

Chapter = 01

Chemical Equilibrium

Q 1. What is a chemical reaction? Discuss it in brief.



CHEMICAL REACTION

A chemical reaction is a chemical change which involve reactants and products. For Example, formation of water from hydrogen gas and oxygen gas, decomposition reaction of Sodium bicarbonate into sodium carbonate, water, and carbon dioxide etc. A chemical Reaction contains two quantities; reactant and product which are separated by an arrow.



Q 2. Define chemical equilibrium with example.

CHEMICAL EQUILIBRIUM

Chemical equilibrium refers to the state of a system in which the concentration of the reactant and the concentration of the products do not change with time and the system does not display any further change in properties



Q 3. Describe dynamic equilibrium with two examples.

DYNAMIC EQUILIBRIUM

Any reaction will be in dynamic equilibrium if it's reversible and the rates of the forward and reverse reactions are equal.

Rate of forward reaction = Rate of reverse reaction

EXAMPLE # 1

If you prepare a solution that is saturated with an aqueous solution of NaCl. If you then add solid crystals of NaCl, the NaCl will be simultaneously dissolving and recrystallizing within the solution. The reaction, $\text{NaCl(s)} \rightleftharpoons \text{Na}^+(\text{aq}) + \text{Cl}^-(\text{aq})$, will be in dynamic equilibrium when the rate of the dissolution of the NaCl equals the rate of recrystallization.



EXAMPLE # 2

Dynamic equilibrium is $\text{NO}_2(\text{g}) + \text{CO}(\text{g}) \rightleftharpoons \text{NO}(\text{g}) + \text{CO}_2(\text{g})$ (again, as long as the two rates are equal). Nitrogen dioxide (NO_2) reacts with carbon monoxide (CO) to form nitrogen oxide (NO) and carbon dioxide (CO_2), and, in the reverse reaction, nitrogen oxide and carbon dioxide react to form nitrogen dioxide and carbon monoxide.

Q 4. Define Reverse reaction and forward reaction.

REVERSE REACTION

A reaction in which product change in to reactant is known as reverse reaction

FORWARD REACTION

A reaction in which reactant change in to product is known as reverse reaction.

Q 5. What are the characteristics of Reversible reaction, forward reaction and dynamic equilibrium?

CHARACTERISTICS OF FORWARD REACTION

1. It is always directed from left to right in a chemical reaction
2. Reactants produce products (Reactants \rightarrow Products)
3. Initially rate is fast but gradually slow down

CHARACTERISTICS OF REVERSE REACTION

1. It is always directed from right to left in a chemical reaction
2. Product produce reactant (Reactants \leftarrow Products)
3. Initially rate is slow but gradually speed up

CHARACTERISTICS OF IN DYNAMIC EQUILIBRIUM

1. A dynamic equilibrium can only exist in a closed system – neither reactants nor Products can enter or leave the system
2. Equilibrium, the concentrations of reactants and products remain constant
3. At equilibrium, the forward and reverse reactions are taking place at equal and opposite rates.
4. Equilibrium can be approached from either side of the reaction equation
5. An Equilibrium state can be disturbed and again achieved under the given Condition of concentration, pressure, and temperature.



Q 6. Distinguished between reversible and irreversible reaction.

REVERSIBLE REACTION	IRREVERSIBLE REACTION
Products are converted back to reactants.	Products are not converted back to reactants.
The reaction appears to have stopped but does not undergo completion.	The reaction stops completely and almost goes to completion.
It is generally carried out in a closed vessel.	It can be carried out in an open or closed vessel
It takes place in both directions. It is represented by e.g. $N_2 + O_2 \rightleftharpoons 2NO$	It takes place only in one direction. It is represented by e.g. $C + O_2 \rightarrow CO_2$

Q 7. State law of mass action How is the active mass is represented?

LAW OF MASS ACTION:

The rate at which a substance reacts is directly proportional to its active mass and the rate of a reaction is directly proportional to the product of the active masses of the reacting substances.

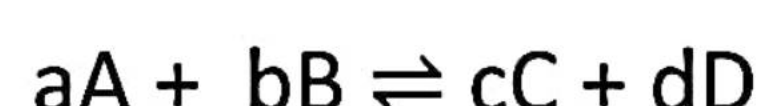
REPRESENTATION

The unit of active mass Mol/dm^3 and its value is expressed in square brackets.

Q 8. Derive an expression for equilibrium constant.

DERIVATION

Let us apply law of mass action on a hypothetical reversible reaction.



First let us discuss forward reaction, where A and B are reactants whereas “a” and “b” are the number of moles needed to balance a chemical equation. The rate of forward reaction according to law of mass action is



$$R_f \propto [A]^a [B]^b$$

$$R_f = k_f [A]^a [B]^b$$

Where k_f is the rate constant for forward reaction.

Likewise, rate of reverse reaction is directly proportional to product of molar concentration of C and D whereas “c” and “d” are number of moles needed to balance a chemical reaction

$$R_r \propto [C]^c [D]^d$$

$$R_r = k_r [C]^c [D]^d$$

Where k_r is the rate constant for reverse reaction. You know at equilibrium rate of forward and reverse reaction becomes equal. So

$$R_f = R_r$$

Putting the values of R_f and R_r , we have

$$k_f [A]^a [B]^b = k_r [C]^c [D]^d$$

By taking constants on L.H.S and variables on R.H.S, we have

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

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

$$\text{OR } K_c = \frac{k_f}{k_r}$$

Hence

$$K_c = \frac{[\text{Product}]}{[\text{Reactant}]}$$

Q 9. Why equilibrium constant may or may not have unit? Justify with example

Since the K_c is the ratio of product and reactant, therefore when the number of moles of an equation are equal the K_c will have no unit. When the number of moles is unequal then it will have the unit



EXAMPLE # 1



$$\text{Since, } K_c = \frac{[\text{Product}]}{[\text{Reactant}]}$$

$$K_c = \frac{[\text{H}_2] [\text{I}_2]}{[\text{HI}]^2}$$

$$\text{unit} = \frac{[\text{mole/dm}^3] [\text{mole/dm}^3]}{[\text{mole/dm}^3]^2}$$

$$\text{unit} = \frac{\frac{\text{mole}}{\text{dm}^3} \times \frac{\text{mole}}{\text{dm}^3}}{\frac{\text{mole}^2}{\text{dm}^6}}$$

$$\text{Unit} = 1$$

EXAMPLE # 1



$$\text{Since, } K_c = \frac{[\text{Product}]}{[\text{Reactant}]}$$

$$K_c = \frac{[\text{PCl}_3] [\text{Cl}_2]}{[\text{PCl}_5]}$$

$$\text{unit} = \frac{\frac{\text{mole}}{\text{dm}^3} \times \frac{\text{mole}}{\text{dm}^3}}{\frac{\text{mole}}{\text{dm}^3}}$$

$$\text{Unit} = \text{mole/dm}^3$$

Q 10. How direction of a reaction can be predicted if K_c is known to you.

DIRECTION OF REACTION

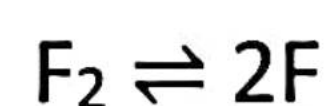
1. If $Q_c = K_c$, the actual product and reactant concentrations are equal to equilibrium concentrations, and the system is stable.
2. If $Q_c < K_c$ increase in product concentration for equilibrium. So, the Reaction occurs, forming additional products.
3. If $Q_c > K_c$, there is decrease in product concentration. As, the process Reverses, forming more reactants.



Q 11. Discuss the extent of chemical reaction on the basis of K_c

K_c IS VERY SMALL

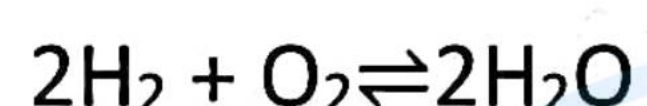
Reactions with low K_c never finish. That is, maximum reactant concentration and minimum product concentration. These are called 'reverse or backward responses'.



$$K_c = 7.4 \times 10^{-13} \text{ at } 227^\circ\text{C}$$

K_c IS VERY LARGE

Reactions with high K_c values are virtually complete. That is, maximum product Concentration and minimum reactant concentration. This type of reaction is known as "Forward reaction"



$$K_c = 2.4 \times 10^{47} \text{ at } 227^\circ\text{C}$$

K_c IS NEITHER VERY SMALL NOR VERY LARGE

Reactions which have moderate value of K_c are considered to be at equilibrium. The Concentration of reactants and products is almost same.

FOR EXAMPLE:



Q 12. How can you predict the following stages of a reaction by comparing the values Of K_c and Q_c .

- 1) Net reaction proceeds in forward direction.
 - 2) Net reaction proceeds in reverse direction
- 1. Net reaction proceeds in forward direction.**

The value of K_c will be very large

- 2. Net reaction proceeds in reverse direction**

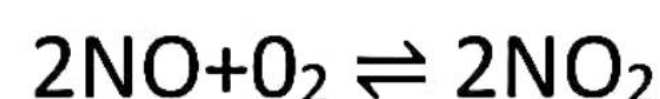
The value of K_c will be very small

Chapter = 01

Numerical Problems

Numerical 01

Equilibrium occurs when nitrogen monoxide gas reacts with oxygen gas to form nitrogen dioxide gas.



At equilibrium at 230 °C, the concentrations are measured to be : $[\text{NO}] = 0.0542 \text{ mol.dm}^{-3}$, $[\text{O}_2] = 0.127 \text{ mol.dm}^{-3}$, and $[\text{NO}_2] = 15.5 \text{ mol.dm}^{-3}$ Calculate the equilibrium constant at this temperature.

Numerical 02

A reaction takes place between iron ion and chloride ion as:

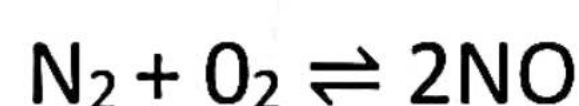


At equilibrium, the concentrations are measured to be (Fe^{+3}) is 0.2 mol.dm^{-3} , Cl^- is 0.28 mol.dm^{-3} and FeCl_4^- is $0.95 \times 10^{-4} \text{ mol.dm}^{-3}$. Calculate equilibrium constant K_c for given reaction.

Numerical 03

Nitrogen oxides are air pollutants produced by the reaction of nitrogen and oxygen at high temperature.

At 2000 °C, the value of the equilibrium constant for the given reaction is 4.1×10^{-4}



Find the concentration of NO in an equilibrium mixture at 1 atm pressure at 2000°C. In air, $[\text{N}_2] = 0.036 \text{ mol/L}$ and $[\text{O}_2] = 0.0089 \text{ mol/L}$.

Book Numerical

1. Dinitrogen tetra oxide N_2O_4 decomposed into nitrogen dioxide NO_2 in a reversible reaction. Derive equilibrium constant expression for the reaction of decomposition. Also interpret unit of K_c for balanced chemical reversible reaction.

2. PCl_5 , PCl_3 , and Cl_2 are at equilibrium at 500K in a closed container and their concentrations are $0.8 \times 10^{-3} \text{ mol dm}^{-3}$, $1.2 \times 10^{-3} \text{ mol dm}^{-3}$ and $1.2 \times 10^{-3} \text{ mol dm}^{-3}$ respectively. Calculate the value of K_c for the reaction along with unit.

3. The value of K_c for the reaction is 1×10^{-4}



At a given temperature, the molar concentration of reaction mixture is $\text{HI} = 2 \times 10^{-5} \text{ mol dm}^{-3}$, $\text{H}_2 = 1 \times 10^{-5} \text{ mol dm}^{-3}$ and $\text{I}_2 = 1 \times 10^{-5} \text{ mol dm}^{-3}$. Predict the direction of the reaction.