Rate of forward reaction [A] [B]

Rate of forward reaction $= K_f$ [A] [B] ::K = proportionality constant or rate constant

Since [C] and [D] are the reactants for the backward reaction so the rate of reverse reaction is given by

Rate of backward reaction [C] [D]

Rate of backward reaction $= K_b$ [C] [D]

At equilibrium

The rate of forward reaction = The rate of backward reaction

Thus $K_f [A] [B] = K_b [C] [D]$

Or $$\frac{K_f}{K_b} = \frac{[C]\,[D]}{[A]\,[B]} \qquad :: \frac{K_f}{K_b} = K_c$$

$$K_c = \frac{[C]\,[D]}{[A]\,[B]} \text{ ....(i)}$$

Equation (i) is called law of mass action. It is defined as “the ratio of the product of the molar concentrations of the products to that of the reactants.

For a more general reaction of the following

$$aA + bB \rightleftharpoons cC + dD$$

Where a, b, c and d represent the number of moles of the species taking part in the chemical reaction. They are called the coefficients of the balanced chemical equation.

According to the law of mass action, the equilibrium constant (K_c) can be written as

$$K_c = \frac{[C]^c\,[D]^d}{[A]^a\,[B]^b} \text{ ....(ii)}$$

Example 7.3: For the dissociation of HI

$$2HI \rightleftharpoons H_2 + I_2$$

K_c at 520 C^0 is 1.6×10^{-2}. Predict the direction in which the system will move to attain the equilibrium if the initial concentrations of HI is 1.02M and that of H_2 and I_2 are 0.01M and 0.01M respectively.

Solution: $$Q_c = \frac{[H_2]_0\,[I_2]_0}{[HI]_0^2} = \frac{[0.01]\,[0.01]}{[1.02]^2} = 9.61 \times 10^{-5}$$

$Q_c = 9.61 \times 10^{-5}$ &

$K_c = 1.6 \times 10^{-2}$

$Q_c < K_c$, the net reaction will occur in the forward direction.

Prediction of the extent of a chemical reaction

I) If the K_c is very large, this indicates that the reaction is complete. The concentrations of products are greater than the concentrations of reactants at equilibrium.

II) If the K_c is very small, then the concentrations of reactants are greater than the concentrations of products at equilibrium.

III) If the K_c = 0, then the concentrations of reactants = concentrations of products at equilibrium.

Example 7.4:

Predict the extent of the given reaction for which K_c is 1×10^{-30} at 25 C^0.

$$N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$$

Since the K_c is very small, therefore the conc. of reactants are greater than the conc. of products.

$$H_{2(g)} + I_{2(g)} \rightleftharpoons HI+_{(g)} + HI_{(g)}$$

1vo 1vol 1vol 1vol

2vol 2vol

3. Effect of change in temperature:

The shifting of equilibrium depends whether the reaction is endothermic or exothermic.

(a) An increase in temperature will shift the equilibrium of endothermic reactions in the forward direction. e.g.,

$$N_{2(g)} + O_{2(g)} + \text{heat} \rightleftharpoons 2NO_{(g)}$$

$$H_2S_{(g)} + \text{heat} \rightleftharpoons H_{2(g)} + S_{(g)}$$

Both reactions are endothermic. Thus, the equilibrium will shift in the forward direction by increasing temperature and more $NO_{(g)}$ and $H_{2(g)} + S_{(s)}$ product form.

(b) An increase in temperature will shift the equilibrium of exothermic reactions in the backward direction. e.g.,

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

$$2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)} + \text{heat}$$

Both reactions are exothermic. Thus the equilibrium will shift in the backward direction by increasing temperature.

4. Effect of catalyst:

A catalyst is a substance which increases the rate of reaction only and lowers the activation energy. A catalyst cannot change the position of equilibrium. Addition of a catalyst increases the speed of forward and backward reaction at the same extent.

INDUSTRIAL APPLICATIONS OF LE CHATELIER PRINCIPLE

Two industrially important reactions are discussed below.

(a) Haber's process: