Chemistry 30
Unit Two: Equilibrium Expressions and the Equilibrium Constant (5)

Equilibrium Constant (A quantitative expression of Equilibrium)

- Equilibrium constant is a mathematical expression that describes the relationship between reactants and products - The equilibrium constant is only applicable at equilibrium.
- The equilibrium constant, K_{eq}, is defined as a relationship between the concentration of the products divided by the concentration of the reactants.
  - If we know the balanced equation, we can properly write out the equilibrium equation.
  - The coefficients that occurs in a balanced equation becomes the exponent to which a given concentration is raised to.
- For the general equation aA + bB <-> cC + dD
  - the $K_{eq} = [C]^c [D]^d / [A]^a [B]^b$
  - Example:

    N_2 (g) + $3H_2$ (g) <-> $2NH_3$ (g) $K_{eq} = [NH_3]^2 / [N_2] [H_2]^3$

- K_{eq} depends upon the [ ] of the reactants and products, meaning that we consider ONLY gaseous and aqueous substances.
  - The concentration of pure liquids and solids remains constant.
  - Example:

    PBr_5 (s) <-> PBr_3 (g) + Br_2 (g) $K_{eq} = [PBr_3] [Br_2] / [PBr_5]$

    * But since PBr_5 is a solid, its concentration is constant – it is not expressed in the equation.

    So this equation becomes:

    $K_{eq} = [PBr_3] [Br_2]$

    * NOTE: Keq is only applicable at a given temperature.

- To calculate Keq you must:
  - Write the balanced equation if it is not provided.
  - Write the equilibrium constant expression.
  - Write the molar [ ], or calculate the molar [ ] of all the known species.
  - Substitute the molar [ ] into the Keq expression and solve.

Numerical value of Keq

- The Keq has a specific value for each reaction and must be determined experimentally.
- If the Keq is close to 1, the reactants and products are about equally favoured.
- If the Keq is large (several positive powers of 10) the products are favoured.
- If the Keq is small (several negative powers of 10) the reactants are favoured.

Effect of Temperature of Keq

- Remember that all chemical reactions either release or absorb energy.
- ΔH is not part of the Keq expression, but ΔH can be used to predict how the Keq will react to temperature changes.
- Example: H_2 (g) + I_2 (g) <-> 2HI (g) + 9.4 kJ
  - By decreasing the temperature, the reaction will shift towards the exothermic reaction, meaning that it will shift to the right. (Increases the products.)

        - This means that Keq will increase, because the formula for Keq is [products] / [reactants]. If the [products] increases, so does the Keq.)
    - The reverse is also true. If we increase the temp, the reaction will shift towards the left (towards the endothermic reaction).
        - This means that Keq will decrease.
- For exothermic reactions, increased temp causes a shift to the left, which increases reactants and decreases Keq (and vice versa).
- For endothermic reactions, increased temp causes a shift to the right, which increases the products and increases Keq (and vice versa).

<u>Example involving Keq</u>

- A mixture of H_2 and I_2 react at 448 ^oC. When equilibrium is established, the [ ] of the participants is found to be: $[H_2]$=0.46 M, $[I_2]$ = 0.39 M, and [HI] = 3.0 M. calculate the Keq at 448 ^oC from these data.

  H_2 (g) + I_2 (g) <-> 2HI (g)

  Keq = $[HI]^2$ / $[H_2]$ $[I_2]$

  Keq = $[3.0]^2$ / [0.46] [0.39]

  Keq = 50.2