7.2 Equilibrium Law in Chemical Reactions

- The equilibrium equation describes the relationship between reactants and products
- The numerical value of the equilibrium equation compares the amount of "product" that is formed (right hand side values) to the amount of "reactant" that is used
- The coefficients of a balanced equation are the exponents of the concentration values

$$aA + bB \leftrightarrow cC + dD$$

$$K_e = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$

(The textbook uses K, however, we will use K_e (equilibrium constant) to avoid confusion with the K(rate constant) value associated with rate.)

- The above equation is used with the concentrations of products and reactants when they reach equilibrium.
  Empirical evidence: page 439 table 1 and page 440 table 2
- We can use the same formula to determine if the reaction has reached equilibrium. Provided values can be placed into the expression and then its K value can be compared to the K_e
- The equilibrium law expression and its associated constant, K_e, describes the behaviour of almost all gaseous and aqueous chemical equilibria. *Solids and liquids have values that remain constant.*

The Equilibrium Constant and Reaction Kinetics

- Read this section to see how the equilibrium law equation is derived.

Calculating K_e

- Always work from a balanced equation, determine the equilibrium law equation, substitute, solve.
- Make sure values are in mol/L
- See examples. Page 443-445
- If the balanced chemical equation is written in reverse then the value of K must be inverted (1/K)

Ex. $A+B \rightarrow C+D$ vs $C+D \rightarrow A+B$

$$K_e = \frac{[C]^c[D]^d}{[A]^a[B]^b} \qquad 1/K_e = \frac{[A]^a[B]^b}{[C]^c[D]^d}$$

Heterogeneous Equilibria

- Homogeneous equilibria: all entities are in the same phase.
- Heterogeneous equilibria: reactants and products are in more than one phase. From before we only include (aq) and (g)

E.g. $NaCl_{(s)} \leftrightarrow Na^+_{(aq)} + Cl^-_{(aq)}$

$$K_e = [Na^+_{(aq)}]\,[Cl^-_{(aq)}]$$

  - We <u>ignore</u> the material in the <u>solid</u> or <u>liquid</u> state since their concentrations do not change. The term mol/L in the case of solids and liquids is equivalent to their density, which will not change during the reaction.

- Reactions involving ionic compounds – single or double displacement
  - Write equilibrium expressions only for net ionic equations

Limitations of Equilibrium Constants and Percent Reaction Values

- We previously learned that **rate of reaction** constant (K) was affected by many factors such as temperature, pressure, concentration, catalysts, etc.
- The **equilibrium constant (K_e)** is also affected by other factors. The equilibrium is temperature and pressure dependent. BUT catalysts do not affect the equilibrium state
- Also, the K_e value will only tell you the ratio of the amounts of products and reactants in a closed system. It does not tell you how fast the reaction takes place.

Magnitude of K

- $K >> 1$ products are heavily favoured and reaction nears completion.
- $K \cong 1$ concentrations of products and reactants are approximately equal at equilibrium.
- $K << 1$ reactants are heavily favoured and reactants do not tend to react.

Homework

- Practice 1,2,3,4,5,6,7
- Questions 1,2,3,4,5,6