CHAPTER 9

CHEMICAL EQUILIBRIUM

MULTIPLE CHOICE QUESTIONS

1. **In chemical reactions the substances that combine are called:**
   (a) Products (b) Reversible reaction
   (c) Reactants (d) Irreversible reaction
2. **Name the reactants in this equation.** $2H_{2(q)} + O_{2(g)} \xrightarrow[\text{heat}]{pt} 2H_2O_{(l)}$
   (a) H_2O (b) H_2 and O_2 (c) O_2 (d) None of these
3. **The reaction in which the products do not recombine to from reactants is known as:**
   (a) Reversible reactions (b) Reactants
   (c) Products (d) Irreversible reactions
4. **The reactions in which the products recombine to form reactants are called:**
   (a) Reactants (b) Reversible reactions
   (c) Irreversible reaction (d) Both and b
5. **Irreversible reaction goes on:**
   (a) Never complete (c) completion (b) Both a and c (d) None of these
6. **Reversible reaction:**
   (a) can complete (b) never complete (c) Both a and b (d) None of these
7. **The colour of hydrogen Iodide (HI) is:**
   (a) Blue (b) Grey (c) Purple (d) Colourless
8. **The colour of iodine (I) is:**
   (a) Purple (b) Green (c) Yellow (d) None of these
9. **At equilibrium the rate of forward and reverse reaction becomes.**
   (a) Greater (b) Normal (c) Equal (d) Lesser
10. **Dynamic means reaction i:**
    (a) Stops (b) Still continuing (c) Opposite direction (d) Both a and b
11. **When reaction ceases to proceed it is called:**
    (a) Dynamic equilibrium (b) Static equilibrium
    (c) chemical equilibrium (d) none of these
12. **Reaction in which reactants react to form products called:**
    (a) forward reactions (b) reverse reactions (c) reversible reaction (d) backward reactions
13. **At initial stage the rate of forward reaction is.**
    (a) low (b) very low (c) very fast (d) all of these
14. **There are _____ possibilities at equilibrium state.**
    (a) three (b) five (c) four (d) two
15. **Reverse reaction take place from:**
    (a) left to right (b) right to left (c) both a and b (d) none of these
16. **Reverse reactions _____ gradually.**
    (a) speeds up (b) negligible (c) slows down (d) none of above
17. **Forward reaction takes place from:**
    (a) left to right (b) right to left (c) both a and b (d) all of these

18. **The characteristics of reversible reaction are the following except.**
(a) products never recombine to from reactant (b) they never complete
(c) they proceed in both ways (d) they have double arrow between them

19. **In the lime kiln the reaction $CaCO_{3(s)} \longrightarrow CaO_s + CO_{2(g)}$ goes to completion because, of**
(a) High temperature (b) CO_2 escapes continuously
(c) CaO is not dissociated (d) CaO is more stable that $CaCO_3$.

20. **For the reaction $2A_g + B_g \rightleftharpoons 3C_g$ the expression for the equilibrium constant is**
(a) $\frac{[2A][B]}{[3C]}$ (b) $\frac{[A]^2[B]}{[C]^3}$ (c) $\frac{[3C]}{[2A][B]}$ (d) $\frac{[C]^3}{[A]^2[B]}$

21. **Which statement is not correct about active mass?**
(a) Rate of reaction is directly proportional to active mass.
(b) The opposing reactions (forward and reverse) stops.
(c)Active mass means total mass of substances.
(d) None of these

22. **When the magnitude of K_c is very large it indicates.**
(a) Reaction mixture consists of almost all products
(b) Reaction mixture has almost all reactants.
(c) Reaction has gone to completion.
(d) All of these

23. **When the magnitude of Kc is very small it indicates.**
(a) equilibrium is never establish
(b) all reactants will be converted to products
(c) reaction will go to complete
(d) the amounts of products is negligible

24. **Reaction will have comparable amounts of reactants and products at equilibrium state have.**
(a) very small Kc value (b) moderate Kc value
(c) very large Kc value (d) none of these

25. **In an irreversible reaction dynamic equilibrium.**
(a) never establishes (b) establish readily
(c) establish after the completion of reaction. (d) establish before the completion of reaction.

26. **For a reaction between PCl_3 and Cl_2 to form PCl_5 the units of Kc are:**
(a) mol dm^{-3} (b) mol^{-1} dm^{-3} (c) mol^{-1} dm^3 (d) mol dm^3

27. **An equilibrium is achievable only in**
(a) open system (b) close system (c) both a and b (d) all of these

28. **At equilibrium state the physical properties like density, colour etc:**
(a) remains same (b) changes (c) all of these (d) none of these

29. **Name the scientist who presented law of mass action.**
(a) Guldberg (b) Bronsted (c) Lowry (d) Lewis

30. **Reversible reactions takes place in:**
(a) single direction (b) both directions (c) both a & b (d) all of these

31. **Numerical value of K_c predicts :**
(a) direction of reaction (b) extent of reaction
(c) both a & b (d) all of these

32. **When H_2 and O_2 combine they form**

(a) H_2O (b) H and O (c) HO_2 (d) none

33. **When H_2 and I_2 combine they form**

(a) H_2O (b) HI (c) I_2 (d) H_2 and I_2

34. **The ratio of product concentration of products raised to power of co-efficient to the products of reactant raised to the power co-efficient is known as.**

(a) Kc (b) Qc (c) forward reaction (d) reverse reaction

35. **In direction of a reaction, reaction proceeds forward then:**

(a) Qc < Kc (b) Qc > Kc (c) Qc = Kc (d) None of them

36. **In direction of a reaction, reaction proceeds reverse then:**

(a) Qc < Kc (b) Qc > Kc (c) Qc = Kc (d) all of these

37. **In direction of a reaction, reaction is at equilibrium then:**

(a) Qc < Kc (b) Qc > Kc (c) Qc = Kc (d) Both a & b

38. **In extent of reaction, the reaction goes to completion have:**

(a) very large Kc value (b) very small Kc value

(c) moderate Kc value (d) None of them

39. **In extent of reaction, the reaction never goes to completion have:**

(a) very large Kc value (b) very small Kc value

(c) moderate Kc value (d) Qc = Kc

40. **Reaction quotient is expressed as:**

(a) K_c (b) Q_c (c) K_r (d) K_f

41. **There are _____ possibilities of predicting extent of reaction**

(a) 1 (b) 2 (c) 3 (d) 4

42. **There are _____ major components of atmosphere:**

(a) 1 (b) 2 (c) 3 (d) 4

43. **The two major components of atmosphere are:**

(a) nitrogen and hydrogen gasses (b) oxygen and hydrogen gasses

(c) nitrogen and carbon dioxide gasses (d) nitrogen and oxygen gasses

44. **Nitrogen and oxygen constituents' _____ of the atmosphere:**

(a) 99% (b) 98% (c) 92% (d) 97%

45. **Gases are being used to manufacture:**

(a) products (b) chemicals (c) reactants (d) Both b & c

46. **Nitrogen is used to prepare:**

(a) carbon dioxide (b) ammonia (c) hydrogen (c) None of these

47. **Oxygen is used to prepare:**

(a) ammonia (b) nitrogen gas (c) oxygen (d) sulphur dioxide

48. **By knowing the value of equilibrium constant _____ can be predicted:**

(a) direction of reaction (b) extent of reaction (c) both a & b (d) all of these

49. **The characteristics of inversible reaction are the following exept**
(a) they never complete
(b) products never recombines to form reactions
(c) they have a double arrow between reactants and products
(d) none of these

50. **Many environmental systems depend for their:**
(a) existence on their delicate equilibrium phenomenona
(b) existence on the water
(c) both of these
(d) none of these

51. **Ammonia is used to manufacture :**
(a) sulphuric acid (b) hydrogen
(c) nitrogenous fertilizers (d) none of these

52. **Sulphur dioxide is used to manufacture:**
(a) sulphuric dioxide (b) ammonia
(c) sulphuric acid (d) nitrogenous fertilizers

53. **Which is the king of chemicals:**
(a) sulphuric dioxide (b) ammonia (c) nitrogen (d) sulphuric acid

54. **Nitrogen and oxygen gasses are being used to manufacture chemicals since the advent of _____ century:**
(a) 18 (b) 20 (c) 19 (d) 21

55. **The reaction in which all the reactants have been converted into products are known as**
(a) incomplete reactions (b) complete reactions
(c) continuous reactions (d) None of them

56. **The lives of aquatic animals and plants are indirectly related to concentration of _____ dissolved in water:**
(a) carbon dioxide (b) oxygen (c) both a & b (d) none of them

57. **Irreversible reaction represented by a _____ between a reactant and a product:**
(a) single arrow (b) K_c (c) double arrow (d) all of these

58. **Irreversible reaction consists of:**
(a) forward reactions (b) reverse reactions
(c) forward & reverse reactions (d) none of them

59. **When CaO reacts with CO_2 they produce:**
(a) $CaCO_3$ (b) $CaCO_2$ (c) Both a & b (d) all of these

60. **In the beginning reverse reactions is**
(a) fast (b) stops (c) slow (d) none of above

61. **Rate of forward reactions takes place at the rate of reverse reaction, the composition of the reaction mixture remains constant is called**

(a) satatic equilibrium (b) dynamic equilibrium

(c) chemical equilibrium state (d) none of these

62. **Point out the co efficient in the following hypothetical reactions**

$2A+3D \longrightarrow 4C+8D$

(a) 2,3,4d (b)2,3,4,3 (c) A,b,c,d (d) 2,3,4,8

63. **An active mass is considered as the molar concerations in units of**

(a) mol dm^{-3} (b) mol^{-3} dm (c) mol^{-2} dm (d) mol^{-2} dm

64. **There are _____characteristics of dynamic equilibrium**

(a) one (b) two (c) three (d) five

65. **The oxidation of cabon monoxides goes to completion at**

(a) 2000K (b) 1000K (c) 100K (d) 200K

66. **The reaction quotient is useful because it predicts the direction of reaction by comparing the value of**

(a) Qc (b) Qc with Kc (c) k_c (d) none of these

67. **For the reactions $H_2 + I_2 \longrightarrow 2HI$. The reactions quotients for this reactions is**

(a) 8.0 (b) 2.0 (c) 9.0 (d) None of these

68. **As the numeric value of Qc (8.0) is less than K_C (57.0) the reaction is not**

(a) in forward direction (b) at equilibrium (c) in reverse direction (d) all of these

ANSWER KEY

1	c	14	d	27	b	40	b	53	d	66	b
2	b	15	b	28	a	41	c	54	b	67	a
3	d	16	a	29	a	42	b	55	b	68	b
4	b	17	a	30	b	43	d	56	b		
5	c	18	a	31	b	44	a	57	a		
6	b	19	b	32	a	45	b	58	a		
7	d	20	d	33	b	46	b	59	a		
8	a	21	c	34	a	47	d	60	c		
9	c	22	a	35	a	48	c	61	c		
10	b	23	d	36	b	49	c	62	d		
11	b	24	b	37	c	50	a	63	a		
12	a	25	a	38	a	51	c	64	d		
13	c	26	c	39	b	52	c	65	b		

SHORT QUESTIONS

CHEMICAL EQUILIBRIUM AND REVERSIBLE REACTION

Q.1 Why reversible reactions never complete?

Ans. **Definition:** The reactions in which the products can combine to form reactants are called reversible reactions.

These reactions never go to completion because, these reactions proceed in both ways i.e., in forward and in reverse direction as,

Rate of forward = Rate of reverse reaction.

$$A + B \underset{R_f}{\overset{R_f}{\rightleftharpoons}} C + D$$

Reactants Products

Q.2 What is a static equilibrium? Explain with an example.

Ans. When a reaction ceases (stop) to proceed. It is called static equilibrium. This happens mostly in physical phenomenon.

Example:

A building remains standing rather than falling down because all the forces action on it are balanced.

Q.3 Why the amounts of reactants and products do not change in reversible reaction?

Ans. In a reversible reaction, products can recombine to form reactants. An equilibrium state is achieved in these reaction and rate of forward and reverse reaction is same. So that is why amount of reactants and product will also be same.

EQUILIBRIUM CONSTANT AND LAW OF MASS ACTION

Q.1 Define the Law of Mass Action.

Ans. 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.

$$A + B \underset{K_r}{\overset{K_f}{\rightleftharpoons}} C + D$$

$$K_C = \frac{[C][D]}{[A][B]}$$

Q.2 How the active mass is represented?

Ans. An active mass is considered as the molar concentration in units of mol dm^{-3} expressed as in square brackets [ ].

Q.3 What do you mean by equilibrium constant?

Ans. Equilibrium constant is a ratio of the product of concentration of product raised to the power of coefficient to the product of concentration reactions raised to the power of coefficient as expressed in the balanced chemical equation.

$$Kc = \frac{\text{Product of concentration of products raised to the power of coefficients}}{\text{Product of concentration of reactants raised to the power of coefficients}}$$

Q.4 Point out the coefficients of each in the following hypothetical reactions:

(a) $2A + 3B \rightleftharpoons 4C + 2D$ (b) $4X \rightleftharpoons 2Y + 3Z$

(c) $2M + 4N \rightleftharpoons 5O$

Ans. (a) $2A + 3B \rightleftharpoons 4C + 2D$

The rate of forward reaction, $R_f = K_f [A]^2 [B]^3$

The rate of reverse reaction $R_r = K_r [C]^4 [D]^2$

$$K_c = \frac{\text{Product of Moler Concentration of Product}}{\text{Product of Moler Concentration of Reactants}}$$

$$K_c = \frac{[C]^4[D]^2}{[A]^2[B]^3}$$

(b) $4X \rightleftharpoons 2Y + 3Z$

The rate of forward reaction, $R_f = K_f [X]^4$

The rate of reverse reaction $R_r = K_r [Y]^2 [Z]^3$

$$Kc = \frac{[Y]^2[Z]^2}{[X]^4}$$

(c) $2M + 4N \rightleftharpoons 5O$

The rate of forward reaction, $R_f = K_f [M^2][N]^4$

The rate of reverse reaction $R_r = K_r [O]^5$

$$K_c = \frac{[O]^5}{[M]^2[N]^4}$$

Q.5 Write the equilibrium constant expressions for the following reactions:

(a) $2NO_{2(g)} \rightleftharpoons N_2O_{4(g)}$ (b) $PCl_{3(g)} + Cl_{2(g)} \rightleftharpoons PCl_{5(g)}$

(c) $2SO_{2(g)} + O_{2(g)} \rightleftharpoons 25O_{3(g)}$

Ans. (a) $2NO_{2(g)} \rightleftharpoons N_2O_{4(g)}$

Rate of forward reaction, $R_f = K_f [NO_2]^2$

Rate of reverse reaction, $R_r = K_r [N_2O_4]$

$$K_c = \frac{[N_2O_4]}{[NO_2]^2}$$

(b) $PCl_{3(g)} + Cl_{2(g)} \rightleftharpoons PCl_{5(g)}$

Rate of forward reaction, $R_f = K_f [PCl_5]$

Rate of reverse reactions, $R_r = K_r [PCl_5]$

Equilibrium constant expression

$$K_c = \frac{[PCl_5]}{[PCl_3][Cl_2]}$$

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

Rate of forward reaction, $R_f = K_f [SO_2]^2[O_2]$

Rate of reverse reactions, $R_r = K_r [SO_3]^2$

Equilibrium constant expression

$$K_c = \frac{[SO_3]^2}{[SO_2]^2[O_2]}$$

APPLICATION OF EQUILIBRIUM CONSTANT

Q.1 What do you mean by the extent of reaction?

Ans. The extent of a reaction indicates to which extent reactants are converted to product or it measures "How far a reaction proceeds before establishing equilibrium state,"

Q.2 Why the reversible reactions do not go to completion?

Ans. The reversible reactions do not go to completion because these reactions proceed in both ways i.e, forward and reverse direction.

When the rate of the forward reaction takes place at the rate of reverse reaction, the equilibrium state is achieved. At this state, the composition of reaction mixture remains constant.

Q.3 If a reaction has large value of K_c will it go to completion and why?

Ans. The large value of K_c indicates the reaction has almost gone to completion because at the equilibrium position the reaction mixture consists of almost all products and reactants are negligible.

Example: $2CO_{(g)} + O_{2(g)} \rightleftharpoons 2CO_{2(g)}$ $\quad K_c = 2.2 \times 10^{22}$

Q.4 Which types of reactions do not go to completion?

Ans. The reactions which have the very small value of K_c, never go to completion.

Example: $N_2O_{4(g)} \rightleftharpoons 2NO_{2(g)}$ $\quad K_c = 0.211$

Q.5 Why the reaction mixture does not have 50% reactants and 50% products at equilibrium position?

Ans. The amount of reactants and products at equilibrium position depends upon the value of K_c.

- If the K_c value is large. The reaction mixture at more products and less reactants at equilibrium state.
- If the K_c value is very small its means reaction mixture consist of more reactants and less products at equilibrium state.
- If the Kc neither small nor large, it means the amount of reactants and products almost same of comparable.

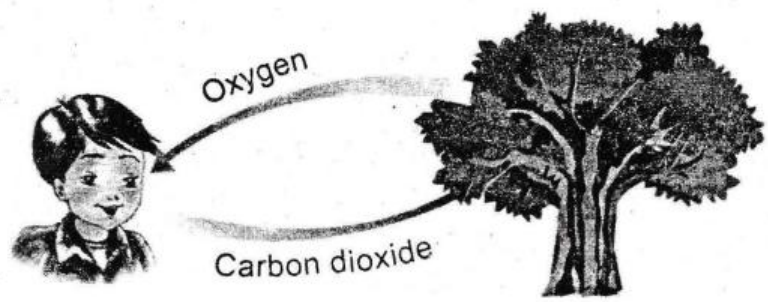
LONG QUESTIONS

Q.1 Write down the equilibrium in nature in detail.

Equilibrium in nature

We owe our existence to equilibrium phenomenon taking place in atmosphere. We inhale oxygen and exhale carbon dioxide, while plants consume carbon dioxide and release oxygen. This natural process is responsible for the existence of life on the Earth.

Many environmental systems depend for their existence on delicate equilibrium phenomenon, For example, concentration of gases in lake water is governed by the principles of equilibrium, The lives of aquatic plant and animals are indirectly related to concentration of dissolved oxygen in water,



9.1 REVERSFFILE REACTION AND DYNAMIC EQUILMRIUM

Q.2 What are chemical reaction? Write down the types of the chemical reaction.

Chemical reaction

A change in which a substance or substances are changed into one or more new substances. Chemical reactions consist of two components, reactant and products.

Reactant

In a chemical reaction the substances that combine are called reactants

Products

The new substances formed during a chemical reaction are called products.

Example

When H_2 and O_2 (reactant) combine they form H_2O (product),

$$2H_2 + O_2 \longrightarrow 2H_2O$$

Types of chemical reactions

There are two types of chemical reactions

Irreversible reaction

Most of the reaction the products do not recombine to form reactants, are called irreversible reactions. They are supposed to complete an are represented by putting a single arrow ($\longrightarrow$) between the reactants and products.

Example

$$2H_2 + O_2 \longrightarrow 2H_2O$$

Q.3 Explain in detail the reversible reaction with the suitable example.

Reversible reaction

The reactions in which the products can recombine to from reactants are called reversible reaction reactions. They never go to completion. These are represented by a double arrow between reactants and products. These reactions proceed in both ways, i.e. they consist of two reactions; forward and reverse, depending upon the conditions.

Explanation of reversible reaction with examples

Let us discuss a reaction between hydrogen and iodine. Because one of the reactant, iodine is purple, while the product hydrogen iodide is colourless, proceedings of the reaction are easily observable.

Forward Reaction

On heating, hydrogen and iodine vapours in a closed flask, hydrogen iodide is formed. As a result, purple colour of iodine fades a it react to form colourles hydrogen iodide.

$$H_2 + I_2 \longrightarrow 2HI$$

Reverse Reaction

When only hydrogen iodide is heated in a flask, purple colour appears because of formation of iodine vapours. Such as

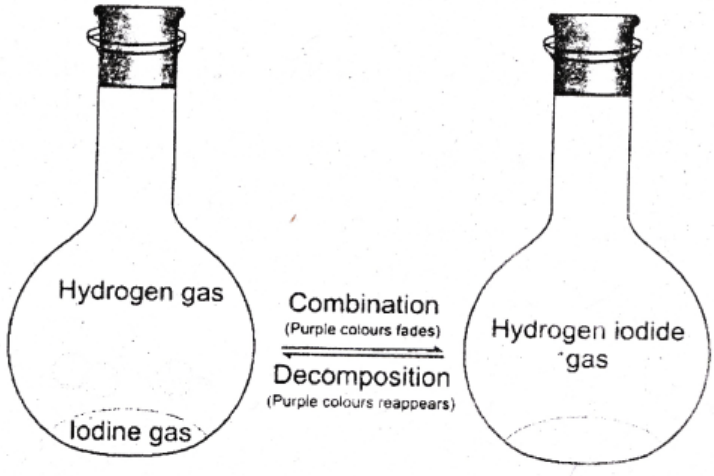
$$2HI \longrightarrow H_2 + I_2$$

In this case, hydrogen iodide acts as reactant and produces hydrogen and iodine vapours. This reaction is reverse of the above. Therefore, it is called as reverse reaction.

At Equilibrium

When both of these reactions are written together as a reversible reaction, they are represented as:

$$2HI \rightleftharpoons H_2 + I_2$$



Example 2

Forward reaction

When calcium oxide and carbon dioxide react, they produce calcium carbonate.

$$CaO + CO_2 \longrightarrow CaCO_3 \text{ (combination)}$$

Reverse reaction

When $CaCO_3$ is heated in an open flask, it decomposes to form calcium oxide and carbon dioxide. CO_2 escapes out and reaction goes to completion:

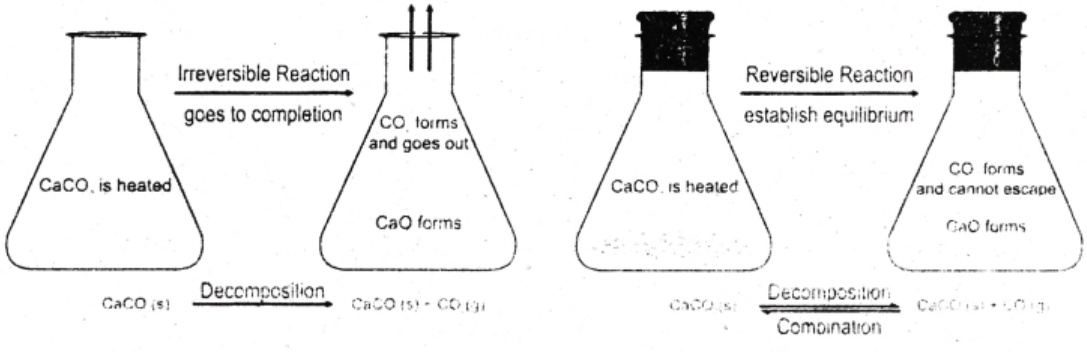
$$CaCO_3 \longrightarrow CaO + CO_2 \text{ (decomposition)}$$

In these two reactions, decomposition is reverse to combination or vice versa.

At equilibrium

In the beginning, forward reaction is fast and reverse reaction is slow. But eventually, the reverse reaction speeds up and both reactions go on at the same rate. At this stage decomposition and combination take place at the same rate but in opposite directions, as a result amounts of $CaCO_3$, CaO and CO_2 do not change. It is written as

$$CaCO_3 \rightleftharpoons CaO + CO_2$$



Q.4 What is chemical equilibrium? Explain the characteristics of dynamic equilibrium.

Chemical equilibrium

When the rate of the forward reaction takes place at the rate of reverse reaction, the composition of the reaction mixture remains constant, it is called chemical equilibrium state.

Possibilities

At equilibrium state there are two possibilities:

(i) Static equilibrium

When reaction ceases to proceed, it is called static equilibrium. This happen mostly in physical phenomenon.

Example: a building remains stand in rather than falling down because all the forces acting on it are balanced. This is an example of static equilibrium.

(ii) Dynamic equilibrium

Then reaction does not stop; only the rates of forward and reverse reaction become equal to each other but take place in opposite directions. This is called dynamic equilibrium state. Dynamic means reaction is still continuing at dynamic equilibrium state.

Rate of forward reaction = Rate of reverse reaction

Explanation: In a reversible reaction, dynamic equilibrium is established before the completion of reaction. At initial stage the rate of forward reaction is very fast and reverse reaction is taking place at a negligible rate. But gradually slows down and reaction speed up. Eventually, both reactions attain the same rate; it is called a dynamic equilibrium state

Characteristic features of dynamic equilibrium

A few important characteristic features of dynamic equilibrium are given below:

(i) Equilibrium is achievable only in a closed system (in which substances can neither leave nor enter).

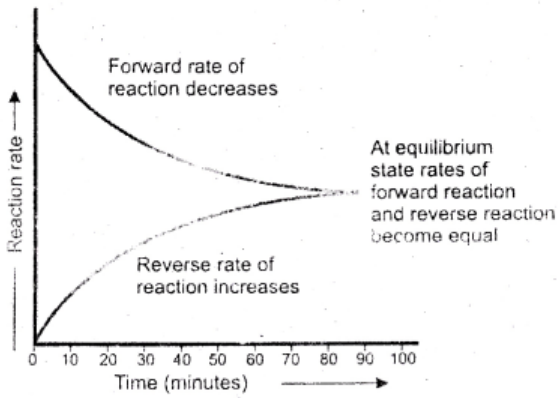
(ii) At equilibrium state a reaction does not stop. Forward and reverse reactions keep on taking place at the same rate but in opposite direction.

(iii) At equilibrium state, the amount (concentration) of reactants and products do not change. Even physical properties like colour, density, etc. remain the same.

(iv) An equilibrium state is attainable from either way, i.e. starting from reactants or from products.

(v) An equilibrium state can be disturbed and again achieved under the given conditions of concentration, pressure and temperature.

Graphical Representation of Equilibrium State



Q.5 State and explain law of mass action. Derive the law of mass action for a general reaction.

Law of Mass Action

Guldberg and wage in 1869 put forward this law.

Statement

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.

Active Mass

Generally, an active mass is considered as the molar concentration in units of moldm^{-3}, expressed as square brackets [ ].

Derivation

Consider for example, a reversible reaction of the type

$$A+B \underset{k_r}{\overset{k_f}{\rightleftharpoons}} C+D$$

Suppose [A], [B], [C] and [D] are the molar concentrations (mole dm^{-3}) of A, B, C and D respectively.

According to the Law of Mass Action

The rate of the forward reaction α [A] [B]

$= k_f$ [A] [B]

Similarly,

The rate of the reverse reaction α [C] [D]

$= k_r$ [C] [D]

Where k_f and k_r are the proportionality constant called specific rate constants of the forward and the reverse reactions respectively.

At equilibrium state:

The rate of forward reaction = The rate of reverse reaction

$$k_f[A][B] = k_r[C][D]$$

$$\frac{k_f}{k_r} = \frac{[C][D]}{[A][B]}$$

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

K_c is called equilibrium constant. It is represented as:

$$K_c = \frac{[C][D]}{[A][B]}$$

Law of Mass Action describes the relationship between active masses of the reactants and the rate of a reaction.

Derivation of the Expression for Equilibrium Constant for General Reaction

Let us apply the law of Mass Action for a general reaction.

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

Statement

The rate of a chemical reaction is directly proportional to the product of the molar concentrations of its reactants raised to power equal to their number of moles in the balanced chemical equation of the reaction.

Derivation

Let us first discuss the forward reaction. A and B are the reactants whereas 'a' and 'b' are their number of moles.

The rate of forward reaction according to law of Mass Action is:

$$R_f \quad \alpha \quad [A]^a[B]^b$$
$$R_f \quad = \quad k_f[A]^a[B]^b$$

Where kf is the rate constant for the forward reaction.

Similarly, the rate of the reverse reaction R_r is directly proportional to the product of [C] [D], where 'c' and 'd' are the number of moles as given in the balanced chemical equation.

Thus,

$$R_r \quad \alpha \quad [C]^c[D]^d$$
$$R_r \quad = \quad k_r[C]^c[D]^d$$

Where k_r is the rate constant for the reverse reaction.

We know that at equilibrium state the rates of both the reactions are equal.

The rate of forward the reaction = The rate of the reverse reaction

Such as: $R_f = R_r$

and putting the values of R_f and R_r

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

By taking the constants on one side and the variables on other side of the equation, the above equation becomes:

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

$$K_C = \frac{k_f}{k_r}$$

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

Where K_c is called equilibrium constant

Q.6 What is equilibrium constant? Explain its units.

Definition

Equilibrium constant is ratio of the product of concentration of products raised to the power of coefficient to the product of concentration of reactants rcsed to the power of coefficient as expressed in the balanced chemical equation.

Formula

$$K_c = \frac{\text{Product of concentration of products raised to the power of coefficients}}{\text{Product of concentration of reactants raised to the power of coefficients}}$$

Unit of K_c

K_c has no units in reactions with equal number of moles on both sides of the equation. This is because concentration units cancel out in the expression for K_c for the reaction.

$$H_2 + I_2 \longrightarrow 2HI$$

$$\text{Units} = \frac{\cancel{\left(\text{mol dm}^{-3}\right)^2}}{\cancel{\left(\text{mol dm}^{-3}\right)}\ \cancel{\left(\text{mol dm}^{-3}\right)}} = \text{no unit}$$

For reactions in which the number of moles of reactants and product are equal in the balanced chemical equation, K_c of course, have units, e.g., for reaction

$$N_2 + 3H_2 \rightleftharpoons 2NH_3$$

$$K_c = \frac{\left(\text{mol dm}^{-3}\right)^2}{\left(\text{mol dm}^{-3}\right)\left(\text{mol dm}^{-3}\right)^3} = \text{mol}^{-2}\text{dm}^6$$

Q.7 What are the importance of equilibrium constant?

Knowing the numerical value of equilibrium constant of a chemical reaction, direction as well as extent of the reaction can be predicted.

(i) Predicting Direction of a Reaction

Direction of a reaction at a particular moment can be predicted by inserting the concentration of the reactants and products at that particular moment in the equilibrium expression.

Example

The gaseous reaction of hydrogen with iodine.

$$H_2 + I_2 \rightleftharpoons 2HI \qquad K_C = 57.0 \text{ at } 700 \text{ K}$$

Explanation

We withdraw the samples from the reaction mixture and determine the concentrations of H_2, I_2 and HI. Suppose concentrations of the components of the mixture are:

$[H_2]_t = 0.10 \text{ mol dm}^{-3}$ $[I_2]_t = 0.20 \text{ mol dm}^{-3}$ and $[HI]_t = 0.40 \text{ mol dm}^{-3}$

The subscript 't' with the concentration symbols means that the concentrations are measured at some time t, not necessarily at equilibrium. When we put these concentrations into the equilibrium constant expression, we obtain a value called the reaction quotient Q_c. The reaction quotient for this reaction is calculated as:

As the numerical value of Q_c (8.0) is less than K_c(57.0), the reaction is not at equilibrium. It requires more concentration of product. Therefore, reaction will move in the forward direction.

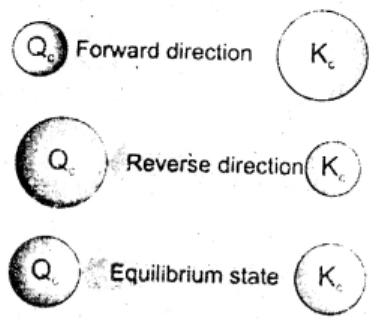
The reaction quotient Q_c is useful because it predicts the direction of the reaction by comparing the value of Q_c with K_c.

(i) **Possibilities of Reaction**

(a) If $Q_c < K_c$; the reaction goes from left to right, i.e., in forward direction to attain equilibrium.

(b) If $Q_c > K_c$; the reaction goes from right to left, i.e., in reverse direction to attain equilibrium.

(c) If Qc = Kc; forward and reverse reactions take place at equal rates i.e., equilibrium has been attained.



(ii) **Predicting Extent of a Reaction**

Numerical value of the equilibrium constant predicts the extent of a reaction. It indicates to which extent reactants are converted to products.

Responsibilities: In general, there are three possibilities of predicting extent of reactions as explained below.

a) **Large numerical value of K_c**

The large value of K, indicates that at equilibrium position the reaction mixture consists of almost all products and reactants are negligible. The reaction has almost gone to completion

For example, oxidation of. carbon monoxide goes to completion at 1000 K.

Example $2CO_{(g)} + O_{2(g)} \rightleftharpoons 2CO_{2(g)}$ $Kc = 2.2 \times 10^{22}$

b) **Small numerical value of K_c**

When the K, value of reaction is small, it indicates that the equilibrium has established with a very small conversion of reactants to products. At equilibrium position, almost all reactants are present but amount of products is negligible. *Such type of reaction never goes to completion.* For example

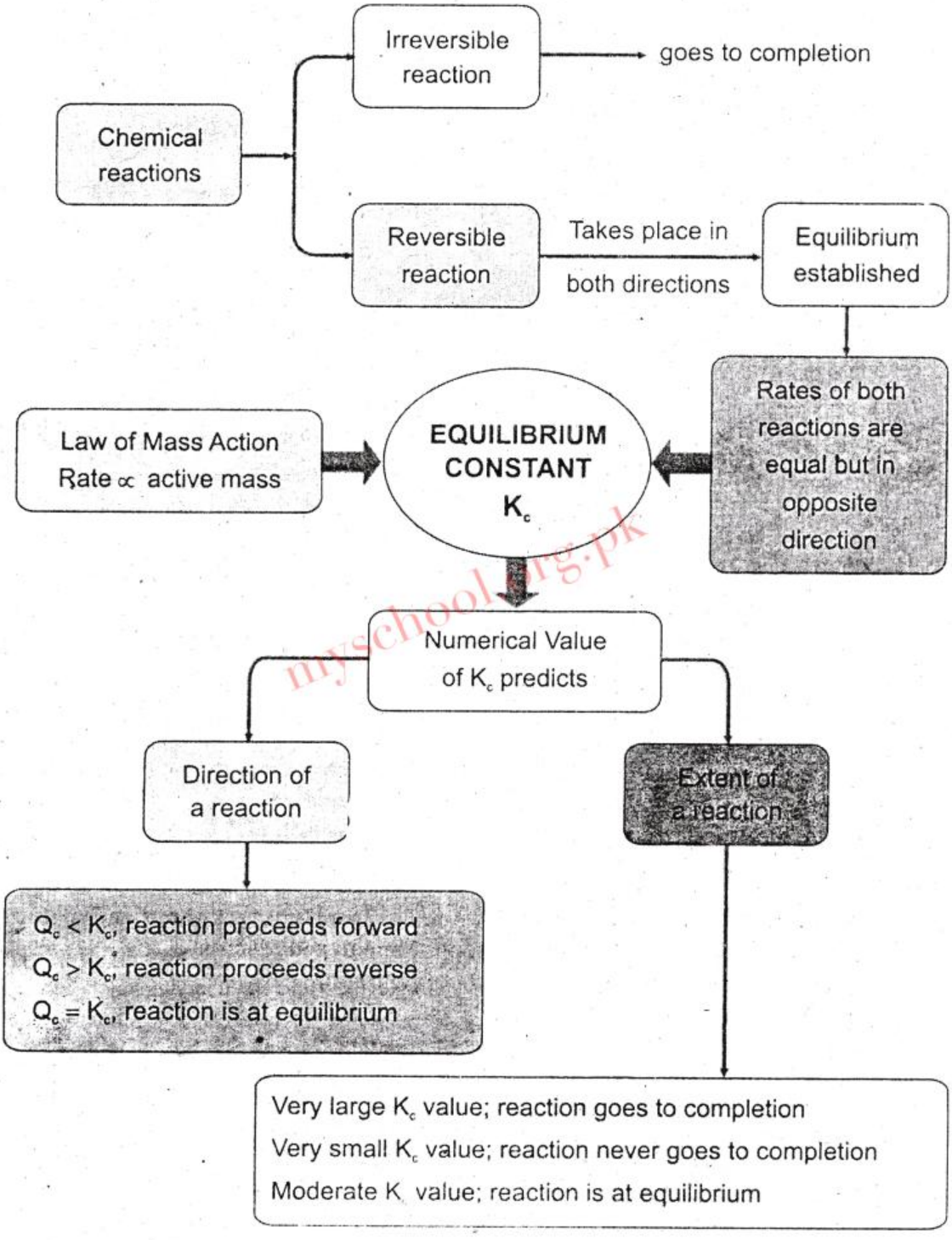
$2NH_3 \rightleftharpoons N_{2(g)} + 3H_{2(g)}$ $Kc = 3.0 \times 10^{-9}$

:) **Numerical value of K, is neither small nor large**

Such reactions have comparable amounts of reactants and products at equilibrium position.

xample: $N_2O_{4(g)} \rightleftharpoons 2NO_{2(g)}$ $Kc = 0.211$

CONCEPT DIAGRAM



EXERCISE

MCQ'S

1. **The characteristics of reversible reactions are the following except:**
   (a) products never recombine to form reactants
   (b) they never complete
   (c) they proceed in both ways
   (d) they have a double arrow between reactants and products

2. **In the lime kiln, the reaction $CaCO_3(s) \longrightarrow . CaO(s) + CO_2(g)$ goes to completion because**
   (a) of high temperature
   (b) CaO is more stable than $CaCO_3$
   (c) CO_2 escapes continuously
   (d) CaO is not dissociated

3. **For the reaction, $2A_{(g)} + B_{(g)} \rightleftharpoons 3C_{(g)}$ the expression for the equilibrium constant is:**
   (a) $\frac{[2A][B]}{[3C]}$
   (b) $\frac{[A]^2[B]}{[C]^3}$
   (c) $\frac{[3C]}{[2A][B]}$
   (d) $\frac{[C]^3}{[A]^2[B]}$

4. **When a system is at equilibrium states**
   (a) the concentration of reactants and products becomes equal
   (b) the opposing reactions (forward and reverse) stop
   (c) the rate of the reverse reaction becomes very low
   (d) the rates of the forward and reverse reactions become equal

5. **Which one of the following statement is not correct about active mass?**
   (a) rate of reaction is directly proportional to active mass
   (b) active mass is taken in molar concentration
   (c) active mass is represented by square brackets
   (d) active mass means total mass of substances

6. **When the magnitude of K_c is very large it indicates**
   (a) reaction mixture consists of almost all products
   (b) reaction mixture has almost all reactants
   (c) reaction has not gone to completion
   (d) reaction mixture has negligible products

7. **When the magnitude of K_c is very small it indicates**
   (a) equilibrium will never establish
   (b) all reactants will be converted to products
   (c) reaction will go to completion '
   (d) the amount of-products is negligible

8. **Reactions which have comparable amounts of reactants and products at equilibrium state have**

(a) very small K_c value (b) very large K_c value

(c) moderate K_c value (d) none of these

9. **At dynamic equilibrium**

(a) the reaction stops to proceed

(b) the amounts of reactants and products are equal

(c) the speeds of the forward and reverse reactions are equal

(d) the reaction can no longer be reversed

10. **In an irreversible reaction dynamic equilibrium**

(a) never establishes

(b) establishes before the completion of reaction

(c) establishes after the completion of reaction

(d) establishes readily

11. **A reverse reaction is one that**

(a) which proceeds from left to right

(b) in which reactants react to form products

(c) which slows down gradually

(d) which speeds up gradually

12. **Nitrogen and hydrogen were reacted together to make ammonia;**

$$N_2 + 3H_2 \rightleftharpoons 2NH_3 \qquad K_c = 2.86\ mol^{-2}dm^6$$

What will be present in the equilibrium mixture?

(a) NH_3 only (b) N_2, H_2 & NH_3 (c) N_2 & H_2 (d) H_2 only

13. **For a reaction between PCl_3 and Cl_2 to form PCl_5, the units of K_c, are:**

(a) mol dm^{-3} (b) mol^{-1} dm^{-3} (c) mol^{-1} dm^3 (d) mol dm^3

ANSWER KEY

1	a	3	d	5	d	7	d	9	c	11	d	13	c
2	c	4	d	6	a	8	c	10	a	12	b	KIPS	

SHORT QUESTIONS

Q.1 What are irreversible reactions? Give a few characteristics of them?

Ans. The reaction, in which the product do not recombine to form reactants are called irreversible reaction.

Characteristics of Irreversible Reactions

- They are represented by (→) between reactant and product.
- These reactions are proceed to completion.
- These reactions may be conduct in open and close vessels.
- There is no sign of equilibrium state in these reactions.

Q.2 Define chemical equilibrium state.

Ans. When the rate of the forward reaction takes place at the rate of reverse reaction, the composition of the reaction mixture remains constant. It is called a chemical equilibrium state.

Example: $N_2+3H_2 \rightleftharpoons 2NH_3$ $K_c = 2.86\ mol^{-2}dm^6$

Q.3 Give the characteristics of reversible reaction.

Ans.

- They are represented by ($\rightleftharpoons$) between reactant and product.
- It can be attainable from either way.
- A reversible reaction can never go to completion.
- Usually, it can be carried out in a closed vessel.
- In reversible reaction, equilibrium state is the ultimate goal.

Q.4 How dynamic equilibrium is established?

Ans. When reaction does not stop, only the rates of forward reverse reactions become equal to each other but take place in opposite directions. This is called dynamic equilibrium state.

Example: $N_2+3H_2 \rightleftharpoons 2NH_3$ $K_c = 2.86\ mol^{-2}dm^6$

Q.5 Why at equilibrium state reaction does not stop?

Ans. At equilibrium state, a reaction does not stop because forward and reverse reactions keep on taking place at the same rate but in opposite direction. Products recombine to from reactants.

Example: $I_2+H_2 \rightleftharpoons 2HI$ $K_c = 57.0$ **at 700 K**

Q.6 Why equilibrium state is attainable from either way?

Ans. An equilibrium sate is attainable from either way because it may start from reactant to give products while products recombine to give reactant again.

Reactants $\rightleftharpoons$ Products

$A+B \rightleftharpoons C+D$

Q.7 What is relationship between active mass and rate of reaction?

Ans. Law of mass action describe the relationship between active masses of the reactants and the rate of a reaction.

According to this law:

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

Example: $A+B \underset{k_r}{\overset{k_f}{\rightleftharpoons}} C+D$

At equilibrium state:

The rate of forward reaction = The rate of reverse reaction

$$k_f[A][B] = k_r[C][D]$$

$$\frac{k_f}{k_r} = \frac{[C][D]}{[A][B]}$$

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

K_c is called equilibrium constant. It is represented as:

$$K_c = \frac{[C][D]}{[A][B]}$$

Law of Mass Action describes the relationship between active masses of the reactants and the rate of a reaction.

Q.8 Derive equilibrium constant expression for the synthesis of ammonia from nitrogen and hydrogen.

Ans. $N_{2(g)} + 3H_{2(g)} \underset{R_r}{\overset{R_f}{\rightleftharpoons}} 2NH_{3(g)}$

The rate of forward reaction: $R_f = K_f[N_2][H_2]^3$

The rate of reverse reaction: $R_r = K_r[NH_3]^2$

$$K_c = \frac{[NH_3]^2}{[N_2][H_2]^3}$$

Q.9 Write the equilibrium constant expression for the following reactions:

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

(ii) $CO_{(g)} + 3H_{2(g)} \rightleftharpoons CH_{4(g)} + H_2O_{(g)}$

Ans. (i) $H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$

The rate of forward reaction $R_f = K_f[H_2][I_2]$

The rate of reverse reaction $R_r = Kr[HI]^2$

The equilibrium constant expression:

$$K_c = \frac{\text{Products}}{\text{Reactants}}$$

$$K_c = \frac{[HI]^2}{[H_2][I_2]}$$

(ii) $CO_{(g)} + 3H_{2(g)} \rightleftharpoons CH_{4(g)} + H_2O_{(g)}$

The rate of forward reaction $R_f = K_f[CO][H_2]^3$

The rate of reverse reaction $R_r = K_r[CH_4][H_2O]$

The equilibrium constant expression:

$$K_c \frac{[CO][H_2]^3}{[CH_4][H_2O]}$$

Q.10 How direction of a reaction can be predicted?

Ans. Direction of a reaction at particular moment can be predicted by inserting the concentration of the reactants and products at that particular amount in the equilibrium expression.

$$K_c = \frac{[\text{Molar concentration of product}]}{[\text{Molar concentration of reactatnt}]}$$

Q.11 How can you know that a reaction has achieved an equilibrium state?

Ans. Dynamic equilibrium

Then reaction does not stop; only the rates of forward and reverse reaction become equal to each other but take place in opposite directions. This is called dynamic equilibrium state. Dynamic means reaction is still continuing at dynamic equilibrium state.

A reaction get achieved a equilibrium state when the:

Rate of forward reaction = Rate of reverse reaction

Explanation: In a reversible reaction, dynamic equilibrium is established before the completion of reaction. At initial stage the rate of forward reaction is very fast and reverse reaction is taking place at a negligible rate. But gradually slows down and reaction speed up. Eventually, both reactions attain the same rate; it is called a dynamic equilibrium state

Q.12 What are the characteristics of a reaction that establishes equilibrium state at once?

Ans. Characteristics

- In these reaction dynamic state equilibrium are called reversible reaction.
  Rate of forward reactions = Rate of reverse reactions
- These reaction does not go to completion.
- These reaction can be proceed in either way.

Q.13 If reaction quotient Qc of a reaction is more than Kc What will be the direction of the reaction?

Ans. If the value of Q_c is more than the K_c. The net reaction goes from right to left or it will move in reverse direction to attain equilibrium.

Q.14 An industry was established based upon a reversible reaction. It failed to achieve products on commercial level. Can you point out the basic reasons of its failure being a chemist?

Ans. In a reversible reaction, the amount of reactants and products remain same when the equilibrium state achieved, if a industry based on the reversible reaction, it cannot be achieved desired commercial product and its required amount that is why a reversible reaction based industry is failed.

EXTENSIVE QUESTIONS

Q.1 Describe a reversible reaction with the help of an example and graph.

Ans. See the topic

Q.2 Write down the macroscopic characteristics of dynamic equilibrium.

Ans. See the topic

Q.3 State the law of Mass Action and derive the expression for equilibrium constant for a general reaction.

Ans. See the topic

Q.4 What is the importance of equilibrium constant?

Ans. See the topic

NUMERICAL

Q.1 For the decomposition of di-nitrogen oxide (N_2O) into nitrogen and oxygen reversible reaction takes place as follows:

$$2N_2O \rightleftharpoons 2N_2 + O_2$$

The concentration of N_2O, N_2 and O_2 are 1.1 mol dm '', 3.90 mol dm^{-3} and 1.95 mol dm^{-3}, respectively at equilibrium. Find' out K_c for this reaction.

Given data:

Concentration of N_2 = 1.1 mol dm^{-3}
Concentration of N_2 = 3.90 mol dm^{-3}
Concentration of Os_2 = 1.95 mole dm^{-3}

Balanced chemical equation:

$$2N_2O \rightleftharpoons 2N_2 + O_2$$

Required data:

Equilibrium constant = K_c = ?

Solution:

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

$$K_c = \frac{[N_2]^2[O_2]}{[N_2O]^2}$$

Putting the value of concentration in above formula.

$$K_c = \frac{[3.90]^2[1.95]}{[11]^2}$$

$$= \frac{15.21 \times 1.95}{[1.1]^2}$$

$$= \frac{29.6595}{1.21}$$

Result: **K_c = 24.51 mol dm^{-3}**

Q.2 Hydrogen iodide decomposes to form hydrogen and iodine. If the equilibrium concentration of HI is 0.078 mol dm^{-3}, H_2 and I_2 is same 0.011 mol dm^{-3}. Calculate the equilibrium constant value for this reversible reaction:

Given data:

Concentration of HI = 0.078 mol dm^{-3}
Concentration of H_2 = 0.011 mol dm^{-3}
Concentration of I_2 = 0.011 mol dm^{-3}

Balanced chemical equation:

$$2HI \rightleftharpoons N_2 + I_2$$

Required data:

Equilibrium constant = K_c = ?

Solution:

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

$$K_c = \frac{[H_2][I_2]}{[HI]^2}$$

Putting the value of concentration in the above carnation.

$$K_c = \frac{[0.011][0.011]}{[0.078]^2}$$

$$= \frac{0.000121}{0.006084}$$

Result: $\mathbf{K_c = 0.01989}$

Q.3 For the fixation of nitrogen following reaction takes place:

$$N_2 + O_2 \rightleftharpoons 2NO$$

When the reaction takes place at 1500 K, the K_c for this is 1.1×10^{-5}. If equilibrium concentrations of nitrogen and oxygen are 1.7×10^{-3} mol dm^{-3} and 6.4×10^{-3} mol dm^{-3}, respectively, how much NO is formed?

Given data:

Concentration of $N_2 = 1.7 \times 10^{-3}$ mol dm^{-3}
Concentration of $O_2 = 6.4 \times 10^{-3}$ mol dm^{-3}
Equilibrium constant value
For given equation $= 1.1 \times 10^{-5}$

Balanced chemical equation:

$$N_2 + O_2 \rightleftharpoons 2NO$$

Required data:

Concentration of NO = ?

Solution:

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

$$K_c = \frac{[NO]^2}{[N_2][O_2]}$$

Putting the value of concentration in the above carnation.

$$1.1 \times 10^{-5} = \frac{[NO]^2}{[1.7 \times 10^{-3}][6.7 \times 10^{-3}]}$$

$$[NO]^2 = (1.1 \times 10^{-5}) \times (1.7 \times 10^{-3}) \times (6.4 \times 10^{-3})$$

$$= \sqrt{1.1968 \times 10^{-10}}$$

$$NO = 1.09 \times 10^{-5} \text{ mol } dm^{-3}$$

Result: $\mathbf{NO = 1.09 \times 10^{-5} \text{ mol } dm^{-3}}$

Q.4 **When nitrogen reacts with hydrogen to form ammonia, the equilibrium mixture contains 0.31 mol dm^{-3} and 0.50 mol dm^{-3} of nitrogen and hydrogen respectively. If the K_c is 0.50 mol dm^{-3} what is the equilibrium concentration of ammonia?**

Given data:

Concentration of N_2 = 0.31mol dm^{-3}
Concentration of H_2 = 0.50 mol dm^{-3}
Equilibrium constant value
For given equation K_C = 0.5 $mol^{-2}dm^6$

Balanced chemical equation:

$$N_2 + 3H_2 \rightleftharpoons 2NH_3$$

Required data:

Concentration of NH_3 = ?

Solution:

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

$$K_c = \frac{[NH_3]^2}{[N_2][H_2]^3}$$

Putting the value of concentration in the above carnation.

$$K_c = \frac{[NH_3]^2}{[0.31][0.50]^3}$$

$$[NH_3]^2 = (0.50) \times (0.31) \times (.50)^3$$

$$= \sqrt{0.019375}$$

$$NH_3 = 0.1392 \text{ mol } dm^{-3}$$

Result: **NH_3 = 0.14 mol dm^{-3}**

CHAPTER 9

CHEMICAL EQUILIBRIUM

MULTIPLE CHOICE QUESTIONS

1. **In chemical reactions the substances that combine are called:**
   (a) Products (b) Reversible reaction
   (c) Reactants (d) Irreversible reaction
2. **Name the reactants in this equation.** $2H_{2(q)} + O_{2(g)} \xrightarrow[\text{heat}]{pt} 2H_2O_{(l)}$
   (a) H_2O (b) H_2 and O_2 (c) O_2 (d) None of these
3. **The reaction in which the products do not recombine to from reactants is known as:**
   (a) Reversible reactions (b) Reactants
   (c) Products (d) Irreversible reactions
4. **The reactions in which the products recombine to form reactants are called:**
   (a) Reactants (b) Reversible reactions
   (c) Irreversible reaction (d) Both and b
5. **Irreversible reaction goes on:**
   (a) Never complete (c) completion (b) Both a and c (d) None of these
6. **Reversible reaction:**
   (a) can complete (b) never complete (c) Both a and b (d) None of these
7. **The colour of hydrogen Iodide (HI) is:**
   (a) Blue (b) Grey (c) Purple (d) Colourless
8. **The colour of iodine (I) is:**
   (a) Purple (b) Green (c) Yellow (d) None of these
9. **At equilibrium the rate of forward and reverse reaction becomes.**
   (a) Greater (b) Normal (c) Equal (d) Lesser
10. **Dynamic means reaction i:**
    (a) Stops (b) Still continuing (c) Opposite direction (d) Both a and b
11. **When reaction ceases to proceed it is called:**
    (a) Dynamic equilibrium (b) Static equilibrium
    (c) chemical equilibrium (d) none of these
12. **Reaction in which reactants react to form products called:**
    (a) forward reactions (b) reverse reactions (c) reversible reaction (d) backward reactions
13. **At initial stage the rate of forward reaction is.**
    (a) low (b) very low (c) very fast (d) all of these
14. **There are _____ possibilities at equilibrium state.**
    (a) three (b) five (c) four (d) two
15. **Reverse reaction take place from:**
    (a) left to right (b) right to left (c) both a and b (d) none of these
16. **Reverse reactions _____ gradually.**
    (a) speeds up (b) negligible (c) slows down (d) none of above
17. **Forward reaction takes place from:**
    (a) left to right (b) right to left (c) both a and b (d) all of these

18. **The characteristics of reversible reaction are the following except.**
(a) products never recombine to from reactant (b) they never complete
(c) they proceed in both ways (d) they have double arrow between them

19. **In the lime kiln the reaction $CaCO_{3(s)} \longrightarrow CaO_s + CO_{2(g)}$ goes to completion because, of**
(a) High temperature (b) CO_2 escapes continuously
(c) CaO is not dissociated (d) CaO is more stable that $CaCO_3$.

20. **For the reaction $2A_g + B_g \rightleftharpoons 3C_g$ the expression for the equilibrium constant is**
(a) $\frac{[2A][B]}{[3C]}$ (b) $\frac{[A]^2[B]}{[C]^3}$ (c) $\frac{[3C]}{[2A][B]}$ (d) $\frac{[C]^3}{[A]^2[B]}$

21. **Which statement is not correct about active mass?**
(a) Rate of reaction is directly proportional to active mass.
(b) The opposing reactions (forward and reverse) stops.
(c)Active mass means total mass of substances.
(d) None of these

22. **When the magnitude of K_c is very large it indicates.**
(a) Reaction mixture consists of almost all products
(b) Reaction mixture has almost all reactants.
(c) Reaction has gone to completion.
(d) All of these

23. **When the magnitude of Kc is very small it indicates.**
(a) equilibrium is never establish
(b) all reactants will be converted to products
(c) reaction will go to complete
(d) the amounts of products is negligible

24. **Reaction will have comparable amounts of reactants and products at equilibrium state have.**
(a) very small Kc value (b) moderate Kc value
(c) very large Kc value (d) none of these

25. **In an irreversible reaction dynamic equilibrium.**
(a) never establishes (b) establish readily
(c) establish after the completion of reaction. (d) establish before the completion of reaction.

26. **For a reaction between PCl_3 and Cl_2 to form PCl_5 the units of Kc are:**
(a) mol dm^{-3} (b) mol^{-1} dm^{-3} (c) mol^{-1} dm^3 (d) mol dm^3

27. **An equilibrium is achievable only in**
(a) open system (b) close system (c) both a and b (d) all of these

28. **At equilibrium state the physical properties like density, colour etc:**
(a) remains same (b) changes (c) all of these (d) none of these

29. **Name the scientist who presented law of mass action.**
(a) Guldberg (b) Bronsted (c) Lowry (d) Lewis

30. **Reversible reactions takes place in:**
(a) single direction (b) both directions (c) both a & b (d) all of these

31. **Numerical value of K_c predicts :**
(a) direction of reaction (b) extent of reaction
(c) both a & b (d) all of these

32. **When H_2 and O_2 combine they form**

(a) H_2O (b) H and O (c) HO_2 (d) none

33. **When H_2 and I_2 combine they form**

(a) H_2O (b) HI (c) I_2 (d) H_2 and I_2

34. **The ratio of product concentration of products raised to power of co-efficient to the products of reactant raised to the power co-efficient is known as.**

(a) Kc (b) Qc (c) forward reaction (d) reverse reaction

35. **In direction of a reaction, reaction proceeds forward then:**

(a) Qc < Kc (b) Qc > Kc (c) Qc = Kc (d) None of them

36. **In direction of a reaction, reaction proceeds reverse then:**

(a) Qc < Kc (b) Qc > Kc (c) Qc = Kc (d) all of these

37. **In direction of a reaction, reaction is at equilibrium then:**

(a) Qc < Kc (b) Qc > Kc (c) Qc = Kc (d) Both a & b

38. **In extent of reaction, the reaction goes to completion have:**

(a) very large Kc value (b) very small Kc value

(c) moderate Kc value (d) None of them

39. **In extent of reaction, the reaction never goes to completion have:**

(a) very large Kc value (b) very small Kc value

(c) moderate Kc value (d) Qc = Kc

40. **Reaction quotient is expressed as:**

(a) K_c (b) Q_c (c) K_r (d) K_f

41. **There are _____ possibilities of predicting extent of reaction**

(a) 1 (b) 2 (c) 3 (d) 4

42. **There are _____ major components of atmosphere:**

(a) 1 (b) 2 (c) 3 (d) 4

43. **The two major components of atmosphere are:**

(a) nitrogen and hydrogen gasses (b) oxygen and hydrogen gasses

(c) nitrogen and carbon dioxide gasses (d) nitrogen and oxygen gasses

44. **Nitrogen and oxygen constituents' _____ of the atmosphere:**

(a) 99% (b) 98% (c) 92% (d) 97%

45. **Gases are being used to manufacture:**

(a) products (b) chemicals (c) reactants (d) Both b & c

46. **Nitrogen is used to prepare:**

(a) carbon dioxide (b) ammonia (c) hydrogen (c) None of these

47. **Oxygen is used to prepare:**

(a) ammonia (b) nitrogen gas (c) oxygen (d) sulphur dioxide

48. **By knowing the value of equilibrium constant _____ can be predicted:**

(a) direction of reaction (b) extent of reaction (c) both a & b (d) all of these

49. **The characteristics of inversible reaction are the following exept**
(a) they never complete
(b) products never recombines to form reactions
(c) they have a double arrow between reactants and products
(d) none of these

50. **Many environmental systems depend for their:**
(a) existence on their delicate equilibrium phenomenona
(b) existence on the water
(c) both of these
(d) none of these

51. **Ammonia is used to manufacture :**
(a) sulphuric acid (b) hydrogen
(c) nitrogenous fertilizers (d) none of these

52. **Sulphur dioxide is used to manufacture:**
(a) sulphuric dioxide (b) ammonia
(c) sulphuric acid (d) nitrogenous fertilizers

53. **Which is the king of chemicals:**
(a) sulphuric dioxide (b) ammonia (c) nitrogen (d) sulphuric acid

54. **Nitrogen and oxygen gasses are being used to manufacture chemicals since the advent of _____ century:**
(a) 18 (b) 20 (c) 19 (d) 21

55. **The reaction in which all the reactants have been converted into products are known as**
(a) incomplete reactions (b) complete reactions
(c) continuous reactions (d) None of them

56. **The lives of aquatic animals and plants are indirectly related to concentration of _____ dissolved in water:**
(a) carbon dioxide (b) oxygen (c) both a & b (d) none of them

57. **Irreversible reaction represented by a _____ between a reactant and a product:**
(a) single arrow (b) K_c (c) double arrow (d) all of these

58. **Irreversible reaction consists of:**
(a) forward reactions (b) reverse reactions
(c) forward & reverse reactions (d) none of them

59. **When CaO reacts with CO_2 they produce:**
(a) $CaCO_3$ (b) $CaCO_2$ (c) Both a & b (d) all of these

60. **In the beginning reverse reactions is**
(a) fast (b) stops (c) slow (d) none of above

61. **Rate of forward reactions takes place at the rate of reverse reaction, the composition of the reaction mixture remains constant is called**

(a) satatic equilibrium (b) dynamic equilibrium

(c) chemical equilibrium state (d) none of these

62. **Point out the co efficient in the following hypothetical reactions**

$2A+3D \longrightarrow 4C+8D$

(a) 2,3,4d (b)2,3,4,3 (c) A,b,c,d (d) 2,3,4,8

63. **An active mass is considered as the molar concerations in units of**

(a) mol dm^{-3} (b) mol^{-3} dm (c) mol^{-2} dm (d) mol^{-2} dm

64. **There are _____characteristics of dynamic equilibrium**

(a) one (b) two (c) three (d) five

65. **The oxidation of cabon monoxides goes to completion at**

(a) 2000K (b) 1000K (c) 100K (d) 200K

66. **The reaction quotient is useful because it predicts the direction of reaction by comparing the value of**

(a) Qc (b) Qc with Kc (c) k_c (d) none of these

67. **For the reactions $H_2 + I_2 \longrightarrow 2HI$. The reactions quotients for this reactions is**

(a) 8.0 (b) 2.0 (c) 9.0 (d) None of these

68. **As the numeric value of Qc (8.0) is less than K_C (57.0) the reaction is not**

(a) in forward direction (b) at equilibrium (c) in reverse direction (d) all of these

ANSWER KEY

1	c	14	d	27	b	40	b	53	d	66	b
2	b	15	b	28	a	41	c	54	b	67	a
3	d	16	a	29	a	42	b	55	b	68	b
4	b	17	a	30	b	43	d	56	b		
5	c	18	a	31	b	44	a	57	a		
6	b	19	b	32	a	45	b	58	a		
7	d	20	d	33	b	46	b	59	a		
8	a	21	c	34	a	47	d	60	c		
9	c	22	a	35	a	48	c	61	c		
10	b	23	d	36	b	49	c	62	d		
11	b	24	b	37	c	50	a	63	a		
12	a	25	a	38	a	51	c	64	d		
13	c	26	c	39	b	52	c	65	b		

SHORT QUESTIONS

CHEMICAL EQUILIBRIUM AND REVERSIBLE REACTION

Q.1 Why reversible reactions never complete?

Ans. **Definition:** The reactions in which the products can combine to form reactants are called reversible reactions.

These reactions never go to completion because, these reactions proceed in both ways i.e., in forward and in reverse direction as,

Rate of forward = Rate of reverse reaction.

$$A + B \underset{R_f}{\overset{R_f}{\rightleftharpoons}} C + D$$

Reactants Products

Q.2 What is a static equilibrium? Explain with an example.

Ans. When a reaction ceases (stop) to proceed. It is called static equilibrium. This happens mostly in physical phenomenon.

Example:

A building remains standing rather than falling down because all the forces action on it are balanced.

Q.3 Why the amounts of reactants and products do not change in reversible reaction?

Ans. In a reversible reaction, products can recombine to form reactants. An equilibrium state is achieved in these reaction and rate of forward and reverse reaction is same. So that is why amount of reactants and product will also be same.

EQUILIBRIUM CONSTANT AND LAW OF MASS ACTION

Q.1 Define the Law of Mass Action.

Ans. 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.

$$A + B \underset{K_r}{\overset{K_f}{\rightleftharpoons}} C + D$$

$$K_C = \frac{[C][D]}{[A][B]}$$

Q.2 How the active mass is represented?

Ans. An active mass is considered as the molar concentration in units of mol dm^{-3} expressed as in square brackets [ ].

Q.3 What do you mean by equilibrium constant?

Ans. Equilibrium constant is a ratio of the product of concentration of product raised to the power of coefficient to the product of concentration reactions raised to the power of coefficient as expressed in the balanced chemical equation.

$$Kc = \frac{\text{Product of concentration of products raised to the power of coefficients}}{\text{Product of concentration of reactants raised to the power of coefficients}}$$

Q.4 Point out the coefficients of each in the following hypothetical reactions:

(a) $2A + 3B \rightleftharpoons 4C + 2D$ (b) $4X \rightleftharpoons 2Y + 3Z$

(c) $2M + 4N \rightleftharpoons 5O$

Ans. (a) $2A + 3B \rightleftharpoons 4C + 2D$

The rate of forward reaction, $R_f = K_f [A]^2 [B]^3$

The rate of reverse reaction $R_r = K_r [C]^4 [D]^2$

$$K_c = \frac{\text{Product of Moler Concentration of Product}}{\text{Product of Moler Concentration of Reactants}}$$

$$K_c = \frac{[C]^4[D]^2}{[A]^2[B]^3}$$

(b) $4X \rightleftharpoons 2Y + 3Z$

The rate of forward reaction, $R_f = K_f [X]^4$

The rate of reverse reaction $R_r = K_r [Y]^2 [Z]^3$

$$Kc = \frac{[Y]^2[Z]^2}{[X]^4}$$

(c) $2M + 4N \rightleftharpoons 5O$

The rate of forward reaction, $R_f = K_f [M^2][N]^4$

The rate of reverse reaction $R_r = K_r [O]^5$

$$K_c = \frac{[O]^5}{[M]^2[N]^4}$$

Q.5 Write the equilibrium constant expressions for the following reactions:

(a) $2NO_{2(g)} \rightleftharpoons N_2O_{4(g)}$ (b) $PCl_{3(g)} + Cl_{2(g)} \rightleftharpoons PCl_{5(g)}$

(c) $2SO_{2(g)} + O_{2(g)} \rightleftharpoons 25O_{3(g)}$

Ans. (a) $2NO_{2(g)} \rightleftharpoons N_2O_{4(g)}$

Rate of forward reaction, $R_f = K_f [NO_2]^2$

Rate of reverse reaction, $R_r = K_r [N_2O_4]$

$$K_c = \frac{[N_2O_4]}{[NO_2]^2}$$

(b) $PCl_{3(g)} + Cl_{2(g)} \rightleftharpoons PCl_{5(g)}$

Rate of forward reaction, $R_f = K_f [PCl_5]$

Rate of reverse reactions, $R_r = K_r [PCl_5]$

Equilibrium constant expression

$$K_c = \frac{[PCl_5]}{[PCl_3][Cl_2]}$$

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

Rate of forward reaction, $R_f = K_f [SO_2]^2[O_2]$

Rate of reverse reactions, $R_r = K_r [SO_3]^2$

Equilibrium constant expression

$$K_c = \frac{[SO_3]^2}{[SO_2]^2[O_2]}$$

APPLICATION OF EQUILIBRIUM CONSTANT

Q.1 What do you mean by the extent of reaction?

Ans. The extent of a reaction indicates to which extent reactants are converted to product or it measures "How far a reaction proceeds before establishing equilibrium state,"

Q.2 Why the reversible reactions do not go to completion?

Ans. The reversible reactions do not go to completion because these reactions proceed in both ways i.e, forward and reverse direction.

When the rate of the forward reaction takes place at the rate of reverse reaction, the equilibrium state is achieved. At this state, the composition of reaction mixture remains constant.

Q.3 If a reaction has large value of K_c will it go to completion and why?

Ans. The large value of K_c indicates the reaction has almost gone to completion because at the equilibrium position the reaction mixture consists of almost all products and reactants are negligible.

Example: $2CO_{(g)} + O_{2(g)} \rightleftharpoons 2CO_{2(g)}$ $\quad K_c = 2.2 \times 10^{22}$

Q.4 Which types of reactions do not go to completion?

Ans. The reactions which have the very small value of K_c, never go to completion.

Example: $N_2O_{4(g)} \rightleftharpoons 2NO_{2(g)}$ $\quad K_c = 0.211$

Q.5 Why the reaction mixture does not have 50% reactants and 50% products at equilibrium position?

Ans. The amount of reactants and products at equilibrium position depends upon the value of K_c.

- If the K_c value is large. The reaction mixture at more products and less reactants at equilibrium state.
- If the K_c value is very small its means reaction mixture consist of more reactants and less products at equilibrium state.
- If the Kc neither small nor large, it means the amount of reactants and products almost same of comparable.

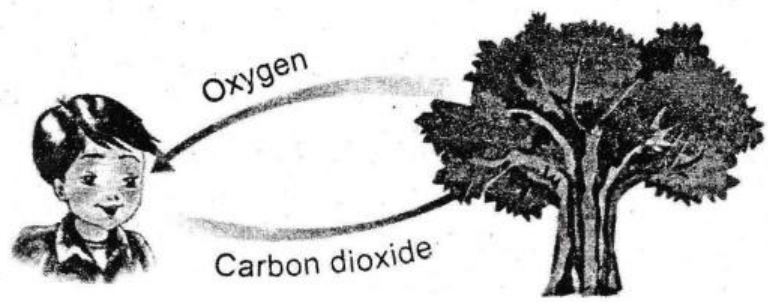
LONG QUESTIONS

Q.1 Write down the equilibrium in nature in detail.

Equilibrium in nature

We owe our existence to equilibrium phenomenon taking place in atmosphere. We inhale oxygen and exhale carbon dioxide, while plants consume carbon dioxide and release oxygen. This natural process is responsible for the existence of life on the Earth.

Many environmental systems depend for their existence on delicate equilibrium phenomenon, For example, concentration of gases in lake water is governed by the principles of equilibrium, The lives of aquatic plant and animals are indirectly related to concentration of dissolved oxygen in water,



9.1 REVERSFFILE REACTION AND DYNAMIC EQUILMRIUM

Q.2 What are chemical reaction? Write down the types of the chemical reaction.

Chemical reaction

A change in which a substance or substances are changed into one or more new substances. Chemical reactions consist of two components, reactant and products.

Reactant

In a chemical reaction the substances that combine are called reactants

Products

The new substances formed during a chemical reaction are called products.

Example

When H_2 and O_2 (reactant) combine they form H_2O (product),

$$2H_2 + O_2 \longrightarrow 2H_2O$$

Types of chemical reactions

There are two types of chemical reactions

Irreversible reaction

Most of the reaction the products do not recombine to form reactants, are called irreversible reactions. They are supposed to complete an are represented by putting a single arrow ($\longrightarrow$) between the reactants and products.

Example

$$2H_2 + O_2 \longrightarrow 2H_2O$$

Q.3 Explain in detail the reversible reaction with the suitable example.

Reversible reaction

The reactions in which the products can recombine to from reactants are called reversible reaction reactions. They never go to completion. These are represented by a double arrow between reactants and products. These reactions proceed in both ways, i.e. they consist of two reactions; forward and reverse, depending upon the conditions.

Explanation of reversible reaction with examples

Let us discuss a reaction between hydrogen and iodine. Because one of the reactant, iodine is purple, while the product hydrogen iodide is colourless, proceedings of the reaction are easily observable.

Forward Reaction

On heating, hydrogen and iodine vapours in a closed flask, hydrogen iodide is formed. As a result, purple colour of iodine fades a it react to form colourles hydrogen iodide.

$$H_2 + I_2 \longrightarrow 2HI$$

Reverse Reaction

When only hydrogen iodide is heated in a flask, purple colour appears because of formation of iodine vapours. Such as

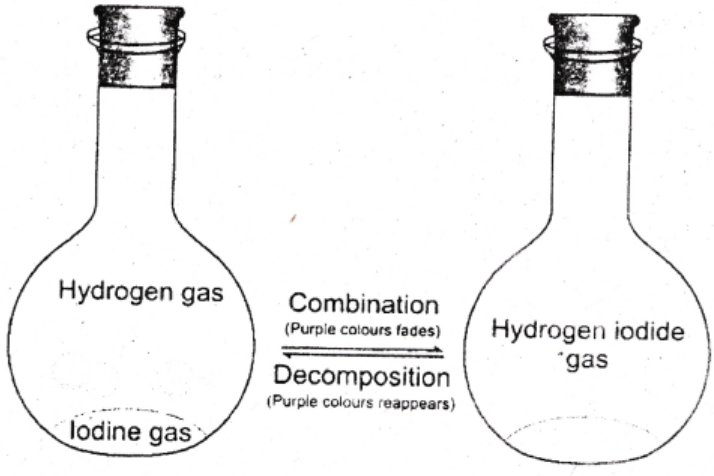
$$2HI \longrightarrow H_2 + I_2$$

In this case, hydrogen iodide acts as reactant and produces hydrogen and iodine vapours. This reaction is reverse of the above. Therefore, it is called as reverse reaction.

At Equilibrium

When both of these reactions are written together as a reversible reaction, they are represented as:

$$2HI \rightleftharpoons H_2 + I_2$$



Example 2

Forward reaction

When calcium oxide and carbon dioxide react, they produce calcium carbonate.

$$CaO + CO_2 \longrightarrow CaCO_3 \text{ (combination)}$$

Reverse reaction

When $CaCO_3$ is heated in an open flask, it decomposes to form calcium oxide and carbon dioxide. CO_2 escapes out and reaction goes to completion:

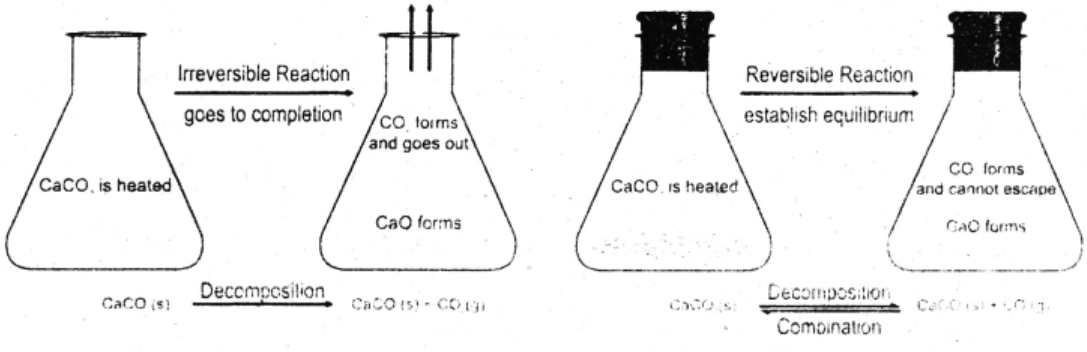
$$CaCO_3 \longrightarrow CaO + CO_2 \text{ (decomposition)}$$

In these two reactions, decomposition is reverse to combination or vice versa.

At equilibrium

In the beginning, forward reaction is fast and reverse reaction is slow. But eventually, the reverse reaction speeds up and both reactions go on at the same rate. At this stage decomposition and combination take place at the same rate but in opposite directions, as a result amounts of $CaCO_3$, CaO and CO_2 do not change. It is written as

$$CaCO_3 \rightleftharpoons CaO + CO_2$$



Q.4 What is chemical equilibrium? Explain the characteristics of dynamic equilibrium.

Chemical equilibrium

When the rate of the forward reaction takes place at the rate of reverse reaction, the composition of the reaction mixture remains constant, it is called chemical equilibrium state.

Possibilities

At equilibrium state there are two possibilities:

(i) Static equilibrium

When reaction ceases to proceed, it is called static equilibrium. This happen mostly in physical phenomenon.

Example: a building remains stand in rather than falling down because all the forces acting on it are balanced. This is an example of static equilibrium.

(ii) Dynamic equilibrium

Then reaction does not stop; only the rates of forward and reverse reaction become equal to each other but take place in opposite directions. This is called dynamic equilibrium state. Dynamic means reaction is still continuing at dynamic equilibrium state.

Rate of forward reaction = Rate of reverse reaction

Explanation: In a reversible reaction, dynamic equilibrium is established before the completion of reaction. At initial stage the rate of forward reaction is very fast and reverse reaction is taking place at a negligible rate. But gradually slows down and reaction speed up. Eventually, both reactions attain the same rate; it is called a dynamic equilibrium state

Characteristic features of dynamic equilibrium

A few important characteristic features of dynamic equilibrium are given below:

(i) Equilibrium is achievable only in a closed system (in which substances can neither leave nor enter).

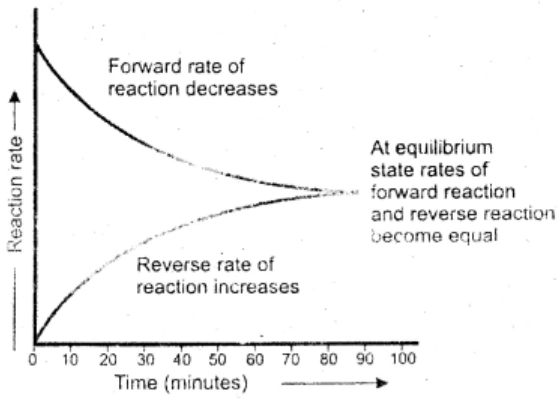
(ii) At equilibrium state a reaction does not stop. Forward and reverse reactions keep on taking place at the same rate but in opposite direction.

(iii) At equilibrium state, the amount (concentration) of reactants and products do not change. Even physical properties like colour, density, etc. remain the same.

(iv) An equilibrium state is attainable from either way, i.e. starting from reactants or from products.

(v) An equilibrium state can be disturbed and again achieved under the given conditions of concentration, pressure and temperature.

Graphical Representation of Equilibrium State



Q.5 State and explain law of mass action. Derive the law of mass action for a general reaction.

Law of Mass Action

Guldberg and wage in 1869 put forward this law.

Statement

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.

Active Mass

Generally, an active mass is considered as the molar concentration in units of moldm^{-3}, expressed as square brackets [ ].

Derivation

Consider for example, a reversible reaction of the type

$$A+B \underset{k_r}{\overset{k_f}{\rightleftharpoons}} C+D$$

Suppose [A], [B], [C] and [D] are the molar concentrations (mole dm^{-3}) of A, B, C and D respectively.

According to the Law of Mass Action

The rate of the forward reaction α [A] [B]

$= k_f$ [A] [B]

Similarly,

The rate of the reverse reaction α [C] [D]

$= k_r$ [C] [D]

Where k_f and k_r are the proportionality constant called specific rate constants of the forward and the reverse reactions respectively.

At equilibrium state:

The rate of forward reaction = The rate of reverse reaction

$$k_f[A][B] = k_r[C][D]$$

$$\frac{k_f}{k_r} = \frac{[C][D]}{[A][B]}$$

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

K_c is called equilibrium constant. It is represented as:

$$K_c = \frac{[C][D]}{[A][B]}$$

Law of Mass Action describes the relationship between active masses of the reactants and the rate of a reaction.

Derivation of the Expression for Equilibrium Constant for General Reaction

Let us apply the law of Mass Action for a general reaction.

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

Statement

The rate of a chemical reaction is directly proportional to the product of the molar concentrations of its reactants raised to power equal to their number of moles in the balanced chemical equation of the reaction.

Derivation

Let us first discuss the forward reaction. A and B are the reactants whereas 'a' and 'b' are their number of moles.

The rate of forward reaction according to law of Mass Action is:

$$R_f \quad \alpha \quad [A]^a[B]^b$$
$$R_f \quad = \quad k_f[A]^a[B]^b$$

Where kf is the rate constant for the forward reaction.

Similarly, the rate of the reverse reaction R_r is directly proportional to the product of [C] [D], where 'c' and 'd' are the number of moles as given in the balanced chemical equation.

Thus,

$$R_r \quad \alpha \quad [C]^c[D]^d$$
$$R_r \quad = \quad k_r[C]^c[D]^d$$

Where k_r is the rate constant for the reverse reaction.

We know that at equilibrium state the rates of both the reactions are equal.

The rate of forward the reaction = The rate of the reverse reaction

Such as: $R_f = R_r$

and putting the values of R_f and R_r

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

By taking the constants on one side and the variables on other side of the equation, the above equation becomes:

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

$$K_C = \frac{k_f}{k_r}$$

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

Where K_c is called equilibrium constant

Q.6 What is equilibrium constant? Explain its units.

Definition

Equilibrium constant is ratio of the product of concentration of products raised to the power of coefficient to the product of concentration of reactants rcsed to the power of coefficient as expressed in the balanced chemical equation.

Formula

$$K_c = \frac{\text{Product of concentration of products raised to the power of coefficients}}{\text{Product of concentration of reactants raised to the power of coefficients}}$$

Unit of K_c

K_c has no units in reactions with equal number of moles on both sides of the equation. This is because concentration units cancel out in the expression for K_c for the reaction.

$$H_2 + I_2 \longrightarrow 2HI$$

$$\text{Units} = \frac{\cancel{\left(\text{mol dm}^{-3}\right)^2}}{\cancel{\left(\text{mol dm}^{-3}\right)}\ \cancel{\left(\text{mol dm}^{-3}\right)}} = \text{no unit}$$

For reactions in which the number of moles of reactants and product are equal in the balanced chemical equation, K_c of course, have units, e.g., for reaction

$$N_2 + 3H_2 \rightleftharpoons 2NH_3$$

$$K_c = \frac{\left(\text{mol dm}^{-3}\right)^2}{\left(\text{mol dm}^{-3}\right)\left(\text{mol dm}^{-3}\right)^3} = \text{mol}^{-2}\text{dm}^6$$

Q.7 What are the importance of equilibrium constant?

Knowing the numerical value of equilibrium constant of a chemical reaction, direction as well as extent of the reaction can be predicted.

(i) Predicting Direction of a Reaction

Direction of a reaction at a particular moment can be predicted by inserting the concentration of the reactants and products at that particular moment in the equilibrium expression.

Example

The gaseous reaction of hydrogen with iodine.

$$H_2 + I_2 \rightleftharpoons 2HI \qquad K_C = 57.0 \text{ at } 700 \text{ K}$$

Explanation

We withdraw the samples from the reaction mixture and determine the concentrations of H_2, I_2 and HI. Suppose concentrations of the components of the mixture are:

$[H_2]_t = 0.10 \text{ mol dm}^{-3}$ $[I_2]_t = 0.20 \text{ mol dm}^{-3}$ and $[HI]_t = 0.40 \text{ mol dm}^{-3}$

The subscript 't' with the concentration symbols means that the concentrations are measured at some time t, not necessarily at equilibrium. When we put these concentrations into the equilibrium constant expression, we obtain a value called the reaction quotient Q_c. The reaction quotient for this reaction is calculated as:

As the numerical value of Q_c (8.0) is less than K_c(57.0), the reaction is not at equilibrium. It requires more concentration of product. Therefore, reaction will move in the forward direction.

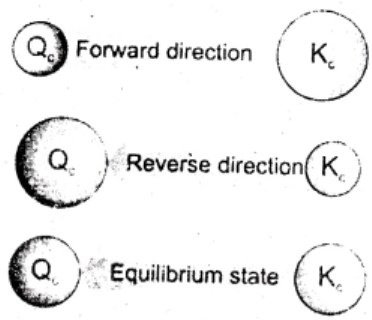
The reaction quotient Q_c is useful because it predicts the direction of the reaction by comparing the value of Q_c with K_c.

(i) **Possibilities of Reaction**

(a) If $Q_c < K_c$; the reaction goes from left to right, i.e., in forward direction to attain equilibrium.

(b) If $Q_c > K_c$; the reaction goes from right to left, i.e., in reverse direction to attain equilibrium.

(c) If Qc = Kc; forward and reverse reactions take place at equal rates i.e., equilibrium has been attained.



(ii) **Predicting Extent of a Reaction**

Numerical value of the equilibrium constant predicts the extent of a reaction. It indicates to which extent reactants are converted to products.

Responsibilities: In general, there are three possibilities of predicting extent of reactions as explained below.

a) **Large numerical value of K_c**

The large value of K, indicates that at equilibrium position the reaction mixture consists of almost all products and reactants are negligible. The reaction has almost gone to completion

For example, oxidation of. carbon monoxide goes to completion at 1000 K.

Example $2CO_{(g)} + O_{2(g)} \rightleftharpoons 2CO_{2(g)}$ $Kc = 2.2 \times 10^{22}$

b) **Small numerical value of K_c**

When the K, value of reaction is small, it indicates that the equilibrium has established with a very small conversion of reactants to products. At equilibrium position, almost all reactants are present but amount of products is negligible. *Such type of reaction never goes to completion.* For example

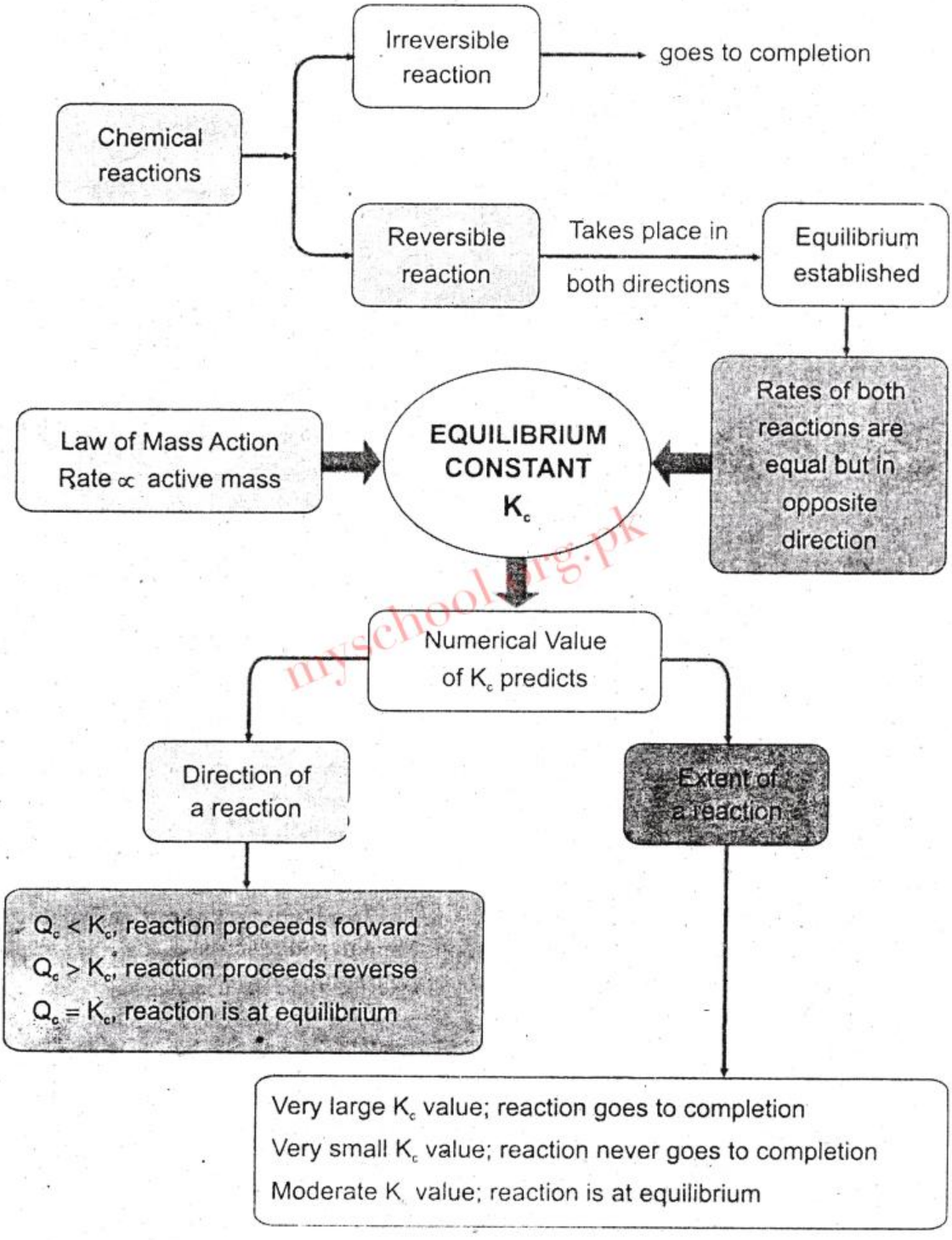
$2NH_3 \rightleftharpoons N_{2(g)} + 3H_{2(g)}$ $Kc = 3.0 \times 10^{-9}$

:) **Numerical value of K, is neither small nor large**

Such reactions have comparable amounts of reactants and products at equilibrium position.

xample: $N_2O_{4(g)} \rightleftharpoons 2NO_{2(g)}$ $Kc = 0.211$

CONCEPT DIAGRAM



EXERCISE

MCQ'S

1. **The characteristics of reversible reactions are the following except:**
   (a) products never recombine to form reactants
   (b) they never complete
   (c) they proceed in both ways
   (d) they have a double arrow between reactants and products

2. **In the lime kiln, the reaction $CaCO_3(s) \longrightarrow . CaO(s) + CO_2(g)$ goes to completion because**
   (a) of high temperature
   (b) CaO is more stable than $CaCO_3$
   (c) CO_2 escapes continuously
   (d) CaO is not dissociated

3. **For the reaction, $2A_{(g)} + B_{(g)} \rightleftharpoons 3C_{(g)}$ the expression for the equilibrium constant is:**
   (a) $\frac{[2A][B]}{[3C]}$
   (b) $\frac{[A]^2[B]}{[C]^3}$
   (c) $\frac{[3C]}{[2A][B]}$
   (d) $\frac{[C]^3}{[A]^2[B]}$

4. **When a system is at equilibrium states**
   (a) the concentration of reactants and products becomes equal
   (b) the opposing reactions (forward and reverse) stop
   (c) the rate of the reverse reaction becomes very low
   (d) the rates of the forward and reverse reactions become equal

5. **Which one of the following statement is not correct about active mass?**
   (a) rate of reaction is directly proportional to active mass
   (b) active mass is taken in molar concentration
   (c) active mass is represented by square brackets
   (d) active mass means total mass of substances

6. **When the magnitude of K_c is very large it indicates**
   (a) reaction mixture consists of almost all products
   (b) reaction mixture has almost all reactants
   (c) reaction has not gone to completion
   (d) reaction mixture has negligible products

7. **When the magnitude of K_c is very small it indicates**
   (a) equilibrium will never establish
   (b) all reactants will be converted to products
   (c) reaction will go to completion '
   (d) the amount of-products is negligible

8. **Reactions which have comparable amounts of reactants and products at equilibrium state have**

(a) very small K_c value (b) very large K_c value

(c) moderate K_c value (d) none of these

9. **At dynamic equilibrium**

(a) the reaction stops to proceed

(b) the amounts of reactants and products are equal

(c) the speeds of the forward and reverse reactions are equal

(d) the reaction can no longer be reversed

10. **In an irreversible reaction dynamic equilibrium**

(a) never establishes

(b) establishes before the completion of reaction

(c) establishes after the completion of reaction

(d) establishes readily

11. **A reverse reaction is one that**

(a) which proceeds from left to right

(b) in which reactants react to form products

(c) which slows down gradually

(d) which speeds up gradually

12. **Nitrogen and hydrogen were reacted together to make ammonia;**

$$N_2 + 3H_2 \rightleftharpoons 2NH_3 \qquad K_c = 2.86\ mol^{-2}dm^6$$

What will be present in the equilibrium mixture?

(a) NH_3 only (b) N_2, H_2 & NH_3 (c) N_2 & H_2 (d) H_2 only

13. **For a reaction between PCl_3 and Cl_2 to form PCl_5, the units of K_c, are:**

(a) mol dm^{-3} (b) mol^{-1} dm^{-3} (c) mol^{-1} dm^3 (d) mol dm^3

ANSWER KEY

1	a	3	d	5	d	7	d	9	c	11	d	13	c
2	c	4	d	6	a	8	c	10	a	12	b	KIPS	

SHORT QUESTIONS

Q.1 What are irreversible reactions? Give a few characteristics of them?

Ans. The reaction, in which the product do not recombine to form reactants are called irreversible reaction.

Characteristics of Irreversible Reactions

- They are represented by (→) between reactant and product.
- These reactions are proceed to completion.
- These reactions may be conduct in open and close vessels.
- There is no sign of equilibrium state in these reactions.

Q.2 Define chemical equilibrium state.

Ans. When the rate of the forward reaction takes place at the rate of reverse reaction, the composition of the reaction mixture remains constant. It is called a chemical equilibrium state.

Example: $N_2+3H_2 \rightleftharpoons 2NH_3$ $K_c = 2.86\ mol^{-2}dm^6$

Q.3 Give the characteristics of reversible reaction.

Ans.

- They are represented by ($\rightleftharpoons$) between reactant and product.
- It can be attainable from either way.
- A reversible reaction can never go to completion.
- Usually, it can be carried out in a closed vessel.
- In reversible reaction, equilibrium state is the ultimate goal.

Q.4 How dynamic equilibrium is established?

Ans. When reaction does not stop, only the rates of forward reverse reactions become equal to each other but take place in opposite directions. This is called dynamic equilibrium state.

Example: $N_2+3H_2 \rightleftharpoons 2NH_3$ $K_c = 2.86\ mol^{-2}dm^6$

Q.5 Why at equilibrium state reaction does not stop?

Ans. At equilibrium state, a reaction does not stop because forward and reverse reactions keep on taking place at the same rate but in opposite direction. Products recombine to from reactants.

Example: $I_2+H_2 \rightleftharpoons 2HI$ $K_c = 57.0$ **at 700 K**

Q.6 Why equilibrium state is attainable from either way?

Ans. An equilibrium sate is attainable from either way because it may start from reactant to give products while products recombine to give reactant again.

Reactants $\rightleftharpoons$ Products

$A+B \rightleftharpoons C+D$

Q.7 What is relationship between active mass and rate of reaction?

Ans. Law of mass action describe the relationship between active masses of the reactants and the rate of a reaction.

According to this law:

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

Example: $A+B \underset{k_r}{\overset{k_f}{\rightleftharpoons}} C+D$

At equilibrium state:

The rate of forward reaction = The rate of reverse reaction

$$k_f[A][B] = k_r[C][D]$$

$$\frac{k_f}{k_r} = \frac{[C][D]}{[A][B]}$$

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

K_c is called equilibrium constant. It is represented as:

$$K_c = \frac{[C][D]}{[A][B]}$$

Law of Mass Action describes the relationship between active masses of the reactants and the rate of a reaction.

Q.8 Derive equilibrium constant expression for the synthesis of ammonia from nitrogen and hydrogen.

Ans. $N_{2(g)} + 3H_{2(g)} \underset{R_r}{\overset{R_f}{\rightleftharpoons}} 2NH_{3(g)}$

The rate of forward reaction: $R_f = K_f[N_2][H_2]^3$

The rate of reverse reaction: $R_r = K_r[NH_3]^2$

$$K_c = \frac{[NH_3]^2}{[N_2][H_2]^3}$$

Q.9 Write the equilibrium constant expression for the following reactions:

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

(ii) $CO_{(g)} + 3H_{2(g)} \rightleftharpoons CH_{4(g)} + H_2O_{(g)}$

Ans. (i) $H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$

The rate of forward reaction $R_f = K_f[H_2][I_2]$

The rate of reverse reaction $R_r = Kr[HI]^2$

The equilibrium constant expression:

$$K_c = \frac{\text{Products}}{\text{Reactants}}$$

$$K_c = \frac{[HI]^2}{[H_2][I_2]}$$

(ii) $CO_{(g)} + 3H_{2(g)} \rightleftharpoons CH_{4(g)} + H_2O_{(g)}$

The rate of forward reaction $R_f = K_f[CO][H_2]^3$

The rate of reverse reaction $R_r = K_r[CH_4][H_2O]$

The equilibrium constant expression:

$$K_c \frac{[CO][H_2]^3}{[CH_4][H_2O]}$$

Q.10 How direction of a reaction can be predicted?

Ans. Direction of a reaction at particular moment can be predicted by inserting the concentration of the reactants and products at that particular amount in the equilibrium expression.

$$K_c = \frac{[\text{Molar concentration of product}]}{[\text{Molar concentration of reactatnt}]}$$

Q.11 How can you know that a reaction has achieved an equilibrium state?

Ans. Dynamic equilibrium

Then reaction does not stop; only the rates of forward and reverse reaction become equal to each other but take place in opposite directions. This is called dynamic equilibrium state. Dynamic means reaction is still continuing at dynamic equilibrium state.

A reaction get achieved a equilibrium state when the:

Rate of forward reaction = Rate of reverse reaction

Explanation: In a reversible reaction, dynamic equilibrium is established before the completion of reaction. At initial stage the rate of forward reaction is very fast and reverse reaction is taking place at a negligible rate. But gradually slows down and reaction speed up. Eventually, both reactions attain the same rate; it is called a dynamic equilibrium state

Q.12 What are the characteristics of a reaction that establishes equilibrium state at once?

Ans. Characteristics

- In these reaction dynamic state equilibrium are called reversible reaction.
  Rate of forward reactions = Rate of reverse reactions
- These reaction does not go to completion.
- These reaction can be proceed in either way.

Q.13 If reaction quotient Qc of a reaction is more than Kc What will be the direction of the reaction?

Ans. If the value of Q_c is more than the K_c. The net reaction goes from right to left or it will move in reverse direction to attain equilibrium.

Q.14 An industry was established based upon a reversible reaction. It failed to achieve products on commercial level. Can you point out the basic reasons of its failure being a chemist?

Ans. In a reversible reaction, the amount of reactants and products remain same when the equilibrium state achieved, if a industry based on the reversible reaction, it cannot be achieved desired commercial product and its required amount that is why a reversible reaction based industry is failed.

EXTENSIVE QUESTIONS

Q.1 Describe a reversible reaction with the help of an example and graph.

Ans. See the topic

Q.2 Write down the macroscopic characteristics of dynamic equilibrium.

Ans. See the topic

Q.3 State the law of Mass Action and derive the expression for equilibrium constant for a general reaction.

Ans. See the topic

Q.4 What is the importance of equilibrium constant?

Ans. See the topic

NUMERICAL

Q.1 For the decomposition of di-nitrogen oxide (N_2O) into nitrogen and oxygen reversible reaction takes place as follows:

$$2N_2O \rightleftharpoons 2N_2 + O_2$$

The concentration of N_2O, N_2 and O_2 are 1.1 mol dm '', 3.90 mol dm^{-3} and 1.95 mol dm^{-3}, respectively at equilibrium. Find' out K_c for this reaction.

Given data:

Concentration of N_2 = 1.1 mol dm^{-3}
Concentration of N_2 = 3.90 mol dm^{-3}
Concentration of Os_2 = 1.95 mole dm^{-3}

Balanced chemical equation:

$$2N_2O \rightleftharpoons 2N_2 + O_2$$

Required data:

Equilibrium constant = K_c = ?

Solution:

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

$$K_c = \frac{[N_2]^2[O_2]}{[N_2O]^2}$$

Putting the value of concentration in above formula.

$$K_c = \frac{[3.90]^2[1.95]}{[11]^2}$$

$$= \frac{15.21 \times 1.95}{[1.1]^2}$$

$$= \frac{29.6595}{1.21}$$

Result: **K_c = 24.51 mol dm^{-3}**

Q.2 Hydrogen iodide decomposes to form hydrogen and iodine. If the equilibrium concentration of HI is 0.078 mol dm^{-3}, H_2 and I_2 is same 0.011 mol dm^{-3}. Calculate the equilibrium constant value for this reversible reaction:

Given data:

Concentration of HI = 0.078 mol dm^{-3}
Concentration of H_2 = 0.011 mol dm^{-3}
Concentration of I_2 = 0.011 mol dm^{-3}

Balanced chemical equation:

$$2HI \rightleftharpoons N_2 + I_2$$

Required data:

Equilibrium constant = K_c = ?

Solution:

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

$$K_c = \frac{[H_2][I_2]}{[HI]^2}$$

Putting the value of concentration in the above carnation.

$$K_c = \frac{[0.011][0.011]}{[0.078]^2}$$

$$= \frac{0.000121}{0.006084}$$

Result: $\mathbf{K_c = 0.01989}$

Q.3 For the fixation of nitrogen following reaction takes place:

$$N_2 + O_2 \rightleftharpoons 2NO$$

When the reaction takes place at 1500 K, the K_c for this is 1.1×10^{-5}. If equilibrium concentrations of nitrogen and oxygen are 1.7×10^{-3} mol dm^{-3} and 6.4×10^{-3} mol dm^{-3}, respectively, how much NO is formed?

Given data:

Concentration of $N_2 = 1.7 \times 10^{-3}$ mol dm^{-3}
Concentration of $O_2 = 6.4 \times 10^{-3}$ mol dm^{-3}
Equilibrium constant value
For given equation $= 1.1 \times 10^{-5}$

Balanced chemical equation:

$$N_2 + O_2 \rightleftharpoons 2NO$$

Required data:

Concentration of NO = ?

Solution:

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

$$K_c = \frac{[NO]^2}{[N_2][O_2]}$$

Putting the value of concentration in the above carnation.

$$1.1 \times 10^{-5} = \frac{[NO]^2}{[1.7 \times 10^{-3}][6.7 \times 10^{-3}]}$$

$$[NO]^2 = (1.1 \times 10^{-5}) \times (1.7 \times 10^{-3}) \times (6.4 \times 10^{-3})$$

$$= \sqrt{1.1968 \times 10^{-10}}$$

$$NO = 1.09 \times 10^{-5} \text{ mol } dm^{-3}$$

Result: $\mathbf{NO = 1.09 \times 10^{-5} \text{ mol } dm^{-3}}$

Q.4 **When nitrogen reacts with hydrogen to form ammonia, the equilibrium mixture contains 0.31 mol dm^{-3} and 0.50 mol dm^{-3} of nitrogen and hydrogen respectively. If the K_c is 0.50 mol dm^{-3} what is the equilibrium concentration of ammonia?**

Given data:

Concentration of N_2 = 0.31mol dm^{-3}
Concentration of H_2 = 0.50 mol dm^{-3}
Equilibrium constant value
For given equation K_C = 0.5 $mol^{-2}dm^6$

Balanced chemical equation:

$$N_2 + 3H_2 \rightleftharpoons 2NH_3$$

Required data:

Concentration of NH_3 = ?

Solution:

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

$$K_c = \frac{[NH_3]^2}{[N_2][H_2]^3}$$

Putting the value of concentration in the above carnation.

$$K_c = \frac{[NH_3]^2}{[0.31][0.50]^3}$$

$$[NH_3]^2 = (0.50) \times (0.31) \times (.50)^3$$

$$= \sqrt{0.019375}$$

$$NH_3 = 0.1392 \text{ mol } dm^{-3}$$

Result: **NH_3 = 0.14 mol dm^{-3}**