

Chemical Equilibrium

SOLUTIONS

Exercise-I (Conceptual Questions)

1. Ans. (3)

For an elementary reaction :

$$r = K[A][B]^2 \quad \dots(I)$$

$$r^1 = K[4A][B/2]^2 \quad \dots(II)$$

Divide (I) by (II)

$$\frac{r}{r^1} = \left(\frac{1}{4}\right) \times (4)$$

$$r = r^1$$

2. Ans. (4)

Catalyst reduces the time taken to attain equilibrium by lowering activation energy.

3. Ans. (4)

At equilibrium :- rate of forward reaction = rate of backward reaction

4. Ans. (4)

5. Ans. (2)

Active mass of pure solid = 1

6. Ans. (4)

$$\begin{aligned} [CO_2] : [H_2] : [N_2] &= \frac{22}{44} : \frac{3}{2} : \frac{7}{28} \\ &= \frac{1}{2} : \frac{3}{2} : \frac{7}{4} \\ &= 1 : 3 : 0.5 \end{aligned}$$

7. Ans. (1)

Catalyst provides an alternate path with lower activation energy.

8. Ans. (2)

Rate of forward and backward reaction is equal

9. Ans. (3)

$$K_{eq.} = \frac{k_f}{k_b}$$

$$\begin{aligned} K_f &= k_{eq.} \times k_b \\ &= 1.5 \times 7.5 \times 10^{-4} \\ &= 11.25 \times 10^{-4} \\ &= 1.12 \times 10^{-3} \end{aligned}$$

10. Ans. (3)

$$K_{eq.} = \frac{k_f}{k_b} = \frac{[B]}{[A]}$$

$$[B] = \frac{k_f}{k_b} \cdot [A]$$

$$= k_f \cdot k_b^{-1} [A]$$

11. Ans. (1)

$$\begin{aligned} K_C &= \frac{[Ag(NH_3)_2^+]}{[Ag^+][NH_3]^2} \\ &= \frac{(10^{-1})}{(10^{-1})(10^3)^2} = 10^{-6} \end{aligned}$$

12. Ans. (4)

$$\begin{aligned} K_p &= K_C (RT)^{\Delta n_g} \\ \Delta n_g &= (3 + 1) - (1 + 2) = 1 \\ K_p &= K_C (RT)^1 \\ K_C &= \frac{k_p}{(RT)} = \frac{.05}{(R \times 1000)} \\ &= 5 \times 10^{-5} R^{-1} \end{aligned}$$

13. Ans. (4)

$$K_p = \frac{(P_{CO})^2}{(P_{CO_2})} = \frac{(2)^2}{(4)} = 1$$

14. Ans. (3)

For $\Delta n_g = 0 \Rightarrow K_p = K_C$

15. Ans. (4)

$$\begin{aligned} K_P &= P_{H_2O}^2 \\ K_C &= [H_2O]^2 \\ K_P &= K_C(RT)^2 \end{aligned}$$

16. Ans. (2)

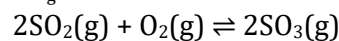
$$\log \frac{k_p}{k_c} + \log(RT) = 0$$

$$\log \frac{k_p}{k_c} = -\log(RT)$$

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

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

$$\Delta n_g = -1$$



$$\Delta n_g = -1$$

17. **Ans. (2)**

$$K_p = K_c(RT)^{\Delta n_g}$$

$$\frac{K_p}{K_c} = (RT)^{\Delta n_g}$$

$$\text{for } \frac{K_p}{K_c} = \text{minimum} \Rightarrow \Delta n_g \rightarrow \text{minimum}$$

$$\text{for } \frac{K_p}{K_c} = \text{maximum} \Rightarrow \Delta n_g \rightarrow \text{maximum}$$

18. **Ans. (1)**

Reverse (1) & multiply by 4.

$$K_2 = \frac{1}{(K_1)^4}$$

19. **Ans. (4)**

Add all given reactions to get K of target equation:

Hence K of $A \rightleftharpoons D$ is $2 \times 4 \times 6 = 48$

20. **Ans. (1)**

Stability $\propto$ Conc.

For reactant to be stable ; conc. of reactant should be more.

Hence K should be less.

So minimum K is of first reaction.

21. **Ans. (3)**

Equilibrium constant depends only on temperature.

22. **Ans. (1)**

Equilibrium constant of a reaction changes with temperature.

23. **Ans. (3)**

Equilibrium constant of a reaction changes with temperature.

24. **Ans. (2)**

Equilibrium constant of a reaction changes with temperature.

25. **Ans. (1)**

$$\left[\frac{1}{T_2} - \frac{1}{T_1} \right] \Rightarrow \left[\frac{T_1 - T_2}{T_1 T_2} \right] < 0.$$

26. **Ans. (1)**

On $\uparrow$ ing Temperature, value of K is increasing. Hence reaction is endothermic.

27. **Ans. (2)**

Equilibrium constant depends only on temperature.

28. **Ans. (4)**

$$K = [B]^2 [C]^3$$

$$K = [B^1]^2 [C^1]^3$$

$$\text{Given : } [C^1] = [2C]$$

$$[B]^2 [C]^3 = [B^1]^2 [2C]^3$$

$$[B^1]^2 = \frac{[B]^2}{8} \Rightarrow [B^1] = \frac{[B]}{2\sqrt{2}}$$

29. **Ans. (1)**

Equilibrium constant depends only on temperature.

30. **Ans. (3)**

Equilibrium constant depends only on temperature.

31. **Ans. (3)**

Equilibrium constant depends only on temperature.

32. **Ans. (3)**

Equilibrium constant depends only on temperature.

33. **Ans. (3)**

(a) Active mass $\rightarrow$ Concentration.

(b) Dynamic nature $\rightarrow$ Chemical equilibrium.

(c) $A + \text{heat} \rightleftharpoons B \rightarrow$ forward reaction increases on $\uparrow$ ing temperature.

$$(d) \log \left(\frac{K_2}{K_1} \right) = \frac{\Delta H}{2.303} \left(\frac{1}{T_1} - \frac{1}{T_2} \right)$$

$\Rightarrow$ Vant Hoff's equation.

$$(e) 2A_{(g)} + B_{(g)} \rightleftharpoons 3C_{(g)} \rightarrow \Delta n_g = 0$$

34. **Ans. (3)**

	P	$\rightleftharpoons$	Q	+	R
t = 0	2		0		0
t = eq.	2 - x		x		x
Given			x	=	0.5

$$\alpha = \frac{x}{2} = \frac{0.5}{2} = 0.25$$

35. **Ans. (1)**

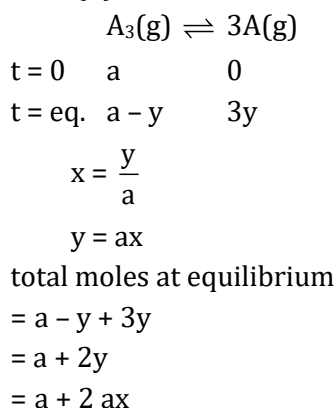
	2CO ₂	$\rightleftharpoons$	2CO	+	O ₂
t = 0	2mol		0		0
t = eq.	2 - 0.8		0.8		0.4
	= 1.2		0.8		0.4

$$40\% \text{ of } 2 = 0.8$$

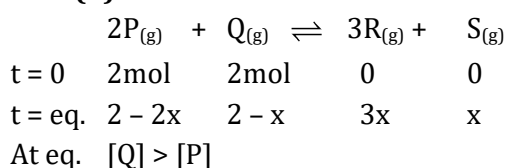
Moles total at equilibrium

$$= 1.2 + 0.8 + 0.4 = 2.4 \text{ moles.}$$

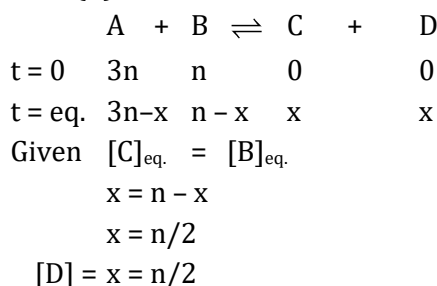
36. Ans. (4)



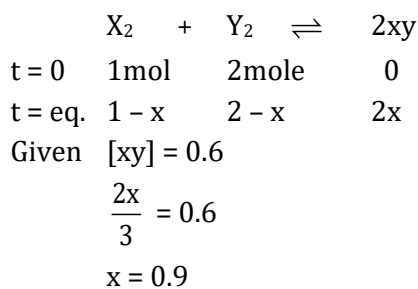
37. Ans. (1)



38. Ans. (1)



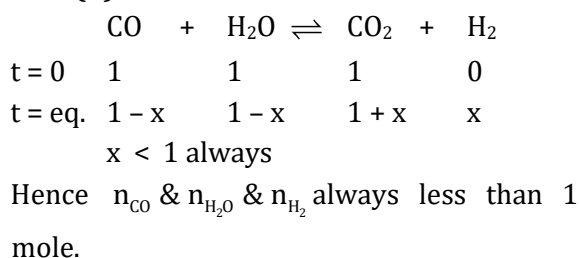
39. Ans. (1)



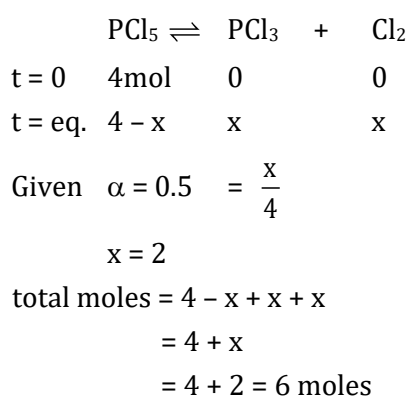
$$[X_2] = \frac{1-x}{3} = \frac{1-0.9}{3} = \frac{0.1}{3}$$

$$[Y_2] = \frac{2-x}{3} = \frac{2-0.9}{3} = \frac{1.1}{3}$$

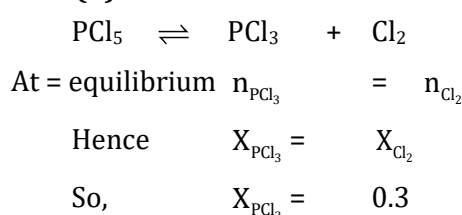
40. Ans. (2)



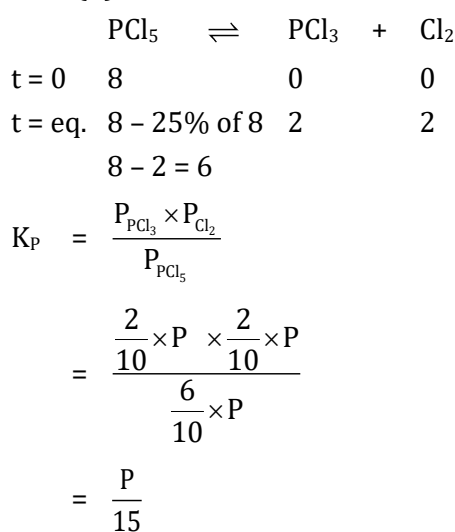
41. Ans. (2)



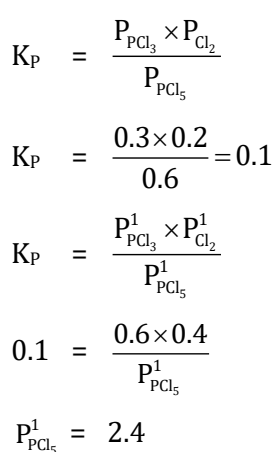
42. Ans. (1)



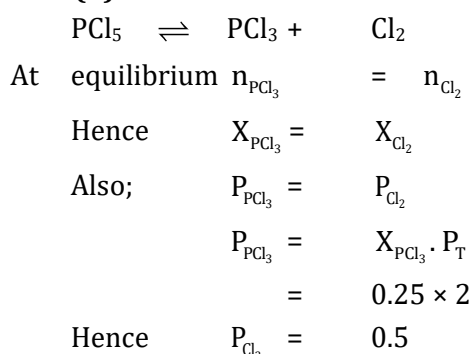
43. Ans. (2)



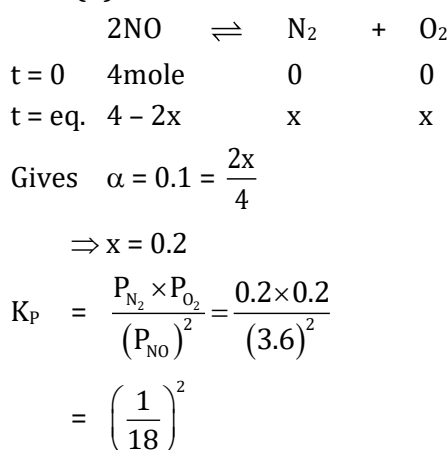
44. Ans. (3)



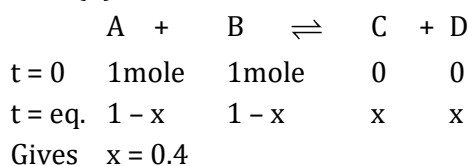
45. Ans. (3)



46. Ans. (1)



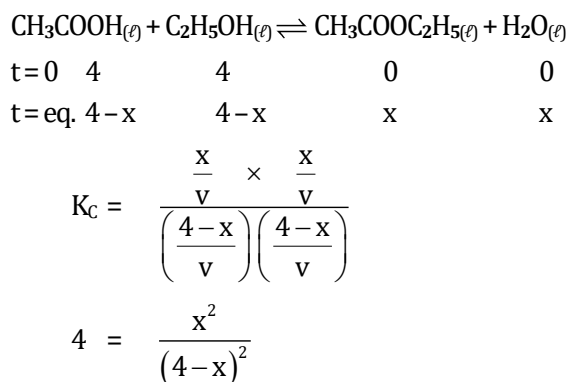
47. Ans. (4)



$$K_C = \frac{[\text{C}][\text{D}]}{[\text{A}][\text{B}]} = \frac{\frac{1.4}{V} \times \frac{0.4}{V}}{\frac{0.6}{V} \times \frac{0.6}{V}}$$

$$K_C = \frac{4}{9}$$

48. Ans. (2)



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

$$8 - 2x = x$$

$$3x = 8$$

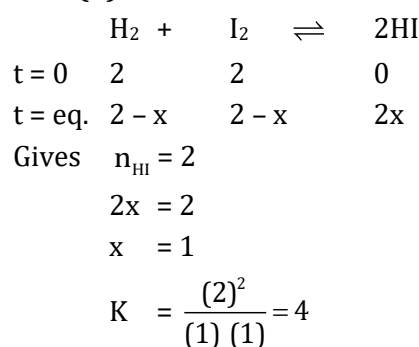
$$x = \frac{8}{3}$$

$$[\text{Acid}] = 4 - x$$

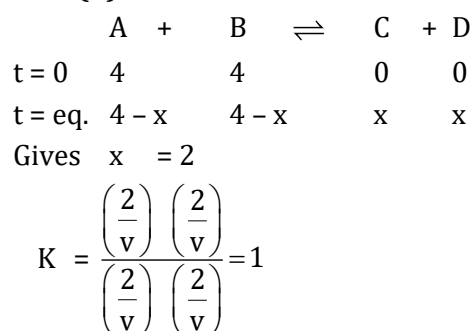
$$= 4 - \frac{8}{3}$$

$$= \frac{4}{3}$$

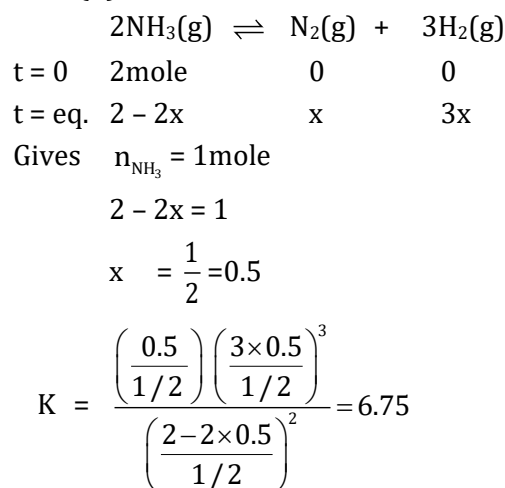
49. Ans. (2)



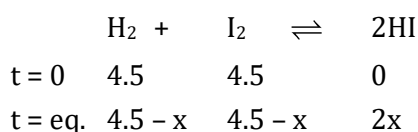
50. Ans. (2)



51. Ans. (2)



52. Ans. (1)

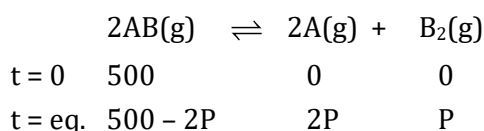
Gives $n_{\text{HI}} = 3 \text{ mole}$

$$2x = 3$$

$$x = 1.5$$

$$K = \frac{\left(\frac{2 \times 1.5}{V}\right)^2}{\left(\frac{3}{V}\right)\left(\frac{3}{V}\right)} = 1$$

53. Ans. (2)

Gives $P_T = 500 - 2P + 2P + P = 625$

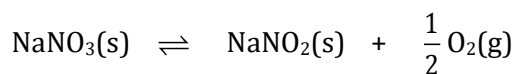
$$P = 125$$

$$\begin{aligned}
 K_p &= \frac{(P_A)^2 \cdot (P_{B_2})}{(P_{AB})^2} \\
 &= \frac{(2 \times 125)^2 (125)}{(250)^2} = 125
 \end{aligned}$$

54. Ans. (2)

On $\uparrow$ Sing concentrations of product at equilibrium, reaction shifts backward & more reactant will be formed.

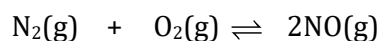
55. Ans. (3)



On $\uparrow$ Sing pressure; reaction shifts forward less gaseous moles.

i.e. above reaction will shift backward.

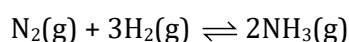
56. Ans. (3)



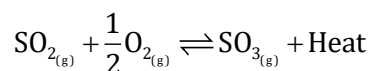
Above reaction is endothermic. Increasing temperature will favours forward reaction.

57. Ans. (3)

On $\uparrow$ Sing pressure; reaction will shift toward less gaseous moles.

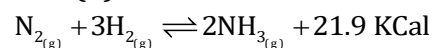


58. Ans. (2)



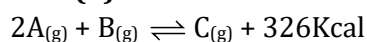
On $\downarrow$ Sing temperature & $\uparrow$ Sing pressure Reaction shifts forward.

59. Ans. (2)



On $\downarrow$ Sing temperature & $\uparrow$ sing pressure reaction shifts forward.

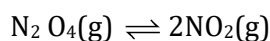
60. Ans. (3)



On $\downarrow$ Sing temperature & $\uparrow$ sing pressure reaction shifts forward.

61. Ans. (1)

On compressing $V \downarrow \Rightarrow P \uparrow$ Hence on $\uparrow$ sing pressure equation shifts towards less gas moles.



Hence balkward reaction is favoured.

62. Ans. (2)

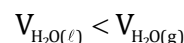
For $\Delta n_g = 0$ equation is unaffected by pressure.

63. Ans. (3)

On adding inert gas at constant volume. Equation is unaffected.

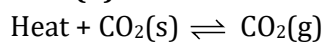
64. Ans. (2)

On $\uparrow$ sing pressure ; equilibrium shifts towards less volume.



Hence B.P. $\uparrow$ ses.

65. Ans. (3)



On cooling temperature $\downarrow$ ses. Reaction shifts backward.

66. Ans. (2)

$$\alpha = \frac{D_T - D_0}{(n-1) D_0}$$



$$D_T = \frac{208.5}{2} = 104.25$$

$$d = 104.25$$

$$n = 2$$

$$\alpha = \frac{104.25 - 104.25}{(2-1) \times 104.25} = 0$$

67. Ans. (1)

$$\alpha = \frac{D_T - D_0}{(n-1) D_0}$$



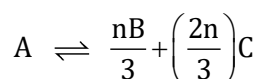
$$n = 2$$

$$\alpha_{200^\circ\text{C}} = \frac{104.25 - 70.2}{(2-1) \times 70.2} = 48.50\%$$

$$\alpha_{250^\circ\text{C}} = \frac{104.25 - 57.9}{(2-1) \times 57.9} = 80\%$$

68. Ans. (2)

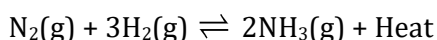
Choose that options for which sum of stoichiometric coefficient of gas product = n



$$\Rightarrow \frac{n}{3} + \frac{2n}{3} = n$$

Exercise-II (Previous Year Questions)

1. Ans. (4)



By decreasing temperature & increasing pressure forward reaction Proceeds.

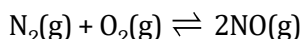
2. Ans. (1)

For a exothermic reaction on increasing temperature K_p decreases

3. Ans. (2)

When $K_{eq.} > 10^3$ product dominates over reactant.

4. Ans. (3)



Multiply above reaction by $\frac{1}{2}$ to get target

reaction hence $K' = (K)^{\frac{1}{2}}$

5. Ans. (1)

Reverse (I)

ADD in (II)

Multiply (III) $\times 3$

$$\frac{1}{K_1} \times K_2 \times (K_3)^3$$

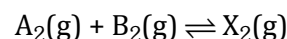
6. Ans. (4)

$$P_1 V_1 = P_2 V_2$$

$$0.4 \times 20 = 1.6 \times V_2$$

$$V_2 = 5 \text{ litre}$$

7. Ans. (1)



On decreasing temperature & increasing pressure forward reaction proceeds.

8. Ans. (1)



$$t = 0 \quad a \quad a \quad 0$$

$$t = \text{eq.} \quad a - 0.8a \quad a - 0.8a \quad 2 \times 0.8a$$

$$0.2a \quad 0.2a \quad 1.6a$$

$$K_c = \frac{[\text{HI}]^2}{[\text{H}_2][\text{I}_2]} = \frac{1.6^2 \times 1.6^2}{0.2 \times 0.2} = 64$$

9. Ans. (3)

$$PV = nRT$$

$$n_T = n_{\text{O}_2} + n_{\text{H}_2}$$

$$= \frac{4}{32} + \frac{2}{2} = \frac{1}{8} + 1 = \frac{9}{8}$$

$$P = \frac{nRT}{V} = \frac{\frac{9}{8} \times 0.0821 \times 273}{1} = 25.18 \text{ atm}$$

10. Ans. (3)

According to dalton's law :

$$P_A = X_A \cdot P_T$$

11. Ans. (4)

$$K_c = \frac{[\text{O}_3]^2}{[\text{O}_2]^3}$$

$$3 \times 10^{-59} = \frac{[\text{O}_3]^2}{[0.040]^3}$$

$$[\text{O}_3] = 4.38 \times 10^{-32}$$

12. Ans. (2)

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

$$\Delta ng = 2 - 1 = 1$$

$$K_c = \frac{K_p}{(RT)} = \frac{3}{(0.083)(1000)} = 3.6 \times 10^{-2}$$

13. Ans. (2)

$$\text{Rate} = k [A]^2 [B]$$

If [A] is tripled and [B] is kept constant.

$$r^1 = k [3A]^2 [B]$$

$$r^1 = 9k [A]^2 [B]$$

$$r^1 = 9r$$

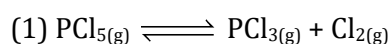
Increased by a factor of nine

14. Ans. (1)

$$K_p = K_c (RT)^{\Delta n_g}$$

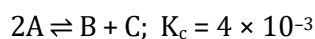
when $\Delta n_g = 0$ then $K_p = K_c$

$$\Delta n_g \neq 0 \quad K_p \neq K_c$$



$$\Delta n_g \neq 0$$

$$K_p \neq K_c$$

15. Ans. (3)

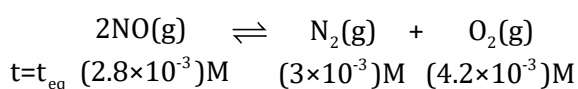
At a given time $\Rightarrow [A] = [B] = [C] = 2 \times 10^{-3} \text{ M}$

$$Q_c = \frac{[B][C]}{[A]^2}$$

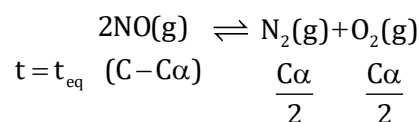
$$Q_c = 1$$

as $Q_c > K_c$

Reaction has a tendency to go in backward direction.

16. Ans. (4)

$$K_c = \frac{3 \times 10^{-3} \times 4.2 \times 10^{-3}}{(2.8 \times 10^{-3})^2} = \frac{3 \times 4.2}{2.8 \times 2.8} = 1.60$$



$$K_c = \frac{(C\alpha)^2}{4C^2(1-\alpha)^2}$$

$$\left(\frac{\alpha}{1-\alpha} \right)^2 = 4 \times 1.6$$

$$\frac{\alpha}{1-\alpha} = 2 \times 1.26$$

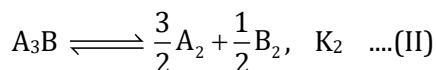
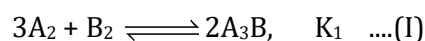
$$\frac{\alpha}{1-\alpha} = 2.52$$

$$\Rightarrow \alpha = 2.52 - 2.52\alpha$$

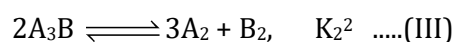
$$\Rightarrow \alpha = \frac{2.52}{3.52} = 0.717$$

17. Ans. (4)

For a reaction



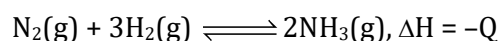
On multiplying by (2) in equation (II)



from (I) & (III)

$$K_2^2 = \frac{1}{K_1}$$

$$K_2 = \frac{1}{\sqrt{K_1}}$$

18. Ans. (4)

for forward direction high pressure, low temperature, and higher concentration of H_2 .

Exercise-III (Analytical Questions)**1. Ans. (2)**

Equilibrium constant only on depends on temperature.

2. Ans. (1)

According to Le-chatelier principle on addition of helium gas at constant pressure and temperature dissociation of PCl_5 is increases.

3. Ans. (4)

Dissolution of gas in liquid in exothermic phenomena.

According to Le-chatelier principle

$T \uparrow$ gas dissolution $\downarrow$

vise-versa

4. Ans. (2)

$$\log \frac{K_2}{K_1} = \frac{\Delta H^0}{2.303R} \left[\frac{T_2 - T_1}{T_1 T_2} \right]$$

5. **Ans. (1)**

Statement-I $\rightarrow$ incorrect

$K_p = K_c$ when $\Delta n_g = 0$

$K_{eq.} \rightarrow$ only depends on temperature

6. **Ans. (4)**

Equilibrium constant only depends on temperature.

7. **Ans. (2)**

At equilibrium

$r_f = r_b$

$\Delta G = 0$

$r_{net} = 0$

$\Delta G = -nFE_{cell}$

$E_{cell} = 0$

8. **Ans. (1)**

At equilibrium

$\Delta G = 0$

$K_p = Q_p$

9. **Ans. (3)**

$K_c > 10^3$ product dominates

$K_c < 10^{-3}$ reactant dominates

$10^{-3} < K_c < 10^3$ both reactant & product are in appreciable concentration.

$Q_c > K_c$ reaction shifts backward.

10. **Ans. (2)**

On increasing temperature if value of K increases reaction is endothermic.

11. **Ans. (4)**

$\Delta G^0 < 0$