EXERCISE - 1 [A]

1. (A)
Irreversible reactions proceeds to completion while reversible reactions do not proceed to completion.

2. (C)
Equilibrium is attained when rate of forward reaction becomes equal to rate of backward reaction.

3. (D)
Equilibrium is attained when rate of forward reaction becomes equal to rate of backward reaction.

4. (D)
$r \propto [B]^2$

5. (A)
According to law of active masses rate of reaction is directly proportional to product of active mass (molarity) raised to stoichiometric co-efficient.

6. (C)

$$K = \frac{[MX_3]^2}{[MX_2]^2[X_2]}$$

$\Rightarrow$ (C)

7. (B)

$$\left(\frac{dx}{dt}\right)_{net} = 2.6\times10^{3}\times10^{-6} - 4.1\times10^{-2}$$

$$= 2.6\times10^{-3} - 41\times10^{-3} = -ve$$

$\Rightarrow$ (B)

8. (B)

$N_2O_4 \rightleftharpoons 2NO_2 \qquad \Delta n_g = 1$

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

$\Rightarrow RT = 1 \qquad (\because K_p = K_c \,\&\, \Delta n_g = 1)$

$\Rightarrow T = 12.18\,K$

9. (C)

$x \rightarrow \Delta n_g = -1$

$y \rightarrow \Delta n_g = 1$

$z \rightarrow \Delta n_g = 0$

$\frac{K_p}{K_c} = (RT)^{\Delta n_g} \qquad$ So $y > z > x$

10. (B)

$K_p = (3.8\times10^{-3})(R\times1000)^2$

$= 25.61$

11. (B)

$$K_P = K_C\left(RT\right)^{\Delta n_g} \Rightarrow K_C = K_P\left(RT\right)^{-\Delta n_g}$$

12. (D)

$$\frac{K_p}{K_c} = \left(RT\right)^{\Delta n_g} = \left(RT\right)^{-1/2}$$

$\Rightarrow$ (D)

13. (B)

$\left(\because \Delta n_g < 0\right)$

14. (A)

$K_P = K_C\left(RT\right)^{\Delta n_g}$, for $K_P = K_C \Rightarrow \left(RT\right)^{\Delta n_g} = 1 \Rightarrow \Delta n_g = 0$

15. (B)

Reversing rxn II and adding when I with get rxn III

So $K_3 = \dfrac{K_1}{K_2} = 10^{-14}$

16. (D)

For the rxn $H_2 + I_2 \rightleftharpoons 2HI$

$r_f = 1.7\times10^{-18}\left[H_2\right]\left[I_2\right] \Rightarrow k_f = 1.7\times10^{-18}$

$r_b = 2.4\times10^{-21}\left[HI\right]^2 \Rightarrow k_b = 2.4\times10^{-21}$

$$\Rightarrow K_1 = \frac{1.7\times10^{-18}}{2.4\times10^{-21}}$$

So for reaction $\dfrac{1}{2}H_2 + \dfrac{1}{2}I_2 \rightleftharpoons HI$

$$K = \sqrt{K_1} = \sqrt{\frac{1.7\times10^{3}}{2.4}} = 26.6$$

17. (B)

Reversing Rxn 1 and adding with Rxn 2 we get the required reaction

$$K_3 = \frac{K_2}{K_1} = 1.8\times10^{-5}$$

18. (D)

For rxn $HI \rightleftharpoons \dfrac{1}{2}H_2 + \dfrac{1}{2}I_2$

$$K = \frac{1}{\sqrt{64}} = \frac{1}{8}$$

19. (B)

Adding all reaction we get the required reaction

$K = K_1K_2K_3$

$\Rightarrow$ (B)

20. (A)

Reverse the second and multiply by $\frac{1}{2}$ to get 1st reaction

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

$\Rightarrow$ (A)

21. (B)
Add the reactions to get required reaction
$K = K_1K_2$
$\Rightarrow$ (B)

22. (C)
Add the reactions and multiply by $\frac{1}{2}$ to get required reaction.
$K = \sqrt{K_1K_2}$
$\Rightarrow$ (C)

23. (C)
Adding the reaction will give overall reaction.
$K = K_1 \times K_2 = 1$

24. (A)

$$K_c = 27 = \frac{[H_2]^3}{[H_2O]^3}$$

$$\Rightarrow \frac{[H_2]}{[H_2O]} = 3$$

25. (A)
$\Delta n \neq 0$

26. (D)
All have $\Delta n = 0$

27. (D)
$\Delta n = 0$ So no units

28. (A)
$\Delta n = 1$
So, units are mol/L

29. (D)
$K_p \Rightarrow atm^2 \left(\because \Delta n_g = 2\right)$

30. (C)
K remains constant

31. (B)

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

i 1 3 0

e 0.5 1.5 1

$n_{tot,\,eq} = 3$

32. (B)

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

i 2 2 0

e 0.8 1.4 0.4

$\Rightarrow \left[NH_3\right]_{eq} = \dfrac{0.4}{5} = 0.08$

$\Rightarrow$(B)

33. (B)

Small value of K indicates that at equilibrium products are much lesser than reactants so (B)

34. (C)

$$2HI \rightleftharpoons H_2 + I_2$$

i 2 0 0

e $2(1-a)$ a a

$n_{tot,\,eq} = 2$

$\Rightarrow$(C)

35. (C)

$$A + 2B \rightleftharpoons C$$

1 1 1.8 0

eq 0.6 1 0.4

$$K_C = \frac{\frac{0.4}{5}}{\frac{0.6}{5} \times \left(\frac{1}{5}\right)^2} = \frac{100}{6}$$

$\Rightarrow$(C)

36. (B)

$$H_2(g) + S(s) \rightleftharpoons H_2S(g)$$

i 0.2

e $0.2 - x$ x

$$\frac{x}{0.2-x} = 6.8\times10^{-2} \Rightarrow x = \frac{6.8\times10^{-2}\times0.2}{1.068}$$

$P_{H_2S} = 0.38\text{atm}$

37. (C)

Higher value of K indicates more tendency to completion.

38. (A)

$$K_p = \frac{p^2_{SO_3}}{P^2_{SO_2}P_{O_2}} \Rightarrow P_{O_2} = \frac{1}{3.5} = 0.29\text{atm}$$

39. (C)

$$\begin{array}{llll} & PCl_3 + & Cl_2 \rightleftharpoons & PCl_5 \\ i & 0 & 0 & \frac{x}{2.5} \\ e & 0.2 & 0.2 & \frac{x}{2.5}-0.2 \end{array}$$

$$\Rightarrow \frac{\frac{x}{2.5}-0.2}{0.2\times0.2}=15$$

$$\frac{x}{2.5}=0.6+0.2=0.8$$

$$\Rightarrow x=2$$

40. (B)

$$\begin{array}{lllll} & 2A + & B \rightleftharpoons & 3C + & 0 \\ i & 2 & 2 & 0 & 0 \\ e & 2-2x & 2-x & 3x & x \end{array}$$

So $[B]>[A]$

$\Rightarrow [B]$

41. (C)

$$\begin{array}{llll} & P_4 + & 6Cl_2 \rightleftharpoons & 4PCl_3 \\ i & x & x & 0 \\ e & x-y & x-6y & 4y \end{array}$$

So $[Cl_2]<[P_4]$

42. (B)

$$2H_2S \rightleftharpoons 2H_2 + S_2$$

$$K=\frac{\left(\frac{0.2}{2}\right)^2\left(\frac{0.8}{2}\right)}{\left(\frac{1}{2}\right)^2}$$

$$=0.016$$

$\Rightarrow$ [B]

43. (A)

Since K is very small reaction will proceed to negligible extent hence $[I]<[I_2]$

44. (B)

$$H_2 + I_2 \rightleftharpoons 2HI$$

$$Q=\frac{\left(\frac{2\times10^{-2}}{2}\right)^2}{\frac{1\times10^{-2}}{2}\times\frac{3\times10^{-2}}{2}}=\frac{4}{3}<K$$

So rxn proceeds in forward direction

45. (D)

$$K_c = \frac{[SO_2]^2[O_2]}{[SO_3]^2} = 10\,\text{mol}/\text{L}$$

$\Rightarrow n_{O_2} = 10 \times 10 = 100$

$\Rightarrow$ no. of O_2 molecules $= 100N_A$

46. (D)

$$\begin{array}{lllll} & SO_3 & +\,CO & \rightleftharpoons SO_2 & +\,CO_2 \\ \text{i} & 2 & 2 & 2 & 2 \\ \text{e} & 2-x & 2-x & 2+x & 2+x \end{array}$$

$$\left(\frac{2+x}{2-x}\right)^2 = \frac{1}{9} \Rightarrow \frac{2+x}{2-x} = \frac{1}{3}$$

$\Rightarrow 6+3x = 2-x$

$4 = -4x \Rightarrow x = -1$

$n_{SO_3} + n_{CO_2} = 2-x+2+x = 4$

$$\frac{n_{SO_2}}{n_{Co}} = \frac{2+x}{2-x} = \frac{1}{3}$$

47. (D)

$$\begin{array}{llll} & N_2 & +\,3H_2 & \rightleftharpoons 2NH_3 \\ \text{i.} & 3 & 10 & 0 \\ \text{e} & 3-x & 10-3x & 2x \end{array}$$

$$\frac{13-2x}{13} = \frac{2}{3} \Rightarrow 39-6x = 26$$

$$\Rightarrow x = \frac{13}{6}$$

$$K_C = \frac{\left(\frac{13/3}{4}\right)^2}{\frac{\frac{5}{6}}{4} \times \left(\frac{\frac{21}{6}}{4}\right)^3}$$

48. (C)

$$\begin{array}{lll} NH_4Hs(s) \rightleftharpoons & NH_3(g) + & H_2S(g) \\ \text{e} & x & x \end{array}$$

$$2x = p \Rightarrow x = \frac{p}{2}$$

$$K_P = x^2 = \frac{p^2}{4}$$

$\Rightarrow$(C)

49. (D)

$$\begin{array}{lllll} A & + & B & \rightleftharpoons & 2C \\ 3 & & 1 & & - \\ 3-x & & 1-x & & 2x \\ 3-\frac{1.5}{2} & & 1-\frac{1.5}{2} & & =1.5 \end{array}$$

$$K = \frac{(1.5)^2}{0.5 \times 2.25} = 4$$

50. (C)

$$Mw_{eq} = \frac{122}{1-\alpha+\frac{\alpha}{2}} = \frac{122}{1-\frac{1}{4}} \Rightarrow 122 \times \frac{4}{3} = 163$$

51. (A)

$$d = \frac{D}{1-\alpha+2\alpha} \Rightarrow \frac{D}{d} = 1+\alpha$$

52. (B)

$$\frac{D}{d} = 1+\alpha$$

$\Rightarrow$ (B)

53. (A)

K_p never changes with pressure

54. (C)

$$PCl_5 \rightleftharpoons PCl_3 + Cl_2$$

i $\quad 2.2 \quad 0 \quad 0$

e $\quad 2.2(1-\alpha) \quad 2.2\alpha \quad 2.2\alpha$

$$n_{OH} = 2.2(1+\alpha) = 2.53 \Rightarrow \alpha = \frac{0.33}{2.2} = 0.15$$

55. (B)

$$PCl_5 \rightleftharpoons PCl_3 + Cl_2$$

i $\quad 1$

e $\quad 1-\alpha \quad \alpha \quad \alpha$

$n_{1-n} = 1+\alpha$

56. (D)

K_p will not change with volume, but α will

57. (A)

$$A \rightleftharpoons 2B$$

i $\quad a \quad 0$

e $\quad a(1-\alpha) \quad 2a\alpha$

$$K_P = \frac{\left(\frac{2a\alpha}{a(1+\alpha)}P\right)^2}{\frac{a(1-\alpha)}{a(1+\alpha)}p} = \frac{4\alpha^2 p}{1-\alpha^2}$$

58. (C)

Exothermic reaction is favored by low T

$\Delta n_g < 0$ is favored by high P

59. (B)

$$\text{Slope} = \frac{-\Delta H}{2.303R} = 1$$

$\Rightarrow \Delta H = -4.606\,\text{cal}$

60. (B)

For I as $T\uparrow\ K\downarrow\ \Rightarrow$ exothermic

For II as $T\uparrow K\uparrow\ \Rightarrow$ endothermic

61. (A)

As $T\uparrow\ K\downarrow \Rightarrow$ exothermic

62. $$T \ge \frac{50,000}{100} = 500$$

SO (D)

63. (D)

At equilibrium $\Delta G = 0$

64. (B)

$$K = e^{\frac{16500}{8.314\times 298}} = 780$$

65. (A)

$$\ell nk = 4 - \frac{2000}{T} = \frac{\Delta S^\circ}{R} - \frac{\Delta H^\circ}{RT}$$

$\Rightarrow \Delta S^\circ = 4R$

66. (D)

For exothermic As $T\uparrow\ K\downarrow$

For endothermic As $T\uparrow K\uparrow$

67. (B)

Since reaction is exothermic increase in temp will favor decomposition of N_2O_4

68. (D)

Since reaction is exothermic increase in temp will favor backward rxn hence $[NH_3]$ will decrease

69. (D)

For endothermic reaction as $T\uparrow, K\uparrow$

70. (D)

K_p can change only with temperature

71. (C)
Since the reaction is exothermic low temperature will favor forward rxn.

72. (A)
Since the reaction in endothermic increasing temperature will increase P_{CO_2}

73. (C)
Endothermic reaction is favored by high T
$\Delta n_g < 0$ reaction is favored by high P

74. (D)
Pressure does not effect K
$\Rightarrow$ (D)

75. Addition of H_2O with decrease SO_3 as it will react with H_2O to form H_2SO_4, hence the rxn will proceed in forward direction.

76. (C)
Only temperature can change K

77. (C)
K remains unaffected if T is constant

78. (C)
K remains unchanged on changing volume of container

79. (C)
$2HI \rightleftharpoons H_2 + I_2$, dissociation reaction of HI has $\Delta n_g = 0$ so change of volume of container will not have any effect.

80. (C)
Increase in P favors backward reach if $\Delta n_g > 0$
So (C)

81. (C)

$$K = \frac{0.3}{0.15 \times P_B} = \frac{P_C}{0.3 \times 2P_B}$$

$\Rightarrow P_C = 1.2 \text{atm}$

82. (A)
Le Chatelier principle applies on disturbance on a system in equilibrium.

83. (B)
Addition of product will shift reaction backwards so $\left[H^+\right]$ will decrease

84. (C)

Since $\Delta n_g > 0$ for reaction increasing volume will favor forward reaction.

85. (C)
Increasing product concentration will favor backward reaction

86. (B)
Adding PCl_5 will favor forward reaction hence Cl_2 will increase

87. (C)
Since $\Delta n_g = 0$ increasing pressure will have no effect.

88. (B)
$\Delta n_g > 0$ so increasing pressure will shift the reaction in backward direction

89. (C)
Exothermic, $\Delta n_g < 0$
So low temperature & high pressure
$\Rightarrow$(C)

90. (D)
Exothermic, $\Delta n_g < 0$
So low temperature & high pressure
$\Rightarrow$ (D)

91. (A)
Endothermic. $\Delta n_g < 0$
So high temperature & high pressure
$\Rightarrow$(A)

92. (B)
Adding N_2O_4 shift the reaction in forward direction, so concentration NO_2 will increase.

93. (A)
Catalyst does not effects equilibrium.

94. (C)
$K = \frac{P_D^2}{P_B}$ $\Rightarrow$ so P_B is doubled so P_D will increase by factor of $\sqrt{2}$

95. (C)
K does not changes on adding of inert

96. (B)
Removal of SO_3 will shift the reaction in forward direction

97. (D)
Since $\Delta n_g = 0$, only temp. change will effect forward reaction

98. (D)

$CaCO_3$ is solid so adding $CaCO_3$ will not change its active mass.

99. (A)

$\Delta n_g > 0$ So backwards reaction is favored

100. (C)

$\Delta n_g = 0$ will not be effected by P

EXERCISE - 1 [B]

1. (D)

$$3A + 6B \rightleftharpoons 3C \quad K_1^3$$

$$C + D \rightleftharpoons 3A \quad K_2$$

Adding $6B + D \rightleftharpoons 2C \quad K_3 = K_1^3 \times K_2$

2. (C)

$$C_{10}H_8(s) \rightleftharpoons C_{10}H_8(g)$$

e $\quad$ $0.1\,\text{mm Hg}$

$$K_P = \frac{0.1}{760} = 1.32 \times 10^{-4}\ \text{atm}$$

$$K_C = \frac{K_P}{RT} = \frac{1.32 \times 10^{-4}}{0.0821 \times 300} = 5.34 \times 10^{-6}$$

3. (C)
Chemical equilibrium cannot be attained in open vessel.

4. (A)
K depends only on T

5. (D)
Since unit of K_P are atm so $\Delta n_g = 1$

6. (A)
For endothermic reaction as $T\uparrow$ $K\uparrow$.

7. (C)
Since T is same, so K remains constant.

8. (A)
For vapour density to decrease, $\Delta n_g > 0$.

9. (D)
For oxide to be stable, K of its dissociation reaction should be least.

10. (A)

$$2SO_2 + O_2 \rightleftharpoons 2SO_3$$

i $\quad 2 \quad 1 \quad 0$

e $\quad 2-2x \quad 1-x \quad 2x$

$$K = \frac{(2x)^2}{(1-x)(2-2x)^2} V$$

11. (B)

$$6HCHO \rightleftharpoons C_6H_{12}O_6$$

i $\quad 0 \quad 1$

e $\quad x \quad 1-x$

$$\frac{1-x}{x^6}=6\times10^{22} \Rightarrow 1-x\approx1$$

So, $\frac{1}{x^6}=6\times10^{22}$

$\Rightarrow$ $x=1.6\times10^{-4}$

12. (C)
For vapour & liquid in equilibrium at boiling point, here KE is almost equal.

13. (D)
Initially only reactants are mixed so $Q=0$, and it will increase with time.

14. (C)
$\Delta n_g>0$ so increase in P will shift reaction in backward direction.

15. (C)
Addition of catalyst has no effect on K or equilibrium concentrations.

16. (B)
Lime kiln is a open vessel so $CO_2(g)$ escapes out.

17. (D)

$$\begin{array}{llll} & 2NOCl \rightleftharpoons & 2NO & + Cl_2 \\ i & C & 0 & 0 \\ e & 1 & C-1 & \frac{C-1}{2} \end{array}$$

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

$\Rightarrow$ $C-1=2$

$\Rightarrow$ $C=3$

18. (A)

$$60=\frac{92}{1+\alpha} \Rightarrow \alpha=\frac{92}{60}-1$$

$$\Rightarrow \alpha=\frac{32}{60}=0.5333$$

19. (D)

$H_2O(\ell)\rightleftharpoons H_2O(s)$

At $-10°C$ reaction is spontaneous so $\Delta G°<0$

Reaction is exothermic so $\Delta H<0$

Liquid to solid so $\Delta S<0$.

20. (D)
On halving the volume pressure will be doubled, and then to achieve new equilibrium reaction will decrease pressure, so at new equilibrium pressure will be less than 2P.

21. (B)

$$XY_2 \rightleftharpoons XY + Y$$

$i \quad 600 \qquad 0 \qquad 0$
$e \quad 600-\mathrm{P} \qquad \mathrm{P} \qquad \mathrm{P}$
$600-\mathrm{P}=800$
$\mathrm{P}=200$
$$\mathrm{K_P}=\frac{200\times200}{400}=100$$

22. (A)

$$\begin{array}{llll} & 2\mathrm{A_2B} & \rightleftharpoons \; 2\mathrm{A_2} & + \; \mathrm{B_2} \\ i & 4 & 0 & 0 \\ e & 4(1-\alpha) & 4\alpha & 2\alpha \end{array}$$

$$\mathrm{K_P}=\frac{\frac{2\alpha}{4+2\alpha}\times\left(\frac{4\alpha}{4+2\alpha}\right)^2}{\left(\frac{4(1-\alpha)}{4+2\alpha}\right)^2}\mathrm{P}$$

So, $\frac{2\alpha}{4+2\alpha}\times\alpha^2=(1-\alpha)^2 \qquad (\because\ \mathrm{K_P}=\mathrm{P})$

$2\alpha^3=(1+\alpha^2-2\alpha)(4+2\alpha)$

$2\alpha^2=4+4\alpha^2-8\alpha+2\alpha+2\alpha^3-4\alpha^2$

$6\alpha=4 \Rightarrow \alpha=\frac{2}{3}$

23. (D)
Le Chatelier's principle can't be applied if all reactions & products are solids.

24. (B)
Adding HCl will increase $\mathrm{H^+}$ concentration
So reaction will be shifted backward.

25. (C)
$\Delta n_g>0$, So (C).

26. (B)
For endothermic as $\mathrm{T}\uparrow\ \mathrm{K}\uparrow$, So (B)

27. (C)
For endothermic as $\mathrm{T}\uparrow\ \mathrm{K}\uparrow$, So (C)

28. (B)
Exothermic will be favoured by low T
$\Delta n_g<0$ will be favoured by high P

29. (A)
$\Delta n_g>0$
Adding inert at constant P will shift reaction in forward direction.

30. (D)
Addition at catalyst does not effects equilibrium concentrations.

31. (C)

$$2.9\times10^{-2}=\frac{\alpha^2}{1-\alpha^2}\times1$$

$$\Rightarrow\ \alpha=0.17$$

32. (C)

$$\begin{array}{llll} & NH_3 & \rightleftharpoons \frac{1}{2}N_2 & + \ \frac{3}{2}H_2 \\ i & 3 & 0 & 0 \\ e & 3-x & \frac{x}{2} & \frac{3}{2}x \end{array}$$

$$\frac{\frac{3}{2}x}{4+x}=\frac{1}{2}$$

$$3x=4+x$$

$$x=2$$

$$K_C=\frac{\left(\frac{3}{V}\right)^{3/2}\left(\frac{1}{V}\right)^{1/2}}{\frac{1}{V}}$$

$$K_C\times V=3^{3/2}.$$

33. (A)

$$\begin{array}{lll} & CO_2 & + \ C(s) \rightleftharpoons 2CO(g) \\ i & 0.5 & \\ e & 0.5-P & \end{array}$$

$$0.5+P=0.8\ \Rightarrow\ P=0.3$$

$$K_P=\frac{(0.6)^2}{0.2}=1.8$$

34. (D)

When ice and water are in equilibrium then $G_{ice}=G_{water}\neq0$

35. (C)

Since, $\Delta n_g>0$ increasing pressure will shift reaction in backwards direction.

EXERCISE - 1 [C]

1. (4)

	A	$+$	$2B$	$\rightleftharpoons$	$2C$	$+$	D
$t = 0$	a		$1.5a$		–		–
At eq.	$a - x$		$1.5a - 2x$		$2x$		x

$a - x = x$ (given)

$$\Rightarrow\ x = \frac{a}{2}$$

$$K_C = \frac{a^2 \times \frac{a}{2}}{\frac{a}{2} \times \left(\frac{a}{2}\right)^2} = 4$$

2. (5)

$$1 \times \frac{92}{1+\alpha} = 1.84 \times 0.082 \times 348 \quad \Rightarrow\ \alpha = 0.75$$

$$K_P = \frac{4 \times 0.75^2}{\left\{1 - (0.75)^2\right\}} = 5.143$$

3. (5)

$2A(g)$	$+$	$H_2O(g)$	$\rightleftharpoons$	$C(g)$	$+$	$3D(g)$
2		0.05		2		2
~0		0.05		3		5

$$3 \times 10^{22} = \frac{3 \times 5^3}{5 \times 10^{-2} \times P_A^2} \ \Rightarrow\ P_A = 5 \times 10^{-10}$$

4. (4)

$$\frac{1}{2}C(s) + \frac{1}{2}CO_2(g) \rightarrow CO(g)$$

	$\frac{1}{2}CO_2(g)$	$CO(g)$
i	P	O
e	$\frac{P}{2}$	P

$$P + \frac{P}{2} = 12$$

$$\Rightarrow\ P = \frac{12 \times 2}{3} = 8\ \text{atm}$$

$$K_p = \frac{8}{(4)^{1/2}} = 4$$

5. (4)

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

	$B(g)$	$2C(g)$
e	P	2P

$$(P)(2P)^2 = 32$$
$$\Rightarrow \quad P = 2$$

6. (1)

$$K_C = \frac{2/5}{2/5} = 1$$

7. (2)

$$\Delta G^\circ = -RT\,\ell n\,K$$
$$\ell n\,K = \frac{-830}{-2\times 300} = \frac{83}{60}$$
$$K = 4$$
$$\begin{array}{lccccccc} & A & + & B & \rightleftharpoons & C & + & D \\ i & n & & n & & & & \\ e & n-x & & n-x & & x & & x \end{array}$$
$$\left(\frac{x}{n-x}\right)^2 = 4$$
$$\Rightarrow \frac{x}{n-x} = 2$$

8. (4)

$$\begin{array}{lcccc} NO & + & NO_3 & \rightleftharpoons & 2NO_2 \\ 1-\frac{x}{2} & & 3-\frac{x}{2} & & x \\ 3-x & & 3-x & & 2x \end{array}$$
$$K = \frac{x^2}{\left(1-\frac{x}{2}\right)\left(3-\frac{x}{2}\right)} \Rightarrow K = \frac{4x^2}{(3-x)^2}$$

Equating the two K $x = \frac{3}{2}$ and then $K = 4$.

9. (2)

$$K_p = K_x (RT)^{\Delta n} = K_c (RT)^2$$
$$\Rightarrow \quad \Delta n = 2$$

10. (3)

For the reactions,

$$A + D \rightleftharpoons P + \frac{C}{2}$$
$$K = \frac{6}{\sqrt{4}} = 3$$

11. (9)

$$\log K = \frac{\Delta S^\circ}{2.3R} - \frac{\Delta H^\circ}{2.3RT}$$

$$\Rightarrow \frac{\Delta S^\circ}{2.3R} = 0.47$$

Hence $\Delta S^\circ = 0.47 \times 2.3 \times 8.3 = 9$

12. (2)

$$N_2O_4(g) \rightleftharpoons 2NO_2$$

2 atm 2 atm $K_p = 2$

$\frac{2}{x} - p = 0.85$ $\frac{2}{x} + 2p$

$$K_p = 2 = \frac{\left(\frac{2}{x} + 2p\right)^2}{0.85}$$

$\Rightarrow \frac{2}{x} + 2p = 1.3$ ...(i)

and $\frac{2}{x} - p = 0.85$ ...(ii)

Eliminating p from equation (i) and (ii) gives x = 2.

13. (2)

$$PCl_5 \rightleftharpoons PCl_3 + Cl_2$$

Eqn-1 : n n n

$K_c = \frac{n}{V}$ ...(i)

Eqn-2 : $n + m$ $n - m$ $n + \frac{20}{3} - m$

$$K_c = \frac{\left(n - m + \frac{20}{3}\right)(n - m)}{(n + m)2V} \quad ...(iv)$$

Also since volume is doubled, moles will also be doubled

$\Rightarrow 3n + \frac{20}{3} - m = 6n$ or $\frac{20}{3} - m = 3n$ ...(iii)

From (i) (ii) and (iii), n = 2

14. (12)

$$K_c = \frac{x}{2(2)^2} = \frac{1}{2}$$

$\Rightarrow x = 4$ mol AB_2 present.

Now let y mol of AB_2 is added.

$$K_c = \frac{1}{2} = \frac{4 + y}{2(2+2)^2}$$

$\Rightarrow y = 12$

15. (1)

$$\Delta G^\circ = -RT\ln K = 0$$

$\Rightarrow \quad K = 1$

1. (D)

To calculate the value of K_4 in the given equation we should apply:

$$\text{eq.}(2)+\text{eqn.}(3)\times 3-\text{eqn.}(1)$$

Hence, $K_4=\frac{K_2K_3^3}{K_1}$

2. (B)

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

$$K_p=K_c(RT)^x$$

Where $x=\Delta n_g=$ number of gaseous moles in product $-$ number of gaseous moles in reactants

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

3. (D)

On adding inert gas at constant volume, the total pressure of the system is increased, but the concentration of each reactant and product remains the same. Hence, there is no effect on the state of equilibrium.

4. (D)

$$\Delta G^\circ=2494.2J$$

$$2A\rightleftharpoons B+C$$

$$[A]=\frac{1}{2},[B]=2,[C]=\frac{1}{2}$$

$$Q=\frac{[B][C]}{[A]^2}=\frac{2\times 1/2}{\left(\frac{1}{2}\right)^2}=4$$

$$\Delta G^\circ=-2.303RT\log K_c$$

$$2494.2J=-2.303\times(8.314J/K/mol)\times(300K)\log K_c$$

$$\Rightarrow \log K_c=-0.4341\Rightarrow K_c=0.37;\therefore Q>K_c$$

5. (A)

$$XY(s)\rightleftharpoons \underset{P}{X(g)}+\underset{P}{Y(g)}\quad\text{(Assume)}$$

At eqm, Total pressure $=2p=10\,\text{bar}$

$\therefore p=5;\text{Now}K_p=(P_x)(P_Y)=P^2=25$

6. (C)

Given, $\Delta H^\circ=-29.8\,kJ\,mol^{-1}$

$$\Delta S^\circ=0.1\,kJ\,K^{-1}$$

From the equation

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ = -29.8 - \left(298 \times (-0.100)\right)$$

$$= -29.8 + 29.8 = 0$$

Now, $\Delta G^\circ = -2.303\,RT\log K_{eq}$

$0 = -2.303\,RT\log K_{eq} \quad \therefore K = 1$

7. (D)

Perturbation	Shifts reaction towards
Removal of CO	Left
Removal of CO_2	Right
Addition of CO_2	Left
Addition of Fe_2O_3	No change (This is a solid compound. Its concentration has no effect on the equilibrium)

8. (B)

As volume ↑ pressure ↓, reaction proceeds in that direction where the number of moles of gases increases.

9. (A)

We know that, $K_p = K_c.(RT)^{\Delta n_g}$

$\therefore$ If $\Delta n_g \neq 0$ then $K_p \neq K_c$

Now, $2C(s) + O_2(g) \rightleftharpoons 2CO(g)$

$\Delta n_g = +1 \Rightarrow K_p = K_c(RT)^1$

Hence, $K_p \neq K_c$

10. (C)

Given, $S + O_2 \rightleftharpoons SO_2$ …………(i); $K_1 = 10^{52}$

$2S + 3O_2 \rightleftharpoons 2SO_3$ ………(ii); $K_2 = 10^{129}$

$2SO_2 + O_2 \rightleftharpoons 2SO_3$ ……..(iii); K=?

To get equation (iii) follow (ii) $-2(i)$,

$2S + 3O_2 \rightarrow 2SO_3 \qquad K_2 = 10^{129}$

$-\left(2S + 2O_2 \rightarrow 2SO_2 \quad K_1' = 10^{104}\right)$

$O_2 \rightarrow 2SO_3 - 2SO_2 \qquad K = 10^{129-104}$

Or $2SO_2 + O_2 \rightarrow 2SO_3 \quad K = 10^{25}$

11. (B)

$$\begin{array}{ccccc} A(s) & \longrightarrow & B(g) & + & C(g) \\ & & P_1 & & P_1 + P_2 \end{array}$$

$K_{P_1} = P_B \times P_C$

$P_1\left(P_1+P_2\right)=x$ ……(i)

$D(s)\longrightarrow C(g)+E(g)$

$\qquad\qquad P_1+P_2 \quad P_2$

$K_{P_1}=P_C\times P_E$

$\left(P_1+P_2\right)P_2=y$ ………(ii)

Adding (i) and (ii)

$\therefore P_1\left(P_1+P_2\right)+P_2\left(P_1+P_2\right)=x+y$

$\Rightarrow\left(P_1+P_2\right)\left(P_1+P_2\right)=\left(P_1+P_2\right)^2=x+y$

$\Rightarrow P_1+P_2=\sqrt{x+y}$

$\therefore$ Total pressure $\left(P_T\right)=P_C+P_B+P_E$

$\left(P_1+P_2\right)+P_1+P_2=2\left(P_1+P_2\right)$

$P_T=2\left(\sqrt{x+y}\right)$

12. (A)

$$\begin{array}{lcccccc} & A & + & 2B & \rightleftharpoons & 2C & + & D \\ t=0 & 2 & & 3 & & 0 & & 0 \\ t_{eq} & 2-x & & 3-2x & & 2x & & x \end{array}$$

Given, $3-2x=2-x$

$\Rightarrow x=1\ \therefore[C]=2,[D]=1,[A]=1,B=1$

$\therefore K_c=\left\{\dfrac{2^2\times1}{1^2\times1}\right\}=4$

13. (A)

$2NH_3(g)\rightleftharpoons N_2(g)+3H_2(g),K=\dfrac{1}{K_P}$

$P_{NH_3} \qquad\qquad P_{N_2} \qquad P_{H_2}$

$\therefore K=\dfrac{1}{K_P}=\dfrac{P_{N_2}\left(P_{H_2}\right)^3}{\left(P_{NH_3}\right)^2}$ ……….(i)

$\Rightarrow P_{total}(P)=P_{N_2}+P_{H_2}+P_{NH_3}$

$\approx P_{N_2}+P_{H_2}\left(\because P_{NH_3}<<P_{total}\right)$

Now,

Partial pressure of $N_2=$ mole fraction of $N_2\times P=\dfrac{1}{4}P;$

Partial pressure of $H_2=\dfrac{3}{4}P$

From eq(i), $\dfrac{1}{K_P}=\dfrac{\left(\dfrac{1}{4}P\right)\left(\dfrac{3}{4}P\right)^3}{\left(P_{NH_3}\right)^2}$

$$P_{NH_3} = \frac{3^{3/2}.P^2.K_P^{1/2}}{16}$$

14. (B)

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

$\Delta n_g =$ No. of gaseous moles of products $-$ No. of gaseous moles of reactants

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

$N_2\left(g\right)+O_2\left(g\right)\rightleftharpoons 2NO\left(g\right), \Delta n_g = 0$

$\frac{K_p}{K_c} = \left(24.62\,dm^3 atm\, mol^{-1}\right)^0 = 1$

$N_2O_4\left(g\right)\rightleftharpoons 2NO_2\left(g\right), \Delta n_g = 1$

$\frac{K_p}{K_c} = 24.62\,dm^3 atm\, mol^{-1}$

$N_2\left(g\right)+3H_2\left(g\right)\rightleftharpoons 2NH_3\left(g\right), \Delta n_g = -2$

$\frac{K_p}{K_c} = \left(24.62dm^3 atm\, mol^{-1}\right)^{-2} = 1.65\times10^{-3} dm^{-6} atm^{-2} mol^2$

15. (C)

$K_p = K_c\left(RT\right)^{\Delta n_g} = K_c\left(RT\right)^{1-3/2} = K_c\left(RT\right)^{-1/2}$

$\Rightarrow K_c = K_p\left(RT\right)^{1/2}$

16. (D)

$N_2\left(g\right)+3H_2\left(g\right)\rightleftharpoons 2NH_3\left(g\right); K_c$

$2NH_3\left(g\right)\rightleftharpoons N_2\left(g\right)+3H_2\left(g\right); \frac{1}{K_c}$

$NH_3\left(g\right)\rightleftharpoons \frac{1}{2}N_2\left(g\right)+\frac{3}{2}H_2\left(g\right); \frac{1}{K_c^{1/2}}$

$\frac{1}{K_c^{1/2}} = \frac{1}{\left(64\right)^{1/2}} = \frac{1}{8}$

17. (B)

At equilibrium, rate of forward reaction= Rate of backward reaction.

18. (D)

$A\rightleftharpoons B+C; K_{eq}^{(1)}$ ....(i)

$B+C\rightleftharpoons P; K_{eq}^{(2)}$ ....(ii)

On adding equations(i) and (ii), we get

$A\rightleftharpoons P$

$K_{eq}\left(\text{overall}\right) = K_{eq}^{(1)}.K_{eq}^{(2)}$

19. (D)

Equilibrium constant

$$K_c = \frac{[B]}{[A]} = \frac{11}{6} \approx 2$$

20. (C)

$\Delta G^{\circ} = -RT\ln K, T_1 = 25\,^{\circ}C, K_1 = 10$

ΔG° at $T_1 = -8.314 \times 298 \times 2.303 \times \log 10 = -5.71\,kJ/mol$

ΔG° at $T_2 = -8.314 \times 373 \times 2.303 \times \log(100)$

$= -14.29\,kJ/mol$

$\Delta G^{\circ} = \Delta H^{\circ} - T\Delta S^{\circ} \Rightarrow -5.71 = \Delta H^{\circ} - 298(\Delta S^{\circ})$ and $-14.29 = \Delta H^{\circ} - 373(\Delta S^{\circ})$

$\Delta H^{\circ} = 28.4\,kJ/mol$

21. (A)

Reaction at equilibrium , $N_2O_4 \rightleftharpoons 2NO_2$. According to Le chatelier's principle.

(A) addition of an inert gas at constant pressure will increase volume or decrease moles per unit volume. Thus equilibrium shifts towards more number of moecules.

22. (C)

$2A(g) \rightleftharpoons 2B(g) + C(g)\ K_1$ ……………(i)

$\frac{3}{2}A(g) \rightleftharpoons \frac{3}{2}B(g) + \frac{3}{4}C(g)\ K_2$ …………..(ii)

eq. (ii) is $\frac{3}{4}$ times of equation (i), hence , $K_2 = (K_1)^{\frac{3}{4}}$

23. (A)

$PCl_5 = 5$ moles; Ar=4 mole

$$P_{Total} = \frac{9 \times 0.082 \times 610}{100} = 4.5\,atm$$

$$P_y = \underbrace{X_y}_{\text{mole fraction of y}} \overbrace{P_T}^{\text{Total pressure}}$$

$$X_{PCl_5} = \frac{5}{9}; X_{Ar} = \frac{4}{9}$$

$$P_{PCl_5} = \frac{5 \times 4.5}{9} = 2.5\,atm; P_{Ar} = \frac{4 \times 4.5}{9} = 2atm$$

$PCl_5 \rightleftharpoons PCl_3 + Cl_2$

$2.5 - P \qquad P \qquad P$

$P_{total} = 2.5 - P + P + P + P_{Ar} = 6atm$

$P = 1.5atm$

$$K_P = \frac{1.5 \times 1.5}{1} = 2.25$$

24. (B)

$$A(g) \rightleftharpoons B(g) + \frac{1}{2}C(g)$$

Initial $\quad n \quad\quad 0 \quad\quad 0$

At equilibrium: $n(1-\alpha) \quad n.\alpha \quad n\frac{\alpha}{2}$

$$(n_{tot}) = n\left(1-\alpha+\alpha+\frac{\alpha}{2}\right)$$

$$\therefore K = \frac{P_C{}^{\frac{1}{2}} \times P_B}{P_A} \Rightarrow K = \frac{\alpha^{\frac{3}{2}} p^{\frac{1}{2}}}{(2+\alpha)^{\frac{1}{2}}(1-\alpha)}$$

25. (6)

Moles of NH_4HS initially taken $= \frac{5.1g}{51g/mol} = 0.1mol$

Volume of vessel $= 2L$

$$NH_4HS(s) \rightleftharpoons NH_3(g) + H_2S(g)$$

Initial $\quad$ 0.1 mol $\quad\quad 0 \quad\quad 0$

At eq. m $\quad 0.1(1-0.2) \quad 0.1\times0.2 \quad 0.1\times0.2$

$\Rightarrow$Partial pressure of each component

$$P = \frac{nRT}{V} = \frac{0.1\times0.2\times0.082\times300}{2} = 0.246atm$$

$$\Rightarrow K_P = P_{NH_3} \times P_{H_2S} = (0.246)^2 = 0.060516$$

$$= 6.05\times10^{-2} \text{ or } 6\times10^{-2}$$

26. (182)

$$A + B \rightleftharpoons C + D : K_{eq} = 100$$

t=0 $\quad 1 \quad 1 \quad\quad 1 \quad 1$

$t = t_{eq} \quad (1-x) \quad (1-x)\,(1+x) \quad (1+x)$

$$K_{eq} = 100 = \frac{(1+x)(1+x)}{(1-x)(1-x)} \Rightarrow 100 = \left(\frac{1+x}{1-x}\right)^2$$

$$10 = \left(\frac{1+x}{1-x}\right) \Rightarrow x = \frac{9}{11}$$

$$[D] = 1 + \frac{9}{11} = \frac{20}{11}$$

$$= 1.8181 = 181.81\times10^{-2} \simeq 182\times10^{-2}$$

27. (0.02)

$$[PtCl_4]^{2-} + H_2O \underset{K_b}{\overset{K_f}{\rightleftharpoons}} [Pt(H_2O)Cl_3]^{-} + Cl^{-}$$

$$\frac{-d\left[[PtCl_4]^{2-}\right]}{dt} = K_f\left[[PtCl_4]^{2-}\right] - K_b\left[[Pt(H_2O)]^{-}\right][Cl]$$

Comparing this equation with the given one:

$$\Rightarrow K_{eq} = \frac{K_f}{K_b} = \frac{4.8\times10^{-5}}{2.4\times10^{-3}} = 0.02$$

28. (1400)

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g); K_c = 1.844$$

$t = 0$ 3moles 0 0

$t = \infty$ $(3-x)$ x x

$$\Rightarrow \frac{[PCl_3][Cl_2]}{[PCl_5]} = \frac{x^2}{3-x} = 1.844$$

$$\Rightarrow x^2 + 1.844x - 5.532 = 0$$

$$x = \frac{-b\pm\sqrt{D}}{2a} = \frac{-1.844+\sqrt{(1.844)^2+4\times5.532}}{2} \cong 1.604$$

$\Rightarrow$Moles of $PCl_5 = 3 - 1.604 \simeq 1.396 \simeq 1.4 \approx 1400\times10^{-3}$

29. (16)

$$K_P = \left(P_{O_2}\right)^{1/2}$$

$$4 = \left(P_{O_2}\right)^{1/2} \Rightarrow P_{O_2} = 16$$

30. (166)

$$2A(g) \rightleftharpoons A_2(g)$$

For homogenous gas phase reaction, $K_{th} = K_P$

$$\Delta G^\circ = -RT\ln K_p$$

$$\Rightarrow 25.2\times10^3 = -8.3\times400\times2.3\log K_p$$

$$\log K_p = \frac{-25.2\times10^3}{8.3\times400\times2.3} \Rightarrow \log K_p = -3.3$$

$$K_p = \text{antilog }(-3,3)$$

$$K_p = 10^{-3.3}; K_p = 10^{-3}.10^{-0.3}$$

$$K_p = 0.501\times10^{-3} = 5\times10^{-4} \because K_p = K_c(RT)^{-1}$$

$$\therefore K_c = 5\times10^{-4}\times8.3\times400 = 1.66 = 166\times10^{-2}$$

31. (72)

$$AB_2(g) \rightleftharpoons A(g) + 2B(g)$$

$t = 0$ 1 – –

$t = eq^m$ $1-\alpha$ α 2α

$\therefore$ No. of moles at equilibirum

$$= 1 + 2\alpha = \frac{PV}{RT} = \frac{1.9\times25}{0.082\times300} \approx 1.93$$

$$\therefore \alpha = 0.465$$

$$\therefore P_{AB_2} = \frac{1-\alpha}{1+2\alpha}\times P_T = \frac{1-0.465}{1+2\times 0.465}\times 1.9 \approx 0.53\,\text{atm}$$

$$P_A = \frac{\alpha}{1+2\alpha}\times P_T = \frac{0.465}{1.93}\times 1.9 \approx 0.46\,\text{atm}$$

$$P_B = \frac{2\alpha}{1+2\alpha}\times P_T = \frac{2\times 0.465}{1.93}\times 1.9 \approx 0.91\,\text{atm}$$

$$K_P = \frac{P_A.(P_B)^2}{P_{AB_2}} = \frac{0.46\times(0.91)^2}{0.53} \approx 0.72 \approx 72\times 10^{-2}$$

32. (2)

$$2NO + O_2 \rightleftharpoons 2NO$$

Initial:	2	1	–
Change:	$2-2x$	$1-x$	$2x$
Equilibrium:	1.2	0.6	0.8

$$K_P = \frac{\left(\frac{0.8}{2.6}\right)^2}{\left(\frac{1.2}{2.6}\right)^2\left(\frac{0.6}{2.6}\right)} = 1.925$$

33. (2)

$$Cu(s) + 2Ag^+(aq) \rightleftharpoons Cu^{2+}(aq) + 2Ag(s);\, 2\times 10^{15}$$

$$\frac{1}{2}Cu^{2+}(aq) + Ag^+(s) \rightleftharpoons \frac{1}{2}Cu(s) + Ag^+(aq);\, K$$

$$K = \frac{1}{\sqrt{2\times 10^{15}}} = 2.23\times 10^{-8}$$

34. (29)

moles of water $= \frac{0.90}{18}$

By ideal gas equation $PV = nRT$

$$V = \frac{nRT}{P} = \frac{0.90\times 0.82\times 300\times 760}{18\times 32} = 29.21 \approx 29$$

35. (125)

$$2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g)$$

$t=0$	2M	–	–
$t=t_{eq}$	$(2-x)M$	xM	$\frac{x}{2}M$

$\because x = 0.4M$

$\therefore [NOCl]_{eq} = 2.0 - 0.4 = 1.6M;\, [Cl_2]_{eq} = 0.2M$

$$\Rightarrow K_c = \frac{[NO]^2[Cl_2]}{[NOCl]^2} = \frac{[0.4]^2[0.2]}{[1.6]^2} = 125\times 10^4$$

36. (2735)

$$HI \rightleftharpoons \frac{1}{2}H_2 + \frac{1}{2}I_2$$

$t_i \quad 1$

$t_{eq} \quad 1-0.4 \quad \frac{0.4}{2} \quad \frac{0.4}{2}$

$$K_P = \frac{(0.2)^{\frac{1}{2}}(0.2)^{\frac{1}{2}}}{1-0.4} = \frac{0.2}{0.6} = \frac{1}{3}$$

$\Delta G = \Delta G^\circ + RT\ln K = 0 \qquad [\therefore \text{at Equilibrium } \Delta G = 0]$

$$\Delta G^\circ = -RT\ln K = -8.31 \times 300 \times 2.3 \times \log\left(\frac{1}{3}\right) = 2735\,J/mol$$

37. (747)

$$2O_3(g) \rightleftharpoons 3O_2(g)$$

$t = 0 \quad 2 \quad 0$

$t = eq. \quad 2-1=1 \quad 3/2$

Total moles at equilibrium $= 1 + 3/2 = 5/2$

Total pressure $= 1$ atm (given)

Partial pressure = moles fracrtion $\times$total pressure

$$P_{O_3} = \frac{1}{5/2} \times 1 = \frac{2}{5}; P_{O_2} = \frac{3/2}{5/2} \times 1 = \frac{3}{5}$$

$$K_P = \frac{(P_{O_2})^3}{(P_{O_3})^2} = \frac{(3/5)^3}{(2/5)^2} = 1.35$$

Free energy change,

$$\Delta G = -RT\ln K_P = -8.3 \times 300 \times \ln 1.35 = -747\,J\,mol^{-1}$$

38. (1107)

Given: 2 mole of N_2 gas was present as inert gas. Equilibrium pressure $= 2.46$atm

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

$t = 0 \quad 5 \quad 0 \quad 0$

$t = Eq^m \quad 5-x \quad x \quad x$

From ideal gas equation, $PV = nRT$

$$2.46 \times 200 = (5 - x + x + x + 2) \times 0.082 \times 600 \Rightarrow x = 3$$

$$K_P = \frac{\left(\frac{3}{10} \times 2.46\right)\left(\frac{3}{10} \times 2.46\right)}{\left(\frac{2}{10} \times 2.46\right)} = 1.107 = 1107 \times 10^{-3}$$

EXERCISE - 2 [A]

1. (B)

$$\begin{array}{lll} & N_2O_4 \rightleftharpoons & 2NO_2 \\ e & x & y \end{array}$$

$x + y = 3P_0$

$\frac{y^2}{x} = \frac{P_0}{2}$

Solving $x = 2P_0$

$y = P_0$

$$\begin{array}{lll} & N_2O_4 \rightleftharpoons & 2NO_2 \\ e & 2P_0 & P_0 \\ d & 4P_0 & 2P_0 \\ e' & 4P_0 - x & 2P_0 + 2x \end{array}$$

$\frac{\left(2P_0 + 2x\right)^2}{4P_0 - x} = \frac{P_0}{2}$

Solving $x = \frac{-17 + \sqrt{161}}{16} P_0$

$P_{tot} = 6P_0 + x = \frac{79 + \sqrt{161}}{16} P_0$

2. (B)

$$\begin{array}{llll} & PCl_5 \rightleftharpoons & PCl_3 & + \; Cl_2 \\ e & 1 & 2 & 3 \\ d & 1 & 2 & 5 \\ e & 1 + x & 2 - x & 5 - x \end{array}$$

$\frac{(5-x)(2-x)}{(1+x)} = 6$

$10 - 7x + x^2 = 6 + 6x$

$x^2 - 13x + 4 = 0$

Solving $x = \frac{13 - \sqrt{153}}{2}$

$X_{PCl_5} = \frac{1+x}{8-x+2} = \frac{1+x}{10-x} = \frac{15-\sqrt{153}}{7+\sqrt{153}}$

3. (C)

Consider uses of 0% and 100% dissolution. If the given value lies in between, answer is possible.

For C at 100% dissociation, molar mass will be 104.25 & at 0% dissociation, molar mass will be 208.5

4. (A)

$PCl_5 \longrightarrow PCl_5 + Cl$

$2(1-\alpha) \qquad 2\alpha \qquad 2\alpha \quad \dfrac{2\alpha}{2(1+\alpha)+1}=\dfrac{1}{7} \qquad\qquad K=\dfrac{\left(\frac{1}{2}\right)\left(\frac{1}{2}\right)}{\left(\frac{3}{2}\right)(150)}=\dfrac{1}{900}$

$14\alpha = 3+2\alpha$
$12\alpha = 3$
$\alpha = \dfrac{1}{4}$
$\therefore PCl_5 \longrightarrow PCl_3 + Cl$
$4(1-\alpha) \quad 4\alpha \quad 4\alpha$

$\dfrac{16\alpha_2^2}{4(1-\alpha)}=\dfrac{1}{900} \qquad\qquad \alpha_2=\dfrac{1}{60}$

Ans. 1.67 %

5. (B)

$$K_P=\left(\frac{0.6}{0.4}\right)^2=\frac{9}{4}=2.25$$

6. (B)

$NH_4I_{(s)} \rightleftharpoons NH_{3(g)} + HI_{(g)}$
$\qquad\qquad\qquad 2p_0 \qquad 2p_0$
$K_p = 4p_0^2$
$NH_4I_{(s)} \rightleftharpoons NH_{3(g)} + HI_{(g)}$
$\qquad\qquad\qquad 2p_0+x \quad 2p_0+x-2y$
$2HI \rightleftharpoons H_2 + I_2$
$2p_0+x-2y \qquad y \qquad y$
$5p_0 = 2p_0+x+2p_0+x-2y+y+y$
$x=\dfrac{p_0}{2}$
$K_p = 4p_0^2 = \left(\dfrac{5p_0}{2}\right)\left(\dfrac{5p_0}{2}-2y\right)$
$y=\dfrac{9p_0}{20}$

For reaction 2 $K_P=\dfrac{\frac{9p_0}{20}\times\frac{9p_0}{20}}{\left(\frac{8p_0}{5}\right)^2}=\dfrac{81}{1024}$

7. (B)

$K_p=\left(p_{NH_3}\right)^2\left(P_{CO_2}\right)$
$\left(P_{CO_2}\right)=p$

$P_{NH_3} = 2P$

$4p^3 = 2.9 \times 10^{-5}$

$P^3 = \frac{29}{4} \times 10^{-6}$

$P = \sqrt[3]{7.25} \times 10^{-2} = 0.0194 \text{atm}$

Total pressure $= 3P$

$= 0.0582 \text{atm}$

8. (A)

$$NH_4HS_{(s)} \rightleftharpoons NH_{3(s)} + H_2S_{(s)}$$

2 1.5

$K_p = 3 \text{atm}^2$

In V_2

$P_{NH_2} = \sqrt{3}$ atm

$P_{H_2S} = \sqrt{3} \text{atm}$

Total pressure, $P :_0 = 2\sqrt{3}$ atm

$\frac{W_{NH_3}}{W_{H_2S}} = \frac{2 \times 17}{1.5 \times 34} = \frac{2}{3}$

9. (C)

$$NH_2CPPNH_4(s) \rightleftharpoons 2NH_3(g) + CO_2(g)$$

e $\frac{2P_0}{3}$ $\frac{P_0}{3}$

d $\frac{4P_0}{3}$ $\frac{2P_0}{3}$

e' $\frac{4P_0}{3} - 2x$ $\frac{2P_0}{3} - x$

$$\left(\frac{2P_0}{3}\right)^2 \left(\frac{P_0}{3}\right) = \left(\frac{4P_0}{3} - 2x\right)^2 \left(\frac{2P_0}{3} - x\right)$$

$\Rightarrow \frac{2P_0}{3} - x = \frac{P_0}{3}$

So at new equilibrium $P_{tot} = P_0$

$K_P = \left(\frac{2P_0}{3}\right)^2 \left(\frac{P_0}{3}\right) = \frac{4P_0^3}{27}$

$K_C = \frac{4P_0^3}{27(RT)^3}$

10. (C)

$$PCl_5 \rightleftharpoons PCl_3 + Cl_2$$

i $3x$

e $3x - x$ x $x - y$

$$CO + Cl_2 \rightleftharpoons COCl_2$$

i $4y$

e $4y - y$ $x - y$ y

$$K_C(I) = \frac{x(x-y)}{2x \times V} = \frac{x-y}{2V}$$

$$[PCl_5] + [CO] = \frac{2x+3y}{V}$$

11. (C)

Endothermic so high T will favor
Decrease in volume so high P will favor

12. (C)

$$2A + B \rightleftharpoons C + 3D$$

	2A	B	C	3D
i	1.5	2.5	0.5	0
e	0.5	2	1	1.5

$$K = \frac{1 \times (1.5)^3}{(0.5)^2 \times 2} = 6.75\,M$$

13. (B)

$$COCl_2 \rightleftharpoons CO + Cl_2$$

	$COCl_2$	CO	Cl_2
i	0.2	0	0
e	0.1	0.1	0.1
d	0.05	0.05 + C	0.05
e'	0.0625	0.0375 + C	0.0375

$$\frac{0.1 \times 0.1}{0.1} = \frac{(0.0375)(0.0375 + C)}{0.0625}$$

$C = 0.129$

$x = 40C = 5.167$

14. (B)

At $t = t_0$ $\quad \frac{W_{CO_2}}{W_{H_2O}} = \frac{W/44}{W/18} = \frac{9}{22}$

So, At $t = t_0$ equilibrium was established.

$$K = \frac{\frac{W}{44} \times \frac{W}{2}}{\frac{W}{18} \times \frac{W}{28}} = \frac{63}{11}$$

$$\frac{n_{H_2}}{n_{CO}} = \frac{W/2}{W/28} = \frac{14}{1}$$

EXERCISE - 2 [B]

One or More Than One Option Correct

1. (A, B, C, D)
Since, reaction is exothermic increasing temperature will favor backward reaction.
Since, $\Delta n_g < 0$, so decreasing pressure will favor backward reaction.
Since, H_2 is reactant removing H_2 will favor backward reaction.
Since, C_2H_6 is product adding C_2H_6 will favor backward reaction.

2. (C, D)
$NaNO_3 \,\&\, NaNO_2$ both are solid, so adding them will not disturb the reaction.

3. (C)
No change in the position of equilibrium an addition of He at constant volume

4. (C, D)
(A) Adding inert at constant volume is not a disturbance
(B) Adding Cl_2 will favor backward reaction
(C) Adding inert at constant pressure will increase volume and forward reaction will be favored.
(D) Increasing volume will favor forward reaction

5. (D)
On addition of reactant reaction will go in forward direction
Since Δn_g is zero, adding inert or changing the volume will not effect equilibrium amount.

6. (A, B, C)
Chemical equilibrium is example of dynamic equation

7. (C, D)

$$AB_{(g)} \rightleftharpoons AB_{(g)} + B_{(g)}$$

$$K_P = \frac{\alpha^2}{1-\alpha^2} \times P$$

So, $\alpha^2 \propto \frac{1}{P}$

8. (A, C)
On increasing pressure reaction will shift forwards if $\Delta n_g < 0$.

9. (C, D)
(A) Addition of O_2 (→), decreasing volume (→)
(B) Addition of CO (→), removal of CO_2 (→)
(C) Increasing temperature (←), decreasing volume (→)
(D) Addition of CO (→), increasing temperature (←)

10. (C, D)
(A) introducing an inert gas at constant volume (no disturbance)
(B) introducing chlorine gas at constant volume (←)
(C) introducing and inert gas at constant pressure (→)
(D) increasing the volume of the container (→)

Comprehension Type

Passage [A] :

1. (C)

$$K_{eq}=\frac{k_f}{k_b}=10$$

$$\frac{\left(P_{H_2}\right)^4}{\left(P_{H_2O}\right)^4}=10$$

$$\left(P_{H_2O}\right)=\left(P_{H_2}\right)(10)^{-1/4}$$

$$\left(P_{H_2O}\right)=\left(P_{H_2}\right)\times10^{-0.25}$$

2. (A)

$$\Delta G^\circ=-2.303\log K$$
$$=-2.303\times8.314\times400\times\log10$$
$$=-7657\,J/k$$

3. (C)

As Δn_g is zero

4. (D)

K_c is independence of volume

5. (B)

As given reaction is exothermic

Passage [B] :

$$\log k_p=\frac{\Delta S^\circ}{2.303R}-\frac{\Delta H^\circ}{2.303R}\left(\frac{1}{T}\right)$$

1. (B)

As slope $=-\dfrac{\Delta H^\circ}{2.303R}$

For line (2) ΔH° is positive

2. (B)

For exothermic reaction K_p decreases with increase in temperature

3. (C)

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

Passage [C] :

$$SrCl_2.6H_2O_{(s)}\rightleftharpoons SrCl_2 2H_2O_{(s)}+4H_2O_{(g)}$$

$$k_p=1.6\times10^{-11}$$

$$\left(P_{H_2O}\right)_I=2\times10^{-3}atm$$

$$Na_2HPO_4.12H_2O_{(s)}\rightleftharpoons Na_2HPO_4.7H_2O_{(s)}+5H_2O_{(g)}\ \ K_p=2.43\times10^{-13}$$

$$\left(P_{H_2O}\right)_{II} = 3\times10^{-3}\text{atm}$$

$$Na_2SO_4.10H_2O_{(s)} \rightleftharpoons Na_2SO_{4(s)} + 10H_2O, K_p = 1\times10^{-20}$$

$$\left(P_{H_2O}\right)_{III} = 1\times10^{-2}\text{atm}$$

1. (A)

$P_{III} > P_{II} > P_I$

2. (C)

Most effective drying agent $SrCl_2 2H_2O$ because P_I is least.

3. (A)

For efflorescent, Relative humidity $< \frac{10^{-2}}{\frac{15.2}{760}} \times 100 = 50\%$

4. (A)

For deliquescent, Relative humidity $> \frac{10^{-2}}{\frac{15.2}{760}} \times 100 = 50\%$

5. (D)

Molar ratio is same as partial pressure

Passage [D] :

$$K_c = \frac{\left(\frac{n_c}{v}\right)^c\left(\frac{n_d}{v}\right)^d}{\left(\frac{n_A}{v}\right)^a\left(\frac{n_B}{v}\right)^b},\ K_p = \frac{\left(\frac{n_cRT}{v}\right)^c\left(\frac{n_DRT}{v}\right)^d}{\left(\frac{n_ART}{v}\right)^a\left(\frac{n_BRT}{v}\right)^b} = K_c\left(RT\right)^{\Delta n_g}$$

$$K_x = \frac{\left(n_c\right)^c\left(n_D\right)^d}{\left(n_A\right)^a\left(n_B\right)^b}\times\left(\sum n\right)^{a+b-c-d}$$

1. (B)

$$K_c = \frac{\left(\frac{n_c}{v}\right)^c\left(\frac{n_d}{v}\right)^d}{\left(\frac{n_A}{v}\right)^a\left(\frac{n_B}{v}\right)^b},\ K_p = \frac{\left(\frac{n_cRT}{v}\right)^c\left(\frac{n_DRT}{v}\right)^d}{\left(\frac{n_ART}{v}\right)^a\left(\frac{n_BRT}{v}\right)^b} = K_c\left(RT\right)^{\Delta n_g}$$

$$K_x = \frac{\left(n_c\right)^c\left(n_D\right)^d}{\left(n_A\right)^a\left(n_B\right)^b}\times\left(\sum n\right)^{a+b-c-d}$$

$$K_p = K_c\left(RT\right)^{\Delta ng} = K_x\left(p\right)^{\Delta ng}$$

2. (C)

$\Delta ng = 1$

$K_p = K_x\left(p\right)$

If $p > 1\,\text{atm}, K_p > K_x$

3. (C)

$\Delta n_g = -1$

$$K_c = K_x \left(\frac{p}{RT}\right)^{-1}$$

$$K_c = K_x \left(\frac{RT}{p}\right)$$

Passage [E] :

$$\ell nk = 2 - \frac{1000}{T} = \frac{\Delta S^\circ}{R} - \frac{\Delta H^\circ}{R}\left(\frac{1}{T}\right)$$

1. (A)

$$\ell nk = 2 - \frac{1000}{T} = \frac{\Delta S^\circ}{R} - \frac{\Delta H^\circ}{R}\left(\frac{1}{T}\right)$$

$\Delta S^\circ = 2R$

2. (B)

For exothermic As $T\uparrow$ $K\downarrow$

For endothermic As $T\uparrow K\uparrow$

3. (B)

$$\log k_{eq} = \frac{\Delta S^\circ}{2.303R} - \frac{\Delta H^\circ}{2.303R}\left(\frac{1}{T}\right)$$

$$\text{Slope } = -\frac{\Delta H^\circ}{2.303R} = 1$$

$\Delta H^\circ = -2.303R$

$= -2.303 \times 8.314$

$= -19.147$

4. (A)

$$\log\left(\frac{4}{T}\right) = \frac{\Delta H^\circ}{2.303R}\left(\frac{1}{300} - \frac{1}{320}\right)$$

$\Delta H^\circ = 13.31 \text{kcal / mole}$

For reverse reaction $\Delta H^\circ = -13.31 \text{kcal / mole}$

Matching Type

1. (A) – P; (B) – R; (C) – Q; (D) – S

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

If $\Delta n_g > 0$ so, $\frac{K_p}{K_c} > 1$

$\Delta n_g < 0, \frac{K_p}{K_c} < 1$

2. (A) – R; (B) – Q; (C) – P; (D) – S

Unit of $k_p = (atm)^{\Delta ng}$

3. (A) – P; (B) – S; (C) – Q; (D) – R

$$\begin{array}{lllll}
\text{(A)} & 2X & \rightleftharpoons & Y & + \quad Z \\
\text{i} & 1 & & 0 & \quad\;\; 0 \\
\text{e} & (1-\alpha) & & \frac{\alpha}{2} & \quad\;\; \frac{\alpha}{2}
\end{array}$$

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

$$\alpha = 2 \times \sqrt{K_C}$$

$$\begin{array}{lllll}
\text{(B)} & X & \rightleftharpoons & Y & + \quad Z \\
\text{i} & 1 & & 0 & \quad\;\; 0 \\
\text{e} & (1-\alpha) & & \alpha & \quad\;\; \alpha
\end{array}$$

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

$$\alpha = \sqrt{K_C}$$

$$\begin{array}{lllll}
\text{(C)} & 3X & \rightleftharpoons & Y & + \quad Z \\
\text{i} & 1 & & 0 & \quad\;\; 0 \\
\text{e} & (1-\alpha) & & \frac{\alpha}{3} & \quad\;\; \frac{\alpha}{3}
\end{array}$$

$$K_C = \frac{\left(\frac{\alpha}{3}\right)^2\left(1-\frac{\alpha}{3}\right)}{(1-\alpha)^3} = \frac{\alpha^2}{9}$$

$$\alpha = 3 \times \sqrt{K_C}$$

$$\begin{array}{lllll}
\text{(D)} & 2X & \rightleftharpoons & Y & + \quad 2Z \\
\text{i} & 1 & & 0 & \quad\;\; 0 \\
\text{e} & (1-\alpha) & & \frac{\alpha}{2} & \quad\;\; \alpha
\end{array}$$

$$K_C = \frac{\left(\frac{\alpha}{2}\right) \times \alpha^2}{(1-\alpha)^2\left(1+\frac{\alpha}{2}\right)} = \frac{\alpha^3}{2}$$

$$\alpha = (2K_c)^{1/3}$$

4. (A) – P; (B) – R; (C) – S; (D) – Q

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

5. (A) – R; (B) – Q; (C) – P; (D) – S

(A) $\Delta n_g = 0$, so increasing pressure will not effect equilibrium

(B) $\Delta n_g > 0$, so increasing pressure shift reaction in backward direction

(C) $\Delta n_g < 0$, so increasing pressure shift reaction in forward direction & reaction in endothermic so increasing temperature shift the reaction in forward direction

(D) $\Delta n_g < 0$, so decreasing pressure shift reaction in backward direction & reaction in endothermic so increasing temperature shift the reaction in forward direction

EXERCISE - 2 [C]

1. $4NO + 6H_2O \rightleftharpoons 4NH_3 + 5O_2$

2. For forward direction :
$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$
$$K_c = \frac{[SO_3]^2}{[SO_2]^2[O_2]} = \frac{(5.0\times10^{-2})^2}{(3.0\times10^{-3})^2\,(3.5\times10^{-3})}$$
$\mathbf{= 7.936 \times 10^4\ M^{-1}}$
and for backward (reverse) direction :
$2SO_3(g) \rightarrow 2SO_2(g) + O_2(g)$
$$K'_c = \frac{[SO_2]^2[O_2]}{[SO_3]^2} = \frac{1}{K_c} \mathbf{= 12.6 \times 10^{-6}\ M}$$

3. Let equilibrium moles of $SO_2 = SO_3 = x$ and that of $O_2 = y$
$$\therefore\ [SO_2] = [SO_3] = \frac{x}{5}\ \text{mol L}^{-1}$$
$$[O_2] = \frac{y}{5}\ \text{mol L}^{-1}$$
$$K_c = \frac{[SO_3]^2}{[SO_2]^2\,[O_2]} = \frac{\left(\frac{x}{5}\right)^2}{\left(\frac{x}{5}\right)^2\left(\frac{y}{5}\right)} = 5 \qquad \text{(given)}$$
$\therefore \quad y = 1$
Hence, O_2 at equilibrium = 1 mol

4. For the reaction, $\Delta n = (2 + 1) - 2 = 1$
$K_p = K_c(RT)^{\Delta n}$
$= 3.75 \times 10^{-6}\,(0.0821 \times 1069)$
$= 3.3 \times 10^{-4}$

5. We first calculate value of K_p
$K_p = \frac{p_{CO_2}\cdot p_{H_2}}{p_{CO}\,p_{H_2O}} = \frac{0.2\times0.1}{2\times0.01} = 1$ $\quad \Delta n_g = (1+1) - (1+1) = 0$ $\quad$ hence, $K_p = K_c = 1$

6. $H_2 + \frac{1}{2}O_2 \rightleftharpoons H_2O \qquad \frac{1}{\sqrt{K_1}}$
$CO_2 \rightleftharpoons CO + \frac{1}{2}O_2 \qquad \sqrt{K_2}$

$H_2 + CO_2 \rightleftharpoons CO + H_2O \qquad \sqrt{\frac{K_2}{K_1}} = \sqrt{\frac{1.4\times10^{-12}}{2.1\times10^{-13}}} = 2.58$

7. $S + S^{2-} \rightleftharpoons S_2^{2-} \qquad K_1 = 12$
$2S + S^{2-} \rightleftharpoons S_3^{\,2-} \qquad K_2 = 130$

So $S+S_2^{2-} \rightleftharpoons S_3^{2-} \qquad K=\frac{K_2}{K_1}=\frac{130}{12}=10.83$

8. $k_f=2.6\times10^3,\ k_b=4.1$

$$\text{So } k=\frac{k_f}{k_b}=\frac{2600}{4.1}=634.15$$

9. $P_{NH_3}=2.8-0.4-0.8=1.6$

$$k_p=\frac{(1.6)^2}{0.8\times(0.4)^3}=50$$

10.

$$\begin{array}{llll} & N_2 & +3H_2 \rightleftharpoons & 2NH_3 \\ i & 1 & 3 & 0 \\ e & \frac{399}{400} & \frac{3\times399}{400} & \frac{2}{400} \end{array}$$

$$K_C=\frac{\left(\frac{2}{1600}\right)^2}{\left(\frac{399}{1600}\right)\left(\frac{3\times399}{1600}\right)^3}$$

$$=\frac{2^2\times1600^2}{3^3\times399^4}=1.5\times10^{-5}$$

For $\frac{1}{2}N_2+\frac{3}{2}H_2 \rightleftharpoons NH_3$

$$K=\sqrt{K_C}=3.87\times10^{-3}$$

11.

$$\begin{array}{llll} & CO & +2H_2 \rightleftharpoons & CH_3OH \\ I & 0.2 & x & 0 \\ e & 0.1 & x-0.2 & 0.1 \end{array}$$

$$n_H=x=\frac{4.92\times5}{0.082\times600}=0.5$$

$$K_C=\frac{\frac{0.1}{5}}{\frac{0.1}{5}\times\left(\frac{0.3}{5}\right)^2}=277.78$$

12. Reaction quotient, Q_c for the reaction will be written as

$$Q_c=\frac{[NH_3(g)]^2}{[N_2(g)][H_2(g)]^3}=\frac{(2.0\times10^{-3})^2}{(1.0\times10^{-3})(3.0\times10^{-3})^3}$$

$$=\frac{4.0\times10^{-6}}{27.0\times10^{-12}}=0.149\times10^6\cong1.5\times10^5$$

Since $Q_c > K_c$, reaction will go in the left direction and ammonia will decompose into hydrogen and nitrogen.

13. The equilibrium constant for the reaction

$CO(g) + 3H_2(g) \rightleftharpoons CH_4(g) + H_2O(g)$ is written as $K_c = \frac{[CH_4][H_2O]}{[CO][H_2]^3}$

Now substituting the values of known concentration and K_c.

$$3.90 = \frac{[CH_4](0.020)}{(0.30)(0.10)^3} \text{ or } \frac{[CH_4]}{c_o} = \frac{(3.90)(0.30)(0.10)^3}{(0.020)} = 0.059$$

(c_o = 1 M is the standard state) and therefore, $[CH_4]$ = 0.059 M

14. For the reaction

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

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

The initial molar concentration of

$$PCl_5 = \frac{1.50 \text{ mol}}{0.500 \text{ L}} = 3.00 \text{ mol L}^{-1}$$

Suppose change in molar concentration of PCl_5 is (-x) mol L^{-1}

Then,

	PCl_5	PCl_3	Cl_2
Initial molar concentration	3.00	0	0
Change in molar concentration	- x	+x	+x
Equilibrium molar concentration	(3.00 – x)	x	x

Now substituting the value of equilibrium concentrations in the expression for equilibrium constant, we get

$$K_c = \frac{[PCl_3][Cl_2]}{[PCl_5]} = \frac{x \times x}{(3.00 - x)} \text{ or } x^2 + 1.80x - 5.40 = 0$$

Therefore,

$$x = \frac{-1.80 \pm \sqrt{(1.80)^2 - 4(1)(-5.40)}}{2} = 1.59 \text{ and } -3.39$$

Since concentration must be positive, therefore, 1.59 mol L^{-1} is selected as appropriate solution.
Therefore, equilibrium concentration of $[PCl_5]$ = (3.00 – 1.59) mol L^{-1} = 1.41 mol L^{-1} and
$[PCl_3]$ = 1.59 mol L^{-1}, $[Cl_2]$ = 1.59 mol L^{-1}

15.

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

Initial 1 1 1
Change: –x + x + x
At equil : (1 – x) (1 + x) (1 – x)

$$[Cl_2] = \frac{(1 - x)\text{mol}}{1L} = 1 + x = 1.5M$$

∴ x = 0.5

∴ $[PCl_5] = \frac{1 - x}{1}$ = 0.5 M

$[Cl_2]$ = 1.5 M

$[PCl_3]$ = 1.5 M

∴ $K_c = \frac{[PCl_3][Cl_2]}{[PCl_5]}$ = 4.5 M

16. Since K for reaction of mg is higher, it will remove Cu^{2+} to a greater extent.

17.

$$2A + 2B \rightleftharpoons 3C + D$$

$$\begin{array}{lllll} i & 2x & x & 0 & 0 \\ e & 2x-2y & x-2y & 3y & y \end{array}$$

$3y=\left(x-2y\right)\times 3 \Rightarrow x=3y$

$K=\left(x-2y\right)\times 3 \Rightarrow x=3y$

18. $$\theta_C=\frac{\left(\frac{8}{10}\right)^2}{\left(\frac{1}{10}\right)^2\times\frac{2}{10}}=\frac{64\times10}{2}=320>K_C$$

So backward

19. $$\theta_C=\frac{\left(\frac{0.5}{50}\right)^2}{\left(\frac{1}{50}\right)\left(\frac{3}{50}\right)^3}=\frac{50^2\times0.5^2}{3^3}=2.3.1>K$$

$\Rightarrow$ So backward

20.

$$\begin{array}{llll} & I_2 \rightleftharpoons & 2I & 0.074+P=0.112 \\ i & 0.074 & 0 & \Rightarrow P=0.038 \\ e & 0.074-P & 2P & K_P=\frac{\left(0.076\right)^2}{0.036}=0.16 \end{array}$$

21. $$\theta=\frac{0.4\times\left(0.2\right)^{\frac{1}{2}}}{0.5}=0.36>K$$

$\Rightarrow$ So backward

22. K remain same

$\left(\frac{0.6}{0.1}\right)^2=\left(\frac{1.24-2x}{0.1+x}\right)^2$

$7.4=\frac{1.24-2x}{0.1+x}$

$x=\frac{0.5}{9.4}=0.053$

$\left[HI\right]=0.1134$

23.

$$\begin{array}{llll} & PCl_5 \rightleftharpoons & PCl_3+ & Cl_2 \\ i & C & 0 & 0 \\ e & C-0.15 & 0.15 & 0.15 \end{array}$$

$0.04=\frac{0.15\times0.15}{C-0.15}$

$C=0.7125$

Moles $=0.7125\times3=2.1375$

24.

$$\begin{array}{llll} & 2NO \quad + & Cl_2 \rightleftharpoons & 2NOCl \\ i & 0.373 & 0.31 & 0 \\ e & 0.373-2P & 0.31-P & 2P \end{array}$$

$$0.683-P=0.544$$

$$P=0.139$$

$$K_P=\frac{(0.278)^2}{(0.095)^2(0.171)}=50.08$$

25. $PCl_5 \rightleftharpoons PCl_3+Cl_2$

$$K_P=\frac{\alpha^2}{1-\alpha^2}P$$

$$\frac{1-\alpha^2}{\alpha^2}=\frac{P}{K_P}$$

$$\frac{1}{\alpha^2}-1=\frac{P}{K_b}$$

$$\frac{1}{\alpha^2}=\frac{P+K_P}{K_P}$$

$$\alpha=\sqrt{\frac{K_P}{P+K_P}}$$

26. $AB(g) \rightleftharpoons A(g)+B(g)$

$$K_P=\frac{\alpha^2}{1-\alpha^2}P$$

$$K_P=\frac{\left(\frac{1}{2}\right)^2}{1-\left(\frac{1}{2}\right)^2}P=\frac{\frac{1}{4}}{\frac{3}{4}}P=\frac{1}{3}P$$

$$\Rightarrow P=2K_P$$

27.

$$\begin{array}{llll} & PCl_3 & +Cl_2 \rightleftharpoons & PCl_5 \\ i & n & n & 0 \\ e & n-y & n-y & y \end{array}$$

$$K_P=\frac{\frac{y}{2n-y}P}{\frac{n-y}{2n-y}P\times\frac{n-y}{2n-y}P}$$

$$K_P=\frac{y(2n-y)}{(n-y)^2}\times\frac{1}{P}$$

28.

$$\begin{array}{llllll} & 4HNO_3 \rightleftharpoons & 2NO_2 & +2H_2O & +O_2 \\ i & P_0 & 0 & 0 & 0 \\ e & P_0-4P' & 4P' & 2P' & P' \end{array}$$

$$P_0 + 3P' = P$$
$$P_0 = P - 3P'$$
$$K_P = \frac{(4P')^4 (2P')^2 (P')}{(P - 7p')^4}$$

29. K_P remains same

$$\frac{\left(\frac{1}{10}\right)^2}{1 - \left(\frac{1}{10}\right)^2} \times 1 = \frac{\alpha^2}{1-\alpha^2} \times 4$$
$$\frac{1}{99} = \frac{\alpha^2}{1-\alpha^2} \times 4$$
$$\frac{\alpha^2}{1-\alpha^2} = \frac{1}{396}$$
$$\alpha = \frac{1}{\sqrt{397}} = 0.05 = 5\%$$

30.

$$PCl_5 \rightleftharpoons PCl_3 + Cl_2$$

i $\quad 2 \qquad 1 \quad 2$

e $\quad 1.2 \qquad 1.8 \quad 2.8$

$$K_C = \frac{\frac{1.8}{5} \times \frac{2.8}{5}}{\frac{1.2}{5}} = \frac{1.8 \times 2.8}{6} = 0.84$$

31.

$$NH_4HS(s) \rightleftharpoons NH_3 + H_2S$$

i $\quad 0.5 \quad 0$

e $\quad 0.5 + P \quad P$

$$P(0.5 + P) = 0.11$$

$P = 0.165$ $\qquad P_{H_2S} = 0.165$

P_{vol} =0.83 $\qquad P_{NH_3} = 0.665$

32. $NH_4HS(S) \rightleftharpoons NH_3 + H_2S$

e $\quad P \quad P$

$$2P = 1.12 \Rightarrow P = 0.56$$
$$K_P = (0.56)^2 = 0.3136$$
$$5 = \frac{[CO_2]}{2.5 \times 10^{-2}} \Rightarrow [CO_2] = 1.25 \times 10^{-1}$$

34. $n_{vol} = \frac{2.05 \times 100}{0.0621 \times 500} = 5$

$$PCl_5 \rightleftharpoons PCl_3 + Cl_2$$

$1 \quad 3 \quad 0 \quad 1$

$e \quad 3(1-\alpha) \quad 3\alpha \quad 1+3\alpha$

$$5 = 4 + 3\alpha \qquad \Rightarrow \qquad \alpha = \frac{1}{3}$$

35.

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

$$= \frac{4\times\frac{1}{16}}{\frac{15}{16}}\times 1 = \frac{4}{15}$$

(ii) $$\frac{4}{15} = \frac{4\alpha^2}{1-\alpha^2}\times 0.1$$

$$\frac{\alpha^2}{1-\alpha^2} = \frac{10}{15} = \frac{2}{3}$$

$$3\alpha^2 = 2 - 2\alpha^2$$

$$\alpha = \sqrt{\frac{2}{5}} = 0.6325$$

36.

$$2SO_2 \quad + \quad O_2 \quad \rightleftharpoons \quad 2SO_3$$

$i \quad 0 \quad 2 \quad 1$

$e \quad 2x \quad 2+x \quad 1-2x$

$$900 = \frac{1}{8\times 900} \Rightarrow x = 0.0118$$

$$P_{SO_2} = 0.0236$$

$$P_{O_2} = 2.0118$$

$$P_{SO_3} = 0.9764$$

37. n_{OH} at equation $= \dfrac{8.5\times 2.5}{0.082\times 750}$

$$= 0.345$$

$$CO + 2H_2 \rightleftharpoons CH_3OH$$

i. $\quad 0.15 \quad x \quad 0$

e. $\quad 0.07 \quad x-0.16 \quad 0.08$

$$x - 0.01 = 0.345 \Rightarrow x = 0.355$$

(i) $$K_C = \frac{\frac{0.08}{2.5}}{\frac{0.07}{2.5}\times\frac{0.195}{2.5}} = 14.65$$

(ii) $$P = \frac{(0.355+0.15)\times 0.0821\times 750}{2.5}$$

$$= 12.438\,\text{atm}$$

38. Species in the solid state are not be considered.

Equilibria	Δn_g	Direction		
		$P\downarrow$	Moles of	
			reactant	product
(A)	- 1	←	↑	↓
(B)	+ 1	→	↓	↑
(C)	- 1	←	↑	↓
(D)	0	No effect	No effect	

In all of the above cases, you can also predict direction by using equation $x \propto \left(\frac{1}{P}\right)^{\Delta n_g/2}$

(A) $x \propto \sqrt{P}$, decrease in P, decreases x

(B) $x \propto \sqrt{\frac{1}{P}}$, decrease in P, increases x

(C) $x \propto \sqrt{P}$, as in (A)

(D) $x \propto P^{\circ}$, no effect

39. $\Delta H^{\circ} = -41.2$ kJ; it is an exothermic reaction with heat lost to the surrounding

$$\underset{\text{less heat}}{\text{Reactant}} - q \rightleftharpoons \underset{\text{more heat}}{\text{products}}$$

If temperature is increased, equilibrium displaces towards the direction of less heat to minimize the stress. This is backward direction, hence amount of H_2 decreases. If temperature is decreased reaction displaces towards forward side, hence K_p increases.

40.

$$2SO_3 \rightleftharpoons 2SO_2 + O_2$$

c 5 0.5 0.12
e' 5.2 0.3 0.12

$$\frac{(0.5)^2 \times 0.12}{5^2} = \frac{(0.3)^2 (0.02 + x)}{(5.2)^2}$$

$$x = 0.34$$

41.

$$SO_2 + NO_2 \rightleftharpoons SO_3 + NO$$

e 0.6 0.2 0.8 0.3
e' 0.4 x 1 0.5

$$\frac{0.8 \times 0.3}{0.6 \times 0.2} = \frac{1 \times 0.5}{x \times 0.4}$$

$$x = 0.625$$

42.

$$H_2 + I_2 \rightleftharpoons 2HI$$

e 3 2 2
e' $3 - \frac{x}{10}$ $2 + \frac{9x}{10}$ $2 + \frac{2x}{10}$

$$\frac{2^2}{3 \times 2} = \frac{\left(2 + \left(\frac{2x}{10}\right)\right)^2}{\left(3 - \frac{x}{10}\right)\left(2 + \frac{9x}{10}\right)}$$

$x = 8.7$

43. We know $\Delta G° = \Delta H° - T\,\Delta S°$

$= -29.8 - 298 \times 0.1 = 0$

Since $\Delta G° = -2.303\, RT \log K$

Hence $\log K = 0$ which gives $K = 1$

44. (A) Above equation represent a straight line of

$$\text{Slope} = -\frac{\Delta H°}{2.303R} = -\tan\theta = -0.5$$

$\therefore \quad \Delta H° = 2.303 \times 8.314 \times 0.5 = 9.574 \text{ J mol}^{-1}$

(B) Also intercept, $\log A = OP = 10$

$\therefore \quad A = 10^{10}$

(C) $$\log K = \log A - \frac{\Delta H°}{2.303RT}$$

$$= 10 - \frac{9.574}{2.303 \times 8.314 \times 298}$$

$$= 10 - 1.68 \times 10^{-3}$$

$$K = 9.96 \times 10^{9}$$

(D) Putting values calculated in (A) and (C) into equation

$$\Delta H° = \frac{2.303\, RT_1T_2}{(T_2 - T_1)} \log \frac{K_2}{K_1}$$

We have

$$9.574 = \frac{2.303 \times 8.314 \times 298 \times 798}{(798 - 298)} \log \frac{K_2}{(9.96 \times 10^{9})}$$

$\therefore \quad K_2$ (Equilibrium constant at 798 K) $= 9.98 \times 10^{9}$

45.

$$\begin{array}{llll} & N_2 & +3H_2 \rightleftharpoons & 2NH_3 \\ e & 0.38 & 0.4 & 2 \\ e' & 0.45 & p & 1.86 \end{array}$$

$$\frac{2^2}{0.38 \times (0.4)^3} = \frac{1.86^2}{0.45 \times p^3}$$

$P = 0.36$

46.

$$\begin{array}{llll} & A \rightleftharpoons & B \quad + & C \\ c & 4.6 & 2.3 & 2.3 \\ d & 2.6 & 2.3 & 2.3 \\ e' & 2.6 + n & 2.3 - x & 2.3 - x \end{array}$$

$$\frac{2.3 \times 2.3}{4.6} = \frac{(2.3 - x)^2}{2.6 - x}$$

$x = 0.44$

$[A] = 3.04$

$[B] = [C] = 1.86$

Level-2

1.

$$\begin{array}{lcccc} & CO_2 + & H_2 \rightleftharpoons & H_2O + & CO \\ e & 0.24 & 0.24 & 0.48 & 0.48 \end{array}$$

(A) $\dfrac{0.6\times0.6}{0.12\times\left(0.12+x\right)}=4$

$x=0.63$

Moles $=0.62\times2=1.26$

(B) $\dfrac{0.6\times0.6}{0.12\times\left(0.12+x\right)}=4$

$x=0.63$

Moles of $CO_2=0.63\times2=1.26$

(C) $\dfrac{0.6\times\left(0.6-x\right)}{0.12\times0.12}=4$

$x=0.504$

$\text{moles}=0.504\times2=1.008$

2.

$$\begin{array}{lccc} & 2H_2O \rightleftharpoons & 2H_2 & + \; O_2 \\ i & n & n & n \\ e & n-y & n+y & n+\frac{y}{2} \end{array}$$

$$K_p=\frac{\left(\dfrac{\left(n+\frac{y}{2}\right)}{3n+\frac{y}{2}}P\right)\left(\dfrac{n+y}{3n+\frac{y}{2}}P\right)^2}{\left(\dfrac{n-y}{3n+\frac{y}{2}}P\right)^2}$$

$$K_P=\frac{\left(n+\frac{y}{2}\right)\left(n+y\right)^2}{\left(3n+\frac{y}{2}\right)\left(n-y\right)^2}P$$

3.

$$\begin{array}{lccc} & KAB_2 \rightleftharpoons & 2AB + & B_2 \\ i & a & 0 & 0 \\ e & a\left(1-\alpha\right) & a\alpha & \dfrac{a\alpha}{2} \end{array}$$

$$K_P=\frac{\left(\dfrac{\frac{\alpha}{2}}{1+\frac{\alpha}{2}}P\right)\left(\dfrac{\alpha}{1+\frac{\alpha}{2}}P\right)^2}{\left(\dfrac{1-\alpha}{1+\frac{\alpha}{2}}P\right)^2}$$

$$K_P = \frac{\alpha^3}{2}P \qquad \left(1-\alpha \approx 1, 1+\frac{\alpha}{2}\right)$$

$$\alpha = \left(\frac{2K_P}{P}\right)^{1/3}$$

4. $$2H_2S \rightleftharpoons 2H_2 + S_2$$

$$10^{-6} = \frac{(0.25\alpha)^2\left(\frac{0.25x}{2}\right)}{\left(0.25(1-\alpha)\right)^2}$$

$$10^{-6} = \frac{1}{8}\alpha^3$$

$$\alpha = 2\times10^{-2}$$

5. $$K_P = \frac{4\times(0.9114)^2}{1-(0.9114)^2}\times1$$

$$=19.62$$

$$19.62 = \frac{4\alpha^2}{1-\alpha^2}\times2$$

$$\alpha = \sqrt{\frac{2.45}{3.45}} = 0.8426$$

6. $$\alpha \rightleftharpoons \beta$$

e. $0.364c \quad 0.636c$

$$K = \frac{636}{364} = 1.747$$

7. $$K_P = \frac{4\times(0.503)^2}{1-(0.503)^2}\times1$$

$$=1.355$$

$$\frac{2\alpha}{1-\alpha} = 8 \Rightarrow 2\alpha = 8-8\alpha$$

$$\alpha = \frac{8}{10} - \frac{4}{5}$$

$$1.355 = \frac{4\times\left(\frac{4}{5}\right)^2}{1-\left(\frac{4}{5}\right)^2}\times P$$

$$1.355 = \frac{4\times\frac{16}{25}}{\frac{9}{25}}\times P$$

$$P = 0.19$$

8. $$Se_6 \rightleftharpoons 3Se_2$$

i $\quad \frac{0.755}{79\times 6} \qquad 0$

e $\quad \frac{0.0755}{79\times 6}(1-\alpha) \quad \frac{0.0755}{29\times 6}\times 3\alpha$

$$\frac{0.0755}{79\times 6}(1+2\alpha)=\frac{\frac{185}{760}\times 0.1142}{0.0821\times 973}$$

$\alpha = 0.59$

$K_P = 264\times 10^{-5}$

9. $P_{CO_2} = 4\times 10^{-2} \qquad CaCO_3 \rightleftharpoons CaO + CO_2(g)$

$2 = \frac{P_{CO}{}^{2}}{P_{CO_2}} \Rightarrow P_{CO} = \sqrt{8\times 10^{-2}}$

$= 2.82\times 10^{-1}\text{atm}$

10. $A(s) \rightleftharpoons A'(g) + H_2S(g)$

e $\qquad 25 \qquad 25$

$K_{b_1} = 25^2 = 625$

$B(s) \rightleftharpoons B'(g) + H_2S(g)$

e $\quad 34 \qquad 34$

$K_{P_2} = 34^2 = 1156$

$A(s) \rightleftharpoons A'(g) + H_2S(g)$

e $\qquad P_1 \qquad P_2 + P_1$

$B(s) \rightleftharpoons B'(g) + H_2S(g)$

e $\qquad P_2 \qquad P_2 + P_1$

$P_1(P_1 + P_2) = 625$

$P_2(P_1 + P_2) = 1156$

$(P_1 + P_2)^2 = 1781$

$P_{vol} = 2(P_1 + P_2) = 2\sqrt{1781}$

$= 84.4$

11. $A + 2B \rightleftharpoons 3C$

i $\quad 8 \quad 8 \qquad 0$

e $\quad 5 \quad 2 \qquad 3$

$B + D \rightleftharpoons 2E$

i $\quad 8 \quad 2 \qquad 0$

e $\quad 2 \quad 1 \qquad 2$

$2B + 2A \rightleftharpoons 4F$

i $\quad 8 \quad 8 \qquad 0$

e $\quad 2 \quad 5 \qquad 4$

$K_1 = \frac{3^3}{5\times 2^2} = \frac{27}{20}$

$$K_2 = \frac{2^2}{2\times1} = 2$$

$$K_3 = \frac{4^4}{2^{y3}\times5^2} = \frac{32}{25}$$

Level-3

1. $$nA \rightleftharpoons A_n$$

$$\begin{array}{lll} i & 1 & 0 \\ e & 1-\alpha & \frac{\alpha}{n} \end{array}$$

$$1-\alpha+\frac{\alpha}{n} = \frac{PV}{RT} \qquad K_C = \frac{\frac{\alpha/n}{V}}{\left(\frac{1-\alpha}{V}\right)^n}$$

$$\frac{PV}{RT} = 1-\alpha\left(1-\frac{1}{n}\right) \qquad K_C = \frac{\alpha\,V^{n-1}}{n\left(1-\alpha\right)^n}$$

$$= 1-\frac{n-1}{n}\frac{nK_C}{V^{n-1}} \qquad K_C = \frac{\alpha V^{n-1}}{n}$$

$$= 1-\frac{\left(n-1\right)K_C}{V^{n-1}} \qquad \alpha = \frac{nK_C}{V^{n-1}}$$

2. $$2NO_2 \rightleftharpoons N_2O_4$$

$$\begin{array}{ll} i & 2P \\ e & 2P-n-y \end{array}$$

$$NO + NO_2 \rightleftharpoons N_2O_3$$

$$\begin{array}{llll} i & P & 2P & \\ e & P-y & 2P-2x-y & y \end{array}$$

$$x = 1.7$$

$$\frac{1.7}{\left(2P-2x-y\right)} = 6.8$$

$$\Rightarrow 2P-2x-y = 0.5$$

$$2P-2x-y+n+P-y+y = 5.05$$

$$0.5+1.7+P = 5.05$$

$$P = 2.65\,,\ y = 1.8$$

$$K_P = \frac{1.8}{1.05\times0.5} = 3.4286$$

3. $$H_2 + CO_2 \rightleftharpoons H_2O + CO$$

$$\begin{array}{lllll} i & 0.1 & 0.2 & & \\ e & 0.07 & 0.17 & 0.03 & 0.03 \end{array}$$

$$K = \frac{9}{119}$$

$$e'\,0.05-a-b \quad 0.17-a+c \quad 0.03+a+b \quad 0.03+a-c$$

$$CoO + H_2 \rightleftharpoons Co + H_2O$$

$$e' \quad 0.03+a-c \qquad 0.17-a+c$$

$$0.03+a+b = 0.09 \Rightarrow a+b = 0.06$$

So $K_2 = \frac{0.09}{0.01} = 9$

$\Rightarrow K_1 = \frac{K_2}{K_3} \Rightarrow K_3 = 119$

4. $$Ag\left(CN\right)_2^- \rightleftharpoons Ag^+ + 2CN^-$$

i	0	0.03	0.1
e	x	$0.03 - x$	$0.1 - 2x$

$$\frac{\left(0.03 - x\right)\left(0.1 - 2x\right)}{x} = 4 \times 10^{-19} \Rightarrow 0.030x - 7.5 \times 10^{-18}$$

PYQ : JEE Advanced

1. (A, B, D)

(a) $\Delta H = C_{P(rxn)} \Delta T$

Hence, enthalpy depends on temperature.

(b) $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g) \qquad K_p = P_{CO_2}$

(c) K_{eq} depends only on temperature and not on Pressure.

(d) Enthalpy of reaction is independent of the catalyst. Catalyst changes activation energy.

2. (8.93)

$$Fe^{2+}(aq) + S^{2-}(aq) \rightleftharpoons FeS(s) \left(K_c = 1.6 \times 10^{17}\right)$$

$t = 0 \qquad 0.03M \qquad 0.1\ M$

At equilibrium $(0.03 - x) \quad (0.1 - x)$

Since, $K_c >> 10^3; 0.03 - x = 0 \ \therefore x = 0.03$ and $0.1 - x = 0.07$

$K_c = \dfrac{1}{(0.07) \times \left[Fe^{2+}\right]} = 1.6 \times 10^{17}$ (conc. of solid is taken as 1)

$$\left[Fef^{2+}\right] = \frac{1}{0.07 \times 1.6} \times 10^{-17} = \frac{250}{28} \times 10^{-17}$$

$= 8.93 \times 10^{-17} \qquad$ (i)

Comparing (i) with given value in question we get, $Y = 8.93$

3. (0.25)

$A \rightleftharpoons B$

$$K_{eq} = \frac{P_B}{P_A}$$

$$K_{1000k} = \frac{10}{1} = 10; K_{2000k} = \frac{100}{1} = 100$$

Now, $\dfrac{\Delta G^{\circ}_{1000k}}{\Delta G^{\circ}_{2000k}} = \dfrac{\left(-RT \ln k_{eq}\right)}{\left(-RT \ln k_{eq}\right)_{2000k}} = \dfrac{1000 \times \ln 10}{2000 \times \ln 100} = 0.25$