

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

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

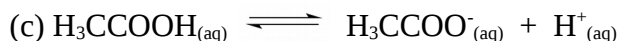
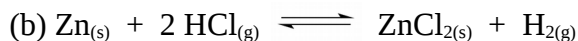
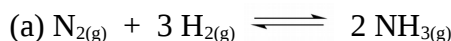
### Learning Objectives

You should be able to:

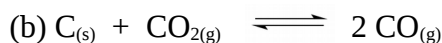
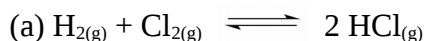
- Define chemical equilibrium and write the equilibrium constant expression in terms of the concentrations of reactants and products for  $K_c$  (reactions in solution);  $K_p$  (reactions in the gaseous state);
- Calculate equilibrium constants and equilibrium concentrations.
- Predict how an equilibrium 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:



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



3. Consider the following equilibrium system:  $\text{C}_{(\text{s})} + \text{CO}_{2(\text{g})} \rightleftharpoons 2 \text{CO}_{(\text{g})}$   $\Delta H^\ominus = 119.8 \text{ kJ}$

How is the equilibrium shifted by the following:

- adding  $\text{CO}_{2(\text{g})}$
- adding  $\text{CO}_{(\text{g})}$
- adding  $\text{C}_{(\text{s})}$
- removing  $\text{CO}_{(\text{g})}$
- removing  $\text{CO}_{2(\text{g})}$
- increasing the temperature
- decreasing the temperature
- increasing the total pressure

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

4. For the reaction:  $\text{CO}_{(g)} + \text{O}_{2(g)} \rightleftharpoons \text{CO}_{2(g)}$

- (a) Balance the equation and write the equilibrium constant expression  $K_p$ .
- (b) At equilibrium, the partial pressure of CO, O<sub>2</sub> and CO<sub>2</sub> are determined to be 2 atm each; calculate the value of  $K_p$ .

5. (a) Write the equilibrium constant expression  $K_{p1}$  for  $2 \text{SO}_{3(g)} \rightleftharpoons 2 \text{SO}_{2(g)} + \text{O}_{2(g)}$

(b) Write the equilibrium constant expression  $K_{p2}$  for  $2 \text{SO}_{2(g)} + \text{O}_{2(g)} \rightleftharpoons 2 \text{SO}_{3(g)}$

(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<sub>3</sub>C-COOH, NH<sub>4</sub><sup>+</sup> 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<sub>3</sub>C-COO<sup>-</sup>, NH<sub>3</sub> and F<sup>-</sup>

- (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<sub>3</sub>C-COOH (H<sub>3</sub>C-COOH is a weak acid with  $K_a = 1.8 \cdot 10^{-5}$ )
- (d) 0.10 M NH<sub>3</sub> (NH<sub>3</sub> is a weak base with  $K_b = 1.8 \cdot 10^{-5}$ )