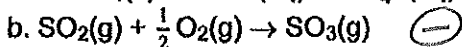
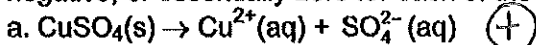
$$\Delta G = -17.8 \frac{\text{kJ}}{\text{mol}}$$

EXERCISES & PROBLEMS

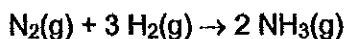
1. For each pair of substances, choose the one having the higher standard entropy value at 25 °C.

- a. CS₂(s) or CS₂(l) b. SO₂(g) or CO₂(g) c. BaSO₄(s) or BaSO₄(aq)

2. Predict, using the intuitive ideas about entropy, whether ΔS_{rxn} will be positive, negative, or essentially zero for each of the following:



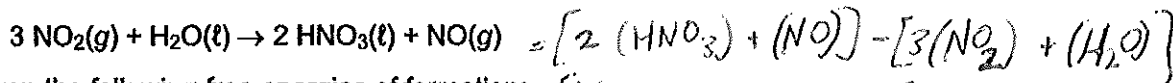
3. Using tabulated values, calculate ΔS° for the following reaction:



-198.5 J / K·mol

$[2 \Delta S^\circ(\text{NH}_3)] - [\Delta S^\circ(\text{N}_2) + 3 \Delta S^\circ(\text{H}_2)]$

4. Calculate ΔG°_{rxn} for the following reaction:

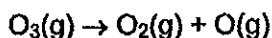


Given the following free energies of formation:

	ΔG _f ^o (kJ/mol)
H ₂ O(l)	-237.2
HNO ₃ (l)	-79.9
NO(g)	86.7
NO ₂ (g)	51.8

$= [2(\text{HNO}_3) + (\text{NO})] - [3(\text{NO}_2) + (\text{H}_2\text{O})]$
 $= [2(-79.9) + 86.7] - [3(51.8) + (-237.2)]$
 $= [-73.1] + [81.8]$
 $= \boxed{8.7 \frac{\text{kJ}}{\text{mol}}}$

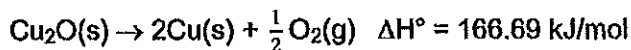
5. Calculate ΔG°_{rxn} for the following reaction at 298 K:



Given: ΔH° = 106.5 kJ and ΔS° = 127.3 J/K.

$\Delta G^\circ = \Delta H - T \Delta S$
 $= 106.5 - 298(0.1273 \frac{\text{kJ}}{\text{K}})$
 $= \boxed{68.6 \frac{\text{kJ}}{\text{mol}}}$

6. The following reaction is nonspontaneous at 25 °C.



$\Delta H = T \Delta S \quad \therefore T = \frac{\Delta H}{\Delta S} = \frac{166.69}{0.0683}$

If ΔS° = 68.3 J/K, above what temperature will the reaction become spontaneous? 2440 K

7. The enthalpy of vaporization of mercury is 58.5 kJ/mol and the normal boiling point is 630 K. What is the entropy of vaporization of mercury?

$\Delta H_v = 58.5 \frac{\text{kJ}}{\text{mol}}$
 $T = 630 \text{ K}$
 $\Delta S = \frac{\Delta H}{T} = \frac{58.5 \frac{\text{kJ}}{\text{mol}}}{630 \text{ K}}$
 $= 0.0930 \frac{\text{kJ}}{\text{mol} \cdot \text{K}}$
 $= \boxed{93.0 \frac{\text{J}}{\text{mol} \cdot \text{K}}}$

8. What is the sign of ΔG for the melting of ice at 5 °C?

(-)

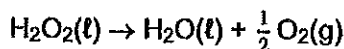
$$e^{-\left(\frac{-1.191 \times 10^5}{2497.6}\right)} = e^{(48.0)}$$

$$\ln K_p = -\frac{\Delta G}{RT}$$

$$K_p = e^{-\left(\frac{\Delta G}{RT}\right)}$$

$$= e^{-\left(\frac{1.191 \times 10^5 \text{ J/mol}}{(8.314 \text{ J/mol}\cdot\text{K})(298)}\right)}$$

9. Hydrogen peroxide (
- H_2O_2
-) decomposes according to the equation:



$$\Delta H^\circ = -98.2 \text{ kJ/mol}$$

$$\Delta S^\circ = +70.1 \text{ J/K}\cdot\text{mol}$$

$$\textcircled{2} \quad \Delta G^\circ = -RT \ln K_p$$

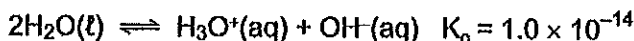
$$\textcircled{1} \quad \Delta G^\circ = \Delta H - T\Delta S$$

$$= (-98.2) - (298)(+0.0701)$$

$$= -119.0 \frac{\text{kJ}}{\text{mol}}$$

- a. Is this reaction spontaneous at 25 °C? \textcircled{Y}
- b. From the following data, calculate the value of K_p for this reaction at 25 °C.

10. The autolization of water at 25 °C has the equilibrium constant,

Calculate the value of ΔG° for this reaction.

11. The equilibrium constant for the reaction:



is the solubility product constant, $K_{sp} = 7.7 \times 10^{-13}$ at 25 °C. Calculate ΔG for the reaction when $[\text{Ag}^+] = 1.0 \times 10^{-2} \text{ M}$ and $[\text{Br}^-] = 1.0 \times 10^{-3} \text{ M}$. Is the reaction spontaneous or nonspontaneous at these concentrations?

12. Explain the difference between
- ΔG
- and
- ΔG°
- .

13. Calculate
- ΔG
- for the following reaction at 25 °C if the pressure of
- CO_2
- is 0.001 atm

Given: $\Delta H^\circ = 177.8 \text{ kJ/mol}$ and $\Delta S^\circ = 160.5 \text{ J/K}\cdot\text{mol}$.

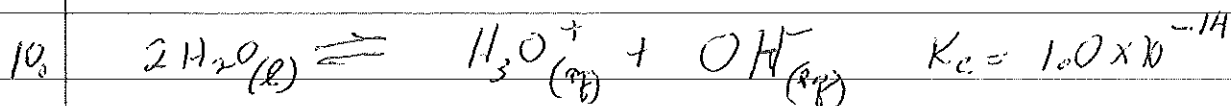
14. When the environment is contaminated by a toxic chemical spill or an oil spill, the substance tends to disperse. How is this consistent with the second law of thermodynamics? In the same regard, which requires less work: cleaning the environment after a spill, or keeping the substance contained before a spill?

* Spreads out \rightarrow more disorder, \therefore inc in S

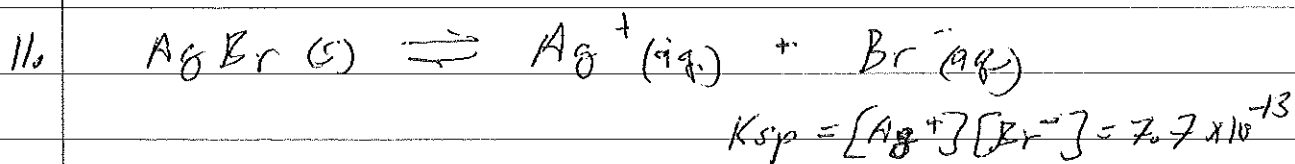
* In cleaning, its the reverse process, \therefore work must be done in the nonspontaneous process

* Keeping the substance contained take less work

W.S. CH 18 Exercises & Problems



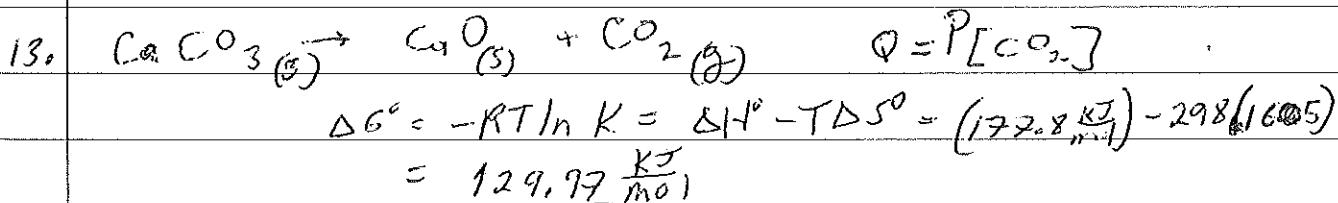
$$\begin{aligned} \Delta G^\circ &= -RT \ln K \\ &= -(8.314 \frac{\text{J}}{\text{mol}\cdot\text{K}})(298 \text{ K}) \ln (1.0 \times 10^{-14}) \\ &= -(-79867 \frac{\text{J}}{\text{mol}}) = \boxed{79.9 \frac{\text{KJ}}{\text{mol}}} \end{aligned}$$



$$\begin{aligned} \Delta G^\circ &= -RT \ln K_{sp} = -(8.314)(298) \ln (7.7 \times 10^{-13}) \\ &= \boxed{69.1 \frac{\text{KJ}}{\text{mol}}} \end{aligned}$$

$$\begin{aligned} \Delta G &= \Delta G^\circ + RT \ln Q \\ &= 69.1 \frac{\text{KJ}}{\text{mol}} + (2477.6) \ln [1.0 \times 10^{-2}][1.00 \times 10^{-3}] \\ &\quad + (-28.524 \frac{\text{KJ}}{\text{mol}}) \\ &= \boxed{40.6 \frac{\text{KJ}}{\text{mol}}} \quad \therefore \text{Rxn is Non spontaneous} \end{aligned}$$

12. ΔG° is the free Energy change at standard state
 concs. are 1 atm, 1 molar



$$\begin{aligned} \Delta G &= \Delta G^\circ + RT \ln Q = (130.0 \frac{\text{KJ}}{\text{mol}}) + (2477 \frac{\text{J}}{\text{mol}}) \ln [0.001] \\ &= \boxed{112.9 \frac{\text{KJ}}{\text{mol}}} \end{aligned}$$