1021SCG Chemistry 1A – Module 3: Physicochemical Concepts
Week 9

References and resources: Blackman, Bottle, Schmid, Mocerino and Wille, 3rd Edn., Chapter 9, Sections 9.1 – 9.5

Learning Objectives

You should be able to:

- Define chemical equilibrium and write the equilibrium constant expression in terms of the concentrations of reactants and products for K_c (reactions in solution); K_p (reactions in the gaseous state);
- Calculate equilibrium constants and equilibrium concentrations.
- Predict how an equilibrium mixture will change in response to the addition or removal of a product or reactant or a change in the pressure or temperature – Le Chatelier's principle,
- Understand the concept of the reaction quotient Q and how to use Q to predict the direction of a reaction.
- Apply the concept of equilibrium constants to acids and bases: K_a, K_b

Workshop and Study Questions

1. Write the equilibrium constant expressions K_c for the following reactions:

(a) $N_{2(g)} + 3\ H_{2(g)} \rightleftharpoons 2\ NH_{3(g)}$

(b) $Zn_{(s)} + 2\ HCl_{(g)} \rightleftharpoons ZnCl_{2(s)} + H_{2(g)}$

(c) $H_3CCOOH_{(aq)} \rightleftharpoons H_3CCOO^-_{(aq)} + H^+_{(aq)}$

2. Write the equilibrium constant expressions K_p for the following reactions:

(a) $H_{2(g)} + Cl_{2(g)} \rightleftharpoons 2\ HCl_{(g)}$

(b) $C_{(s)} + CO_{2(g)} \rightleftharpoons 2\ CO_{(g)}$

(c) $2\ N_2O_{5(g)} \rightleftharpoons 4\ NO_{2(g)} + O_{2(g)}$

3. Consider the following equilibrium system: $C_{(s)} + CO_{2(g)} \rightleftharpoons 2\ CO_{(g)}$ $\Delta H^{\emptyset} = 119.8$ kJ

How is the equilibrium shifted by the following:
(a) adding $CO_{2(g)}$
(b) adding $CO_{(g)}$
(c) adding $C_{(s)}$
(d) removing $CO_{(g)}$
(e) removing $CO_{2(g)}$
(f) increasing the temperature
(g) decreasing the temperature
(h) increasing the total pressure

(i) decreasing the total pressure
(j) adding a catalyst

4. For the reaction: $CO_{(g)} + O_{2(g)} \rightleftharpoons CO_{2(g)}$
(a) Balance the equation and write the equilibrium constant expression K_p.
(b) At equilibrium, the partial pressure of CO, O_2 and CO_2 are determined to be 2 atm each; calculate the value of K_p.

5. (a) Write the equilibrium constant expression K_{p1} for $2\ SO_{3(g)} \rightleftharpoons 2\ SO_{2(g)} + O_{2(g)}$
(b) Write the equilibrium constant expression K_{p2} for $2\ SO_{2(g)} + O_{2(g)} \rightleftharpoons 2\ SO_{3(g)}$
(c) If $K_{p1} = 2.4 \cdot 10^{-3}$ at 700°C, what is the value of K_{p2}?

6. For each of the following weak acids $H_3C\text{-}COOH$, NH_4^+ and HF
(a) Write the weak acid equilibria.
(b) Identify the conjugate base in (a) above.
(c) Write the K_a expression (where K_a is the equilibrium constant for the dissociation of an acid in aqueous solution).

7. For each of the following weak bases $H_3C\text{-}COO^-$, NH_3 and F^-
(a) Write the weak base equilibria.
(b) Identify the conjugate acid in (a) above.
(c) Write the K_b expression (where K_b is the equilibrium constant for the dissociation of a base in aqueous solution)

8. Calculate the pH of the following solutions:
(a) 0.0010 M HCl (HCl is a strong acid)
(b) 0.0010 M KOH (KOH is a strong base)
(c) 0.10 M $H_3C\text{-}COOH$ ($H_3C\text{-}COOH$ is a weak acid with $K_a = 1.8 \cdot 10^{-5}$)
(d) 0.10 M NH_3 (NH_3 is a weak base with $K_b = 1.8 \cdot 10^{-5}$)