

CH 223 Practice Problem Set #1

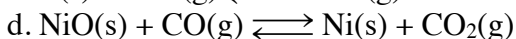
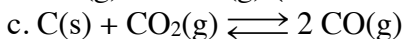
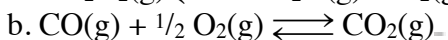
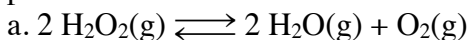
This is a *practice problem set* and not the actual graded problem set that you will turn in for credit.

Answers to each problem can be found at the end of this assignment.

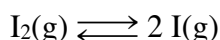
Covering: **Chapter Thirteen and Chapter Guide One**

Important Tables and/or Constants: **R = 0.082057 L atm mol⁻¹ K⁻¹, 760 mm Hg = 1 atm**

1. Write equilibrium constant expressions for the following reactions. For gases use either pressures or concentrations.



2. $K = 5.6 \times 10^{-12}$ at 500 K for the dissociation of iodine molecules to iodine atoms.



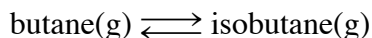
A mixture has $[\text{I}_2] = 0.020 \text{ mol/L}$ and $[\text{I}] = 2.0 \times 10^{-8} \text{ mol/L}$. Is the reaction at equilibrium (at 500 K)? If not, which way must the reaction proceed to reach equilibrium?

3. The reaction



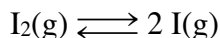
was examined at 250 °C. At equilibrium, $[\text{PCl}_5] = 4.2 \times 10^{-5} \text{ mol/L}$, $[\text{PCl}_3] = 1.3 \times 10^{-2} \text{ mol/L}$, and $[\text{Cl}_2] = 3.9 \times 10^{-3} \text{ mol/L}$. Calculate K for the reaction.

4. The value of K for the interconversion of butane and isobutane is 2.5 at 25 °C.



If you place 0.017 mol of butane in a 0.50 L flask at 25 °C and allow equilibrium to be established, what will be the equilibrium concentrations of the two forms of butane?

5. The equilibrium constant for the dissociation of iodine molecules to iodine atoms



is 3.76×10^{-3} at 1000 K. Suppose 0.105 mol of I_2 is placed in a 12.3 L flask at 1000 K. What are the concentrations of I_2 and I when the system comes to equilibrium?

6. Dinitrogen trioxide decomposes to NO and NO_2 in an endothermic process ($\Delta H = 40.5 \text{ kJ/mol}$).



Predict the effect of the following changes on the position of the equilibrium; that is, state which way the equilibrium will shift (left, right, or no change) when each of the following changes is made.

a. adding more $\text{N}_2\text{O}_3(\text{g})$

b. adding more $\text{NO}_2(\text{g})$

c. increasing the volume of the reaction flask

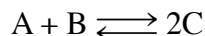
d. lowering the temperature

7. Consider the isomerization of butane with an equilibrium constant of $K = 2.5$ (see question #4, above.) The system is originally at equilibrium with $[\text{butane}] = 1.0 \text{ M}$ and $[\text{isobutane}] = 2.5 \text{ M}$.

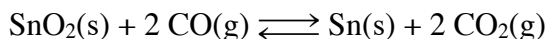
a. If 0.50 mol/L of isobutane is suddenly added and the system shifts to a new equilibrium position, what is the equilibrium concentration of each gas?

b. If 0.50 mol/L of butane is added and the system shifts to a new equilibrium position, what is the equilibrium concentration of each gas?

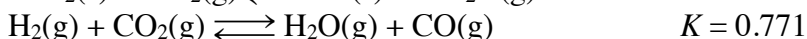
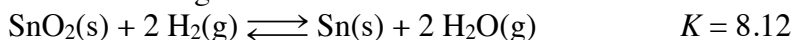
8. Which of the following correctly relates the equilibrium constants for the two reactions shown?



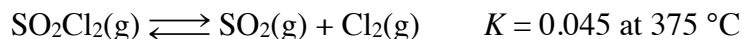
- a. $K_2 = 1/(K_1)^{1/2}$
 b. $K_2 = 1/K_1$
 c. $K_2 = K_1^2$
 d. $K_2 = -K_1^{1/2}$
9. Calculate K for the reaction



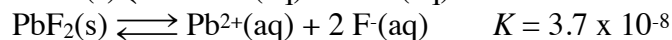
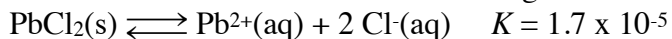
given the following information:



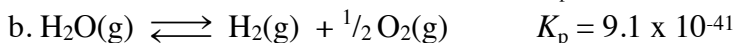
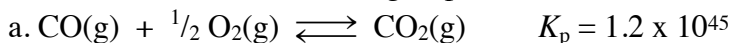
10. Ammonium hydrogen sulfide decomposes on heating. $\text{NH}_4\text{HS}(\text{s}) \rightleftharpoons \text{NH}_3(\text{g}) + \text{H}_2\text{S}(\text{g})$
 If K_p for this reaction is 0.11 at 25 °C (when the partial pressures are measured in atmospheres), what is the total pressure in the flask at equilibrium?
11. Sulfuryl chloride, SO_2Cl_2 , is a compound with very irritating vapors; it is used as a reagent in the synthesis of organic compounds. When heated to a sufficiently high temperature it decomposes to SO_2 and Cl_2 .



- a. Suppose 6.70 g of SO_2Cl_2 is placed in a 1.00 L flask and then heated to 375 °C. What is the concentration of each of the compounds in the system when equilibrium is achieved? What fraction of SO_2Cl_2 has dissociated?
- b. What are the concentrations of SO_2Cl_2 , SO_2 , and Cl_2 at equilibrium in the 1.00 L flask at 375 °C if you begin with a mixture of SO_2Cl_2 (6.70 g) and Cl_2 (1.00 atm)? What fraction of SO_2Cl_2 has dissociated?
- c. Compare the fractions of SO_2Cl_2 in parts (a) and (b). Do they agree with your expectations based on Le Chatelier's principle?
12. Neither PbCl_2 nor PbF_2 is appreciably soluble in water. If solid PbCl_2 and solid PbF_2 are placed in equal amounts of water in separate beakers, in which beaker is the concentration of Pb^{2+} greater? Equilibrium constants for these solids dissolving in water are as follows:



13. Characterize each of the following as product- or reactant- favored.



14. The reaction of hydrogen and iodine to give hydrogen iodide has an equilibrium constant, K_c , of 56 at 435 °C.
- a. What is the value of K_p ?
- b. Suppose you mix 0.45 mol of H_2 and 0.45 mol of I_2 in a 10.0 L flask at 435 °C. What is the total pressure of the mixture before and after equilibrium is achieved?
- c. What is the partial pressure of each gas at equilibrium?

Answers to the Practice Problem Set:

1. *Answers:*

$$\text{a. } K = \frac{[\text{H}_2\text{O}]^2[\text{O}_2]}{[\text{H}_2\text{O}_2]^2} \qquad K_p = \frac{P_{\text{H}_2\text{O}}^2 P_{\text{O}_2}}{P_{\text{H}_2\text{O}_2}^2}$$

$$\text{b. } K = \frac{[\text{CO}_2]}{[\text{CO}][\text{O}_2]^{1/2}} \qquad K_p = \frac{P_{\text{CO}_2}}{P_{\text{CO}} P_{\text{O}_2}^{1/2}}$$

$$\text{c. } K = \frac{[\text{CO}]^2}{[\text{CO}_2]} \qquad K_p = \frac{P_{\text{CO}}^2}{P_{\text{CO}_2}}$$

$$\text{d. } K = \frac{[\text{CO}_2]}{[\text{CO}]} \qquad K_p = \frac{P_{\text{CO}_2}}{P_{\text{CO}}}$$

2. No, $Q = 2.0 \times 10^{-14}$, and $Q < K$, so to the right (more products)

3. $K = 1.2$

4. [isobutane] = 0.024 M, and [butane] = 0.010 M

5. $[\text{I}_2] = 0.00614$ and $[\text{I}] = 0.00480$ M

6. a. right b. left c. right d. left

7. a. [butane] = 1.1 M, [isobutane] = 2.9 M; b. [butane] = 1.1 M, [isobutane] = 2.9 M

8. equation (a)

9. 13.7

10. 0.66 atm

11. a. $[\text{SO}_2\text{Cl}_2] = 0.020$ M, $[\text{SO}_2] = [\text{Cl}_2] = 0.030$ M, and fraction = 0.60 b. $[\text{SO}_2\text{Cl}_2] = 0.025$ M, $[\text{SO}_2] = 0.025$ M, $[\text{Cl}_2] = 0.044$ M, and fraction = 0.50 c. Yes, Le Chatelier's principle predicts equilibrium moves to the reactant side, confirmed

12. PbCl_2

13. a. product favored b. reactant favored c. product favored

14. a. $K_p = 56$ b. *before:* 5.2 atm *after:* 5.2 atm c. $P_{\text{H}_2} = P_{\text{I}_2} = 0.55$ atm, $P_{\text{HI}} = 4.1$ atm