# Chemistry Study Materials for Class 11
# (NCERT Based Notes of Chapter- 07)
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## Equilibrium

### Characteristics of Equilibrium constant

The important characteristics of equilibrium constant are:

1. Equilibrium constant is applicable only when the concentrations of the reactants and products have attained their equilibrium state.
2. The value of equilibrium constant is independent of the initial concentrations of reactants and products.
3. The value of equilibrium constant depends on temperature.
4. The equilibrium constant for the reverse reaction is the reciprocal of that of the forward reaction.
5. If for the reaction $A \rightleftharpoons B$, the value of equilibrium constant is K,

   Then for the reaction $nA \rightleftharpoons nB$, its value is $K^n$.

### Applications of equilibrium constant

The important applications of equilibrium constant are:

**1.** ***Prediction of the extent of a reaction***

Greater the value of equilibrium constant, greater will be the concentration of products. In general,

**a)** If $K_c > 10^3$ (i.e. Kc is very large), the reaction proceeds nearly to completion

**b)** If $K_c < 10^{-3}$ (i.e. if Kc is very small), the reaction proceeds rarely.

**c)** If the value of Kc is in between $10^3$ and $10^{-3}$ appreciable concentrations of both reactants and products are present.

**2. *Prediction of the direction of the reaction***

By knowing the values of Kc and Qc, we can predict the direction of a reaction. The reaction quotient (Qc) is defined in the same way as the equilibrium constant (Kc) except that the concentrations in Qc are not necessarily the equilibrium values.

For a general reaction, $aA + bB \rightleftharpoons cC + dD$,

the reaction quotient, $Qc = \dfrac{[C]^c[D]^d}{[A]^a[B]^b}$

If Qc > Kc, the reaction will proceed in the direction of reactants (reverse direction).

If Qc < Kc, the reaction will proceed in the direction of products (forward direction).

If Qc = Kc, the reaction mixture is at equilibrium.

**3. *Calculation of equilibrium concentrations***

By knowing the value of equilibrium constant, we can calculate the equilibrium concentrations of reactants and products.

## Relationship between Equilibrium Constant (Kc), Reaction Quotient (Q) and Gibbs Energy (G)

The Gibb's energy change of a reaction is related to the reaction quotient (Q) by the equation: $\Delta G = \Delta G^0 + RT \ln Q$

Where, $\Delta G^0$ is standard Gibbs energy.

At equilibrium, $\Delta G = 0$ and Q = Kc, so the equation becomes,

$$0 = \Delta G^0 + RT \ln Kc$$

Or, $\Delta G^0 = - RT \ln Kc$

On changing the base, we get $\Delta G^0 = - 2.303RT \log Kc$

We know that for a spontaneous process ΔG should be negative.

So the value of Kc should be positive.

## Factors affecting equilibrium

The important factors affecting equilibrium are temperature, pressure, concentration and catalyst.

The effect of these factors on equilibrium state can be explained by using **Le Chatelier's Principle**.

It states **that *whenever there is a change in concentration, pressure or temperature of a system at equilibrium, the system will try to readjust in such a way so as to cancel the effect of that change***.

### 1. Effect of concentration change

If we change the concentration of reactants or products in an equilibrium process, then according to Le Chatelier's principle, the system will try to reduce the effect of that change. For this the rate of either forward or backward reaction changes

In general, an increase in concentration of reactants increases the rate of forward reaction (i.e. the equilibrium is shifted to the forward direction) and an increase in concentration of products increase the rate of backward reaction rate (i.e. the equilibrium is shifted to the backward direction).

For example in the reaction;

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

If we increase the concentration of $SO_2$ or $O_2$, the system will try to reduce the concentration by shifting the reaction to forward direction.

If we remove $SO_3$ from the reaction mixture, its concentration decreases. Here also to increase the concentration, the system will shift to the forward direction.

In Haber process for the preparation of ammonia, the amount of ammonia formed can be increased by increasing the concentration of $N_2$ or $H_2$ or by removing $NH_3$ from the reaction mixture.

**2. Effect of temperature change**

According to Le Chatelier's principle, increase in temperature favours endothermic process and decrease in temperature favours exothermic process. In a reversible reaction, if the forward reaction is endothermic, the backward reaction will be exothermic.

Eg. $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2\,NH_{3(g)}$; $\Delta H = -92.38 kJ/mol$

Here since $\Delta H$ is negative, the forward reaction is exothermic. So to increase the production of $NH_3$, temperature should decrease. At higher temperature, the rate of backward reaction increases. i.e. the ammonia formed is decomposed to $N_2$ and $H_2$.

**3. Effect of pressure change**

Pressure has its role only in gaseous reactions. In general an increase in pressure favours the reaction in which number of moles decreases and vice versa.

Thus in the reaction, $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2\,NH_{3(g)}$, when the pressure increases, the system will try to reduce the pressure. This can be achieved by shifting the reaction into the direction in which no. of moles decreases (since pressure is directly proportional to the number of moles). So in this reaction, the equilibrium will shift to the forward direction.

If the volume of the reaction mixture is halved, the concentration and the partial pressure become doubled. So the reaction is shifted to the direction in which the number of moles or volume decreases.

**4. Effect of catalyst**

In an equilibrium reaction, a catalyst increases the rate of both forward and backward reactions simultaneously and helps to attain the equilibrium faster. It lowers the activation energy for the forward and backward reactions by exactly the same amount. It does not affect the equilibrium composition of the reaction mixture.

Thus in Haber process for the manufacture of ammonia, iron (Fe) acts as the catalyst. In contact process for the manufacture of sulphuric acid, $V_2O_5$ (Vanadium pentoxide) is used as the catalyst for the conversion of $SO_2$ to $SO_3$.

## 5. Effect of inert gas addition

If an inert gas (which does not take part in the reaction) is added to an equilibrium mixture at constant volume (or at constant pressure), there is no change to the equilibrium. It is because the addition of inert gas at constant volume (or at constant pressure) does not change the partial pressure or the concentration of the reactants and the products.

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