CHEMICAL EQUILIBRIUM

LAW OF MASS ACTION

1. In a chemical equilibrium, the rate constant for the backward reaction is 7.5×10^{-4} and the equilibrium constant is 1.5. The rate constant for the forward reaction is:-

(1) 2×10^{-3} (2) 5×10^{-4}
(3) 1.12×10^{-3} (4) 9.0×10^{-4}

2. In this reaction $Ag^+ + 2NH_3 \rightleftharpoons Ag(NH_3)_2^+$ at 298K molar concentration of Ag^+, $Ag(NH_3)_2^+$ and NH_3 is 10^{-1}, 10^{-1} , and 10^3. The value of K_C at 298K for this equilibrium :-

(1) 10^{-6} (2) 10^6
(3) 2×10^{-3} (4) 2×10^6

3. At 1000 K, the value of K_p for the reaction :

$A(g) + 2B(g) \rightleftharpoons 3C(g) + D(g)$

is 0.05 atm. The value of K_C in terms of R would be :-

(1) 20000 R (2) 0.02 R
(3) 5×10^{-5} R (4) $5 \times 10^{-5} \times R^{-1}$

4. For the reaction

$CuSO_4.5H_2O_{(s)} \rightleftharpoons CuSO_4 . 3H_2O_{(s)} + 2H_2O_{(g)}$

Which one is correct representation :–

(1) $K_p = p^2_{H_2O}$ (2) $K_c = [H_2O]^2$
(3) $K_p = K_c(RT)^2$ (4) All

5. $\log \frac{K_p}{K_c} + \log RT = 0$ is true relationship for the following reaction:-

(1) $PCl_5 \rightleftharpoons PCl_3 + Cl_2$
(2) $2SO_2 + O_2 \rightleftharpoons 2SO_3$
(3) $N_2 + 3H_2 \rightleftharpoons 2NH_3$
(4) (2) and (3) both

6. Consider the two gaseous equilibrium involving SO_2 and the corresponding equilibrium constants at 299 K

$SO_2 (g) + \frac{1}{2} O_2 (g) \rightleftharpoons SO_3 (g) \ ; K_1$

$4SO_3 (g) \rightleftharpoons 4 SO_2 (g) + 2O_2 (g) \ ; K_2$

The value of the equilibrium constant are related by :-

(1) $K_2 = \frac{1}{(K_1)^4}$ (2) $K_2 = K_1^4$
(3) $K_2 = \left(\frac{1}{K_1}\right)^{\frac{1}{4}}$ (4) $K_2 = \frac{1}{K_1}$

7. Which Oxide of Nitrogen is most stable :-

(1) $2NO_{2\,(g)} \rightleftharpoons N_{2\,(g)} + 2O_{2\,(g)}$
$K = 6.7 \times 10^{16}$ mol L^{-1}

(2) $2\ NO_{(g)} \rightleftharpoons N_{2\,(g)} + O_{2\,(g)}$
$K = 2.2 \times 10^{30}$

(3) $2\ N_2O_{5\,(g)} \rightleftharpoons 2N_{2(g)} + 5O_{2\,(g)}$
$K = 1.2 \times 10^{34}$ mol^5 L^{-5}

(4) $2N_2O_{(g)} \rightleftharpoons 2N_{2\,(g)} + O_{2\,(g)}$
$K = 3.5 \times 10^{33}$ mol L^{-1}

8. For a reaction $N_2 + 3H_2 \rightleftharpoons 2NH_3$, the value of K_C does not depends upon :-

(a) Initial concentration of the reactants
(b) Pressure
(c) Temperature
(d) Catalyst

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

9. Effect of increasing temperature on equilibrium constant is given by $\log K_2 - \log K_1 = \frac{-\Delta H}{2.303R} \left[\frac{1}{T_2} - \frac{1}{T_1}\right]$. Then for an endothermic reaction the false statement is:-

(1) $\left[\frac{1}{T_2} - \frac{1}{T_1}\right]$ = positive (2) $\log K_2 > \log K_1$
(3) ΔH = positive (4) $K_2 > K_1$

10. In system $A(s) \rightleftharpoons 2B(g) + 3C(g)$ at equilibrium if concentration of 'C' is doubled then concentration of B at equilibrium.

(1) Double its original concentration
(2) Half its original concentration
(3) $2\sqrt{2}$ its original concentration
(4) $\frac{1}{2\sqrt{2}}$ its original concentration

11. The equilibrium constant (K_P) for the reaction $PCl_5\ (g) \rightleftharpoons PCl_3(g) + Cl_2(g)$ is 16. If the volume of the container is reduced to one-half its original volume, the value of K_P for the reaction at the same temperature will be :-

(1) 32 (2) 64 (3) 16 (4) 4

12. The equilbrium constant for the reaction :

$N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$ at 2000 K is 4×10^4. In presence of catalyst the equilibrium is established ten times faster at the same temperature. What is the value of equilibrium constant in presence of catalyst :-

(1) 40×10^{-4} (2) 4×10^{-4}

(3) 4×10^4 (4) None

DEGREE OF DISSOCIATION AND APPLICATION OF LAW OF MASS ACTION

13. For the reaction : $P \rightleftharpoons Q + R$. Initially 2 mol of P was taken. Up to equilibrium 0.5 mol of P was dissociated. What would be the degree of dissociation :-

(1) 0.5 (2) 1 (3) 0.25 (4) 4.2

14. The dissociation of CO_2 can be expressed as $2CO_2 \rightleftharpoons 2CO + O_2$. If the 2 mol of CO_2 is taken initially and 40% of the CO_2 is dissociated completely. What is the total number of moles at equilibrium:-

(1) 2.4 (2) 2.0 (3) 1.2 (4) 5

15. In a 13 L vessel initially following reaction occur $C(s) + S_2(g) \rightleftharpoons CS_2(g)$ by 12 g C, 64 g S_2, 76 g CS_2 at 1027°C temperature then total pressure is.

(1) 200R (2) 158R (3) 100R (4) 79R

16. The reaction $A + B \rightleftharpoons C + D$ is studied in a one litre Vessel at 250°C. The initial concentration of A was 3n and of B was n. After equilibrium was attained then equilibrium concentration of C was found to be equal to equilibrium concentration of B. What is the concentration of D at equilibrium :-

(1) $\frac{n}{2}$ (2) $\left(3n-\frac{n}{2}\right)$

(3) $\left(n+\frac{n}{2}\right)$ (4) n

17. In the reaction $PCl_5 \rightleftharpoons PCl_3 + Cl_2$ the partial pressure of PCl_3, Cl_2 and PCl_5 are 0.3, 0.2 and 0.6 atm respectively at equilibrium. If partial pressure of PCl_3 and Cl_2 was increased twice, what will be the partial pressure of PCl_5 is in atm at new equilibrium condition :-

(1) 0.3 (2) 1.2 (3) 2.4 (4) 0.15

18. In a 0.25 L tube dissociation of 4 mol of NO is take place. If its degree of dissociation is 10%. The value of K_p for reaction $2NO \rightleftharpoons N_2 + O_2$ is :-

(1) $\frac{1}{(18)^2}$ (2) $\frac{1}{(8)^2}$

(3) $\frac{1}{16}$ (4) $\frac{1}{32}$

19. K_c for the esterification reaction :

$CH_3COOH + C_2H_5OH \rightleftharpoons CH_3COOC_2H_5 + H_2O$

is 4. If 4 mol each of acid and alcohol are taken initially, what is the equilibrium concentration of the acid in 1 litre container :-

(1) $\frac{2}{3}$ (2) $\frac{4}{3}$ (3) $\frac{3}{4}$ (4) $\frac{3}{2}$

20. 4 moles of A are mixed with 4 moles of B, when 2 mol of C are formed at equilibrium, according to the reaction, $A + B \rightleftharpoons C + D$. The equilibrium constant is :-

(1) 4 (2) 1 (3) $\sqrt{2}$ (4) $\sqrt{4}$

21. 1.50 mol each of hydrogen and iodine were placed in a sealed 10 L container maintained at 717 K. At equilibrium 1.25 mol each of hydrogen and iodine were left behind. The equilibrium constant, K_c for the reaction

$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$ at 717 K is

(1) 0.4 (2) 0.16 (3) 25 (4) 50

LE-CHATLIER'S PRINCIPLE

22. When $NaNO_3$ is heated in a closed vessel, O_2 is liberated and $NaNO_2$ is left behind. At equilibrium –

(1) Addition of $NaNO_3$ favours forward reaction

(2) Addition of $NaNO_2$ favours reverse reaction

(3) Increasing pressure favours reverse reaction.

(4) Decreasing temperature favours forward reaction.

23. In which of the following equilibrium reactions, the equilibrium would shift to right side, if total pressure is decreased :-

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

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

(3) $N_2O_4 \rightleftharpoons 2NO_2$

(4) $H_2 + Cl_2 \rightleftharpoons 2HCl$

24. For the manufacture of ammonia by the reaction $N_2 + 3H_2 \rightleftharpoons 2NH_3 + 21.9$ k Cal, the favourable conditions are :-

(1) Low temperature, low pressure & catalyst

(2) Low temperature, high pressure & catalyst

(3) High temperature, low pressure & catalyst

(4) High temperature, high pressure & catalyst

25. In the reaction $2A_{(g)} + B_{(g)} \rightleftharpoons C_{(g)} + 362$ kCal. Which combination of pressure and temperature gives the highest yield of C at equilibrium:-

(1) 1000 atm and 500°C

(2) 500 atm and 500°C

(3) 1000 atm and 50°C

(4) 500 atm and 100°C

26. The reaction in which yield of production cannot be increased by the application of high pressure is :-

(1) $PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g)$

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

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

(4) $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

27. In a vessel containing SO_3, SO_2 and O_2 at equilibrium, some helium gas is introduced so that the total pressure increases while temperature and volume remain constant. According to Le-Chatelier principle, the dissociation of SO_3 ,

(1) Increases (2) Decreases

(3) Remains unaltered (4) None of these

PHYSICAL EQUILIBRIUM

28. For the equilibrium reaction, $H_2O\ (\ell) \rightleftharpoons H_2O_{(g)}$, What happens, if pressure is applied:-

(1) More water evaporates

(2) The boiling point of water is increased

(3) No effect on boiling point

(4) None of the above

29. On cooling of following system at equilibrium $CO_{2(s)} \rightleftharpoons CO_{2(g)}$:-

(1) There is no effect on the equilibrium state

(2) More gas is formed

(3) More gas is solidifies

(4) None of above

CALCULATION OF DEGREE OF DISSOCIATION BY V.D. METHOD

30. Vapour density of PCl_5 is 104.25 at t°C. Then degree of dissociation of PCl_5 is. (Mw = 208.5)

(1) 20% (2) 0%

(3) 30% (4) 15%

31. When heating PCl_5 then it decompose PCl_3 and Cl_2 in form of gas, The vapour density of gas mixture is 70.2 and 57.9 at 200° C and 250°C. The degree of dissociation of PCl_5 at 200°C and 250°C is

(1) 48.50% & 80% (2) 60% & 70%

(3) 70% & 80% (4) 80% & 90%

32. The equation $\alpha = \dfrac{D-d}{(n-1)d}$ is correctly matched for

Where D = Theoretical vapour density

d = Observed vapour density

(1) $A \rightleftharpoons \dfrac{nB}{2} + \dfrac{nC}{3}$

(2) $A \rightleftharpoons \dfrac{nB}{3} + \left(\dfrac{2n}{3}\right)C$

(3) $A \rightleftharpoons \left(\dfrac{n}{2}\right)B + \left(\dfrac{n}{4}\right)C$

(4) $A \rightleftharpoons \left(\dfrac{n}{2}\right)B + C$

SOLUTION

CHEMICAL EQUILIBRIUM

1. $K_C = \frac{k_f}{k_b} \Rightarrow k_f = k_c . k_b$

$= 1.5 \times 7.5 \times 10^{-4}$

$= 1.12 \times 10^{-3}$

2. $Ag^+ + 2NH_3 \rightleftharpoons Ag(NH_3)_2^+$

At eq^m $10^{-1}M$ 10^3M $10^{-1}M$

$$K_C = \frac{10^{-1}}{(10^{-1})(10^3)^2} = 10^{-6}$$

3. $K_p = K_c (RT)^{\Delta ng}$

$\Delta ng = (3 + 1) - (1 + 2) = 1$

So $K_C = \frac{K_p}{RT}$

$$K_C = \frac{.05}{R \times 1000} = 5 \times 10^{-5} R^{-1}$$

4. $CuSO_4.5H_2O(s) \rightleftharpoons CuSO_4.3H_2O(s) + 2H_2O(g)$

$k_p = P^2_{H_2O}$

$k_c = [H_2O]^2$

$k_p = k_c (RT)^2$ $(\Delta ng = 2)$

5. $\log\left(\frac{k_p}{k_c}\right) + \log(RT) = 0$

$= \log 1$

$\log\left(\frac{k_p}{k_c} \times RT\right) = \log 1$

$\frac{k_p}{k_c}.(RT) = 1$

$k_p = k_c (RT)^{-1}$

$\Delta ng = -1$

$2SO_2 + O_2 \rightleftharpoons 2SO_3$; $\Delta ng = -1$

6. equation (1) $= \frac{-eq^n(ii)}{4}$

$$k_1 = \frac{1}{k_2^{1/4}} \Rightarrow k_1^4 = \frac{1}{k_2}$$

or

$$k_2 = \frac{1}{k_1^4}$$

7. Low value of k_c means extent of reactant is low means reactant is stable.

So NO_2 is stalbe among others

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

k_c depends upon temp.

It does not depends upon pressure, initial concentration, catalyst.

9. $\log k_2 - \log k_1 = \frac{-\Delta H}{2.303R} \cdot \left(\frac{1}{T_2} - \frac{1}{T_1}\right)$

or $\log\left(\frac{k_2}{k_1}\right) = \frac{-\Delta H}{2.303R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$

on increasing temperature means

$T_2 > T_1$

So $\left(\frac{1}{T_2} - \frac{1}{T_1}\right) < 0$

Endothermic Reaction $\Delta H > 0$

$k_2 > k_1$

$\log k_2 > \log k_1$

10. $A(s) \rightleftharpoons 2B(g) + 3C(g)$

$k_c = [B]^2[C]^3 = [B_{New}]^2[2C]^3$

$$[B_{new}] = \frac{[B]}{2\sqrt{2}}$$

11. k_p does not depends upon change in volume of container

12. k_p or k_c does not depends upon catalyst

13. $\alpha = \frac{n_{dissociated}}{n_{initial}} = \frac{0.5}{2} = .75$

$= 75\%$

14. $2CO_2 \rightleftharpoons 2CO + O_2$

2mole – –

$2(1-\alpha)$ 2α α

$n_T = 2(1 - \alpha) + 2\alpha + \alpha$

$= 2 + \alpha = 2.4$ $(\alpha = 40\%)$

15. $C(s) + S_2(g) \rightleftharpoons CS_2(g)$

12gm 64gm 76gm

1mole 1mole 1mole

(solid)

$PV = n RT$

$P \times 13$ Lit $= 2 \times R \times 1300$

$P = 200 R$

16. $A + B \rightleftharpoons C + D$

3n n – –

3n-x n–x x x

given $[C] = (B) \Rightarrow x = n - x \Rightarrow x = \frac{n}{2}$

$$[D]_{eq} = \frac{n}{2}$$

17. $k_p = \frac{P_{PCl_3}.P_{Cl_2}}{P_{PCl_5}} = \frac{P'_{PCl_3} P'_{Cl_2}}{P'_{PCl_5}}$

$$\Rightarrow \frac{0.3 \times 0.2}{0.6} = \frac{0.6 \times 0.4}{P'_{PCl_5}}$$

$$P'_{PCl_5} = 2.4$$

18. $2NO \rightleftharpoons N_2 + O_2$

4mole – –

$4(1-\alpha) \quad \frac{4\alpha}{2} \quad \frac{4\alpha}{2} \quad (\alpha = 10\% = 0.1)$

3.6 .2 .2 moles

$k_p = k_c (\Delta n_g = 0)$

$$= \frac{\left(\frac{.2}{V}\right)\left(\frac{.2}{V}\right)}{\left(\frac{3.6}{V}\right)^2} = \frac{1}{(18)^2}$$

19. $CH_3COOH + C_2H_5OH \rightleftharpoons CH_3COOC_2H_5 + H_2O$

4mole 4mole

4–x 4–x x x

$$k_c = 4 = \frac{x.x}{(4-x)(4-x)}$$

$$2 = \frac{x}{4-x}$$

$8-2x = x$

$x = 8/3$

$$[CH_3COOH] = 4 - \frac{8}{3}$$

$$[CH_3COOH] = \frac{4}{3} \text{ M in 1 lit continer}$$

20. $A + B \rightleftharpoons C + D$

4mole mole – –

4–x 4–x x x

given $n(C) = 2 \Rightarrow x = 2$

$$k_c = \frac{\left(\frac{x}{v}\right)\left(\frac{x}{v}\right)}{\left(\frac{4-x}{v}\right)\left(\frac{4-x}{v}\right)} = \left(\frac{x}{4-x}\right)^2$$

$$= \left(\frac{2}{4-2}\right)^2 = 1$$

21. $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$

1.5 mole 1.5 mole –

1.5–x 1.5–x 2x

given $1.5 - x = 1.25$

$x = 0.25$

$$k_c = \frac{(2x/v)^2}{\left(\frac{1.5-x}{v}\right)\left(\frac{1.5-x}{v}\right)}$$

$$= \left(\frac{2x}{1.5-x}\right)^2$$

$$= \left(\frac{0.25 \times 2}{1.25}\right)^2 = \frac{4}{25} = 0.16$$

22. $NaNO_3(s) \rightleftharpoons NaNO_2(s) + O_2(g)$

Addition of solid does not effect on equilibrium state

P ↑ reaction move BD

23. On decreasing pressure Reaction move right side menas F.D. if

$\Delta ng > 0$

24. $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3 + 21.9$ kcal

manufacturing of NH_3 favoure

High pressure ($\Delta ng < 0$)

low temperature ($\Delta H < 0$)

and suitable catalyst

25. $2A(g) + B(g) \rightleftharpoons C(g) + 362$ kcal

High yeild of C(g) means reaction favoured in F.D if

T low ($\Delta H < 0$)

P High($\Delta ng < 0$)

26. yield of product can not be increased by apply pressure if $\Delta ng > 0$ or $\Delta ng = 0$

27. $SO_3 \rightleftharpoons SO_2 + \frac{1}{2}O_2$

Addition of He inert gas of constant volume Re^n neither goes to F.D. nor B.D.

So α_{SO_3} remain same

28. $H_2O(\ell) \rightleftharpoons H_2O(g)$

P ↑ ; $\Delta ng > 0$; Re^n goes B.D.

Boiling point increases.

29. $CO_2(s) \rightleftharpoons CO_2(g)$

On cooling reaction goes B.D

($\Delta H > 0$)

So CO2(g) solidifies.

30. $PCl_5 \rightleftharpoons PCl_3 + Cl_2$

$$\frac{D}{d} = 1 + (n-1)\alpha$$

$$\frac{M_0/2}{d} = 1 + (2-1)\alpha$$

$$\frac{208.5/2}{104.25} = 1 + \alpha$$

$\alpha = 0$

31. $PCl_5 \rightleftharpoons PCl_3 + Cl_2$

$$\frac{D}{d} = 1 + (n-1)\alpha$$

$$\frac{208.5/2}{70.2} = 1 + \alpha \quad \text{(At 200°C)}$$

$\alpha_{200} = 0.485 = 48.5\%$

$$\frac{208.5/2}{57.9} = 1 + \alpha_{250}$$

$\alpha_{250} = 0.80 = 80\%$

32. $$\alpha = \frac{D-d}{(n-1)d}$$

n : sum of stoichiometric coefficient of product