Topic 7 Equilibrium (SL)

Syllabus:

7.1 Equilibrium

A state of equilibrium is reached in a closed system when the rates of the forward and backward reactions are equal.

The equilibrium law describes how the equilibrium constant (kc) can be determined for a particular chemical reaction.

The magnitude of the equilibrium constant indicates the extent of a reaction at equilibrium and its temperature dependent.

Calculate the reaction quotient(Q) which is the equilibrium expression with non-equilibrium concentrations.

- Equilibrium is reached when the rates of the forward and backward reactions are equal for a reversible reaction in a closed system.
- Characteristics of equilibrium
  1. It is for reversible reaction only.
  2. It occurs in a closed system.
  3. Dynamic equilibrium: forward reaction rate = backward reaction rate
  4. The concentrations of reactants and products are constant.
  5. Reactants keep reacting to attain product side and products keep reacting to attain reactant side.

- **Physical system**

  Physical system is the system involving physical change, like phase change.

  $H_2O(l) \rightleftharpoons H_2O(g)$

  $NaCl(s) \rightleftharpoons Na^+(aq) + Cl^-(aq)$

- **Chemical system**

  Chemical system is the system involving chemical change.

  $2NO_2(g) \rightleftharpoons N_2O_4(g)$

- **Equilibrium Law**
- The law of chemical equilibrium states that at a given temperature the ratio of the concentration of products to the concentration of reactants is a constant, which is called equilibrium constant (**Kc**).

- For example,

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

$$Kc = \frac{[NH_3]^2}{[N_2][H_2]^3} \qquad \text{Unit: } \frac{\cancel{(\text{mol dm}^{-3})^2}}{(\text{mol dm}^{-3})(\text{mol dm}^{-3})^{\cancel{3}\,1}} = \frac{1}{(\text{mol dm}^{-3})^2} = \text{mol}^{-2}\ \text{dm}^6$$

$O_2(g) + 4HCl(g) \rightleftharpoons 2H_2O(g) + 2Cl_2(g)$

$$Kc = \frac{[H_2O]^2[Cl_2]^2}{[O_2][HCl]^4} \qquad \text{Unit: } \frac{\cancel{(mol\ dm^{-3})^2}\cancel{(mol\ dm^{-3})^2}}{(mol\ dm^{-3})\cancel{(mol\ dm^{-3})^4}} = \frac{1}{mol\ dm^{-3}} = \text{mol}^{-1}\ \text{dm}^3$$

Exercise

1. Write the the equilibrium constant expression, K_c, for the following reaction and state the unit.

(a) $2NOBr(g) \rightleftharpoons 2NO(g) + Br_2(g)$

(b) $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$

(c) $2NO_2(g) \rightleftharpoons 2NO(g) + O_2(g)$

(d) $HCOOH(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + HCOO^-(aq)$

MCQ

1. Which statement about chemical equilibrium implies they are dynamic?
   A. The position of equilibrium constantly changes.
   B. The rates of forward and backward reactions change.
   C. The reactants and products continue to react.
   D. The concentrations of the reactants and products continue to change.

2. Which are characteristics of a dynamic equilibrium?

   I. Amounts of products and reactants are constant.
   II. Amounts of products and reactants are equal.
   III. The rate of the forward reaction is equal to the rate of the backward reaction.

   A. I and II only
   B. I and III only
   C. II and III only
   D. I, II and III

3. What is the equilibrium constant expression, K_c, for this reaction?

$$2NO(g) + H_2(g) \rightleftharpoons N_2O(g) + H_2O(g)$$

   A. $K_c = \frac{[N_2O]+[H_2O]}{2[NO]+[H_2]}$
   B. $K_c = \frac{[NO]^2[H_2]}{[N_2O][H_2O]}$
   C. $K_c = \frac{2[NO]+[H_2]}{[N_2O]+[H_2O]}$
   D. $K_c = \frac{[N_2O][H_2O]}{[NO]^2[H_2]}$

4. What is the equilibrium constant expression, K_c, for the following reaction?

$$2NH_3(g) + 2O_2(g) \rightleftharpoons N_2O(g) + 3H_2O(g)$$

A. $\frac{3[H_2O][N_2O]}{2[NH_3]2[O_2]}$

B. $\frac{[NH_3]^2[O_2]^2}{[N_2O][H_2O]^3}$

C. $\frac{2[NH_3]2[O_2]}{3[H_2O][N_2O]}$

D. $\frac{[N_2O][H_2O]^3}{[NH_3]^2[O_2]^2}$