EQUILIBRIUM

FACT/DEFINITION TYPE QUESTIONS

1. Which of the following is not a general characteristic of equilibria involving physical processes ?

(a) Equilibrium is possible only in a closed system at a given temperature.

(b) All measurable properties of the system remain constant.

(c) All the physical processes stop at equilibrium.

(d) The opposing processes occur at the same rate and there is dynamic but stable condition.

2. The liquid which has a ....vapour pressure is more volatile and has a ....boiling point.

(a) Higher , higher (b) Lower, lower

(c) Higher, lower (d) Lower, higher

3. Boiling point of the liquid depends on the atmospheric pressure. It depends on the altitude of the place; at high altitude the boiling point.............

(a) increases

(b) decreases

(c) either decreases or increases

(d) remains same

4. In an experiment three watch glasses containing separately 1mL each of acetone, ethyl alcohol, and water are exposed to atmosphere and the experiment with different volumes of the liquids in a warmer room is repeated, it is observed that in all such cases the liquid eventually disappears and the time taken for complete evaporation in each case was different. The possible reason is/are

(a) the nature of the liquids is different

(b) the amount of the liquids is different

(c) the temperature is different

(d) All of the above

5. A small amount of acetone is taken in a watch glass and it is kept open in atmosphere. Which statement is correct for the given experiment?

(a) The rate of condensation from vapour to liquid state is higher than the rate of evaporation.

(b) The rate of condensation from vapour to liquid state is equal to the rate of evaporation.

(c) The rate of condensation from vapour to liquid state is much less than the rate of evaporation.

(d) The rate of condensation from vapour to liquid state is equal or less than the rate of evaporation.

6. When pressure is applied to the equilibrium system

$$\text{Ice} \rightleftharpoons \text{Water}$$

Which of the following phenomenon will happen?

(a) More ice will be formed

(b) Water will evaporate

(c) More water will be formed

(d) Equilibrium will not be formed

7. A reaction is said to be in equilibrium when

(a) the rate of transformation of reactant to products is equal to the rate of transformation of products to the reactants.

(b) 50% of the reactants are converted to products.

(c) the reaction is near completion and all the reactants are converted to products.

(d) the volume of reactants is just equal to the volume of the products.

8. Which of the following is not true about a reversible reaction?

(a) The reaction does not proceed to completion

(b) It cannot be influenced by a catalyst

(c) Number of moles of reactants and products is always equal

(d) It can be attained only in a closed container

9. If the synthesis of ammonia from Haber's process is carried out with exactly the same starting conditions (of partial pressure and temperature) but using D_2 (deuterium) in place of H_2. Then

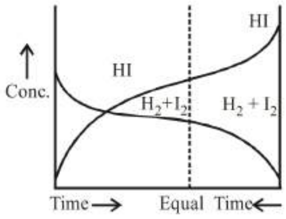
(a) the equilibrium will be disturbed

(b) the composition of reaction mixture will remain same at equilibrium.

(c) Use of isotope in reaction will not produce ammonia.

(d) At equilibrium rate of forward reaction will be greater than the rate of reverse reaction

10. Consider the following graph and mark the correct statement.



(a) Chemical equilibrium in the reaction, $H_2 + I_2 \rightleftharpoons 2HI$ can be attained from other directions.

(b) Equilibrium can be detained when H_2 and I_2 are mixed in an open vessel.

(c) The concentrations of H_2 and I_2 keep decreasing while concentration of HI keeps increasing with time.

(d) We can find out equilibrium concentration of H_2 and I_2 from the given graph.

11. What are the product formed when Deuterium is added equilibrium reaction of H_2 and I_2 ?

(i) HD (ii) DI

(iii) D_2 (iv) HI

(a) (i), (ii) and (iv) (b) (i) and (ii)

(c) (ii) and (iv) (d) All of these

12. If a system is at equilibrium, the rate of forward to the reverse reaction is :

(a) less (b) equal

(c) high (d) at equilibrium

13. K_1 and K_2 are equilibrium constant for reactions (1) and (2)

$N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$ ....(1)

$NO(g) \rightleftharpoons \frac{1}{2}N_2(g) + \frac{1}{2}O_2(g)$ ......(2)

Then,

(a) $K_1 = \left(\frac{1}{K_2}\right)^2$ (b) $K_1 = K_2^2$

(c) $K_1 = \frac{1}{K_2}$ (d) $K_1 = (K_2)^0$

14. The equilibrium constant for the reversible reaction $N_2 + 3H_2 \rightleftharpoons 2NH_3$ is K and for reaction $\frac{1}{2}N_2 + \frac{3}{2}H_2 \rightleftharpoons NH_3$, the equilibrium constant is K'

The K and K' will be related as:

(a) $K \times K' = 1$ (b) $K = K'$

(c) $K' = \sqrt{K}$ (d) $K = \sqrt{K'}$

15. In the following equilibrium reaction

$2A \rightleftharpoons B + C,$

the equilibrium concentrations of A, B and C are 1×10^{-3} M, 2×10^{-3} M and 3×10^{-3} M respectively at 300 K. The value of K_c for this equilibrium at the same temperature is

(a) $\frac{1}{6}$ (b) 6

(c) $\frac{1}{36}$ (d) 36

16. Given the reaction between 2 gases represented by A_2 and B_2 to give the compound AB(g).

$A_2(g) + B_2(g) \rightleftharpoons 2AB(g)$.

At equilibrium, the concentration

of $A_2 = 3.0 \times 10^{-3}$ M

of $B_2 = 4.2 \times 10^{-3}$ M

of $AB = 2.8 \times 10^{-3}$ M

If the reaction takes place in a sealed vessel at 527°C, then the value of K_C will be :

(a) 2.0 (b) 1.9

(c) 0.62 (d) 4.5

17. A reaction is $A + B \rightleftharpoons C + D$. Initially we start with equal concentrations of A and B. At equilibrium we find that the moles of C is two times of A. What is the equilibrium constant of the reaction?

(a) $\frac{1}{4}$ (b) $\frac{1}{2}$

(c) 4 (d) 2

18. In $A + B \rightleftharpoons C$. The unit of equilibrium constant is :

(a) Litre mole^{-1} (b) Mole litre

(c) Mole litre^{-1} (d) No unit

19. For the reaction $C(s) + CO_2(g) \rightleftharpoons 2CO(g)$, the partial pressures of CO_2 and CO are 2.0 and 4.0 atm respectively at equilibrium. The K_p for the reaction is.

(a) 0.5 (b) 4.0

(c) 8.0 (d) 32.0

20. In which of the following equilibrium K_c and K_p are not equal?

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

(b) $SO_2(g) + NO_2(g) \rightleftharpoons SO_3(g) + NO(g)$

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

(d) $2C(s) + O_2(g) \rightleftharpoons 2CO_2(g)$

21. For the following reaction in gaseous phase

$CO(g) + \frac{1}{2}O_2(g) \rightarrow CO_2(g)$, K_p / K_c is

(a) $(RT)^{1/2}$ (b) $(RT)^{-1/2}$

(c) (RT) (d) $(RT)^{-1}$

22. The K_p/K_C ratio will be highest in case of

(a) $CO(g) + \frac{1}{2}O_2(g) \rightleftharpoons CO_2(g)$

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

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

(d) $7H_2(g) + 2NO_2(g) \rightleftharpoons 2NH_3(g) + 4H_2O(g)$

23. For a chemical reaction ;

$$A(g) + B(\ell) \rightleftharpoons D(g) + E(g)$$

Hypothetically at what temperature, $K_p = K_c$

(when, $R = 0.08$ ℓ-atm/mole-K)

(a) $T = 0$ K (b) $T = 1$K

(c) $T = 12.5$ K (d) $T = 273$ K

24. Steam reacts with iron at high temperature to give hydrogen gas and Fe_3O_4 (s). The correct expression for the equilibrium constant is

(a) $\dfrac{P_{H_2}^2}{P_{H_2O}^2}$ (b) $\dfrac{(P_{H_2})^4}{(P_{H_2O})^4}$

(c) $\dfrac{(P_{H_2})^4[Fe_3O_4]}{(P_{H_2O})^4[Fe]}$ (d) $\dfrac{[Fe_3O_4]}{[Fe]}$

25. For the reaction $C_{(s)} + CO_{2(g)} \rightarrow 2CO_{(g)}$, $K_p = 63$ atm at 1000 K. If at equilibrium : $P_{CO} = 10\,P_{CO_2}$, then the total pressure of the gases at equilibrium is

(a) 6.3 atm (b) 6.93 atm

(c) 0.63 atm (d) 0.693 atm

26. The rate constant for forward and backward reaction of hydrolysis of ester are 1.1×10^{-2} and 1.5×10^{-3} per minute respectively. Equilibrium constant for the reaction

$CH_3COOC_2H_5 + H^+ \rightleftharpoons CH_3COOH + C_2H_5OH$ is

(a) 4.33 (b) 5.33

(c) 6.33 (d) 7.33

27. Value of K_P in the reaction

$MgCO_{3(s)} \rightarrow MgO_{(s)} + CO_{2(g)}$ is

(a) $K_P = P_{CO_2}$

(b) $K_P = P_{CO_2} \times \dfrac{P_{CO_2} \times P_{MgO}}{P_{MgCO_3}}$

(c) $K_P = \dfrac{P_{CO_2} \times P_{MgO}}{P_{MgCO_3}}$

(d) $K_P = \dfrac{P_{MgCO_3}}{P_{CO_2} \times P_{MgO}}$

28. Which of the following is an example of homogeneous equilibrium ?

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

(b) $C(s) + H_2O(g) \rightleftharpoons CO(g) + H_2(g)$

(c) $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$

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

29. Unit of equilibrium constant for the given reaction is

$Ni(s) + 4CO(g) \rightleftharpoons Ni(CO)_4(g)$

(a) $(mol/l)^{-3}$ (b) $(mol/l)^3$

(c) $(mol/l)^{-4}$ (d) $(mol/l)^4$

30. The thermal dissociation of calcium carbonate showing heterogeneous equilibrium is

$$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$$

For this reactions which of the following is/are true

(i) $K_c' = [CO_2(g)]$

(ii) $Kp = pCO_2$

(iii) $[CaCO_3(s)]$ and $[CaO(s)]$ are both constant

(iv) $[CO_2(g)]$ is constant

(a) (i), (ii) and (iv) (b) (i), (ii) and (iii)

(c) (ii) and (iv) (d) (i), (iii) and (iv)

31. In a reversible chemical reaction having two reactants in equilibrium, if the concentration of the reactants are doubled then the equilibrium constant will

(a) Also be doubled (b) Be halved

(c) Become one-fourth (d) Remain the same

32. On doubling P and V with constant temperature the equilibrium constant will

(a) remain constant (b) become double

(c) become one-fourth (d) None of these

33. If for the reaction

$N_2 + 3H_2 \rightleftharpoons 2NH_3$, $\Delta H = -92.38$KJ/mole than what happens if the temperature is increased?

(a) Reaction proceed forward

(b) Reaction proceed backward

(c) No effect on the formation of product

(d) None of these

34. If K_c is in the range of .... appreciable concentrations of both reactants and products are present.

(a) 10^{-4} to 10^4 (b) 10^{-3} to 10^3

(c) 10^{+3} to 10^{-3} (d) 10^{-5} to 10^3

35. The reaction quotient (Q) for the reaction

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

is given by $Q = \dfrac{[NH_3]^2}{[N_2][H_2]^3}$. The reaction will proceed from right to left if

(a) $Q = 0$ (b) $Q = K_c$

(c) $Q < K_c$ (d) $Q > K_c$

where K_c is the equilibrium constant

36. The reaction quotient Q is used to

(a) predict the extent of a reaction on the basis of its magnitude

(b) predict the direction of the reaction

(c) calculate equilibrium concentrations

(d) calculate equilibrium constant

37. The correct relationship between free energy change in a reaction and the corresponding equilibrium constant, K_c is

(a) $\Delta G = RT \ln K_c$ (b) $-\Delta G = RT \ln K_c$

(c) $\Delta G° = RT \ln K_c$ (d) $-\Delta G° = RT \ln K_c$

38. Using the equation ($K = e^{-\Delta G^{\ominus}/RT}$), the reaction spontaneity can be interpreted in terms of the value of ΔG° is/are

(a) If $\Delta G^{\ominus} > 0$, then $-\Delta G^{\ominus}/RT$ is positive, and $e^{-\Delta G^{\ominus}/RT} > 1$ making $K > 1$, which implies a spontaneous reaction or the reaction which proceeds in the forward direction to such an extent that the products are present predominantly.

(b) If $\Delta G^{\ominus} > 0$, then $-\Delta G^{\ominus}/RT$ is negative, and $e^{-\Delta G^{\ominus}/RT} < 1$ making $K < 1$, which implies a non-spontaneous reaction or a reaction which proceeds in the forward direction to such a small degree that only a very minute quantity of product is formed.

(c) Both (a) and (b)

(d) None of the above

39. Which of the following relation represents correct relation between standard electrode potential and equilibrium constant?

I. $\log K = \dfrac{nFE^{\circ}}{2.303\ RT}$

II. $K = e^{\frac{nFE^{\circ}}{RT}}$

III. $\log K = \dfrac{-nFE^{\circ}}{2.303\ RT}$

IV. $\log K = 0.4342\dfrac{-nFE^{\circ}}{RT}$

Choose the correct statement(s).

(a) I, II and III are correct

(b) II and III are correct

(c) I, II and IV are correct

(d) I and IV are correct

40. According to Le-chatelier's principle, adding heat to a solid $\rightleftharpoons$ liquid equilibrium will cause the

(a) temperature to increase

(b) temperature to decrease

(c) amount of liquid to decrease

(d) amount of solid to decrease

41. Which one of the following information can be obtained on the basis of Le Chatelier principle?

(a) Dissociation constant of a weak acid

(b) Entropy change in a reaction

(c) Equilibrium constant of a chemical reaction

(d) Shift in equilibrium position on changing value of a constraint

42. For the manufacture of ammonia by the reaction

$$N_2 + 3H_2 \rightleftharpoons 2NH_3 + 2\,\text{kcal}$$

the favourable conditions are

(a) Low temperature, low pressure and catalyst

(b) Low temperature, high pressure and catalyst

(c) High temperature, low pressure and catalyst

(d) High temperature, high pressure and catalyst

43. Which of the following reaction will be favoured at low pressure ?

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

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

(c) $PCl_5 \rightleftharpoons PCl_3 + Cl_2$

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

44. The equilibrium which remains unaffected by pressure change is

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

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

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

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

45. Suitable conditions for melting of ice :

(a) high temperature and high pressure

(b) high temperature and low pressure

(c) low temperature and low pressure

(d) low temperature and high pressure

46. In which of the following reactions, the equilibrium remains unaffected on addition of small amount of argon at constant volume?

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

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

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

(d) The equilibrium will remain unaffected in all the three cases.

47. Le-Chatelier principle is not applicable to

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

(b) $Fe(s) + S(s) \rightleftharpoons FeS(s)$

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

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

48. In an equilibrium reaction if temperature increases

(a) equilibrium constant increases

(b) equilibrium constant decreases

(c) any of the above

(d) no effect

49. In a two-step exothermic reaction

$$A_2(g) + B_2(g) \underset{\text{Step 1}}{\rightleftharpoons} 3C(g) \underset{\text{Step 2}}{\rightleftharpoons} D(g)$$

Steps 1 and 2 are favoured respectively by

(a) high pressure, high temperature and low pressure, low temperature

(b) high pressure, low temperature and low pressure, high temperature

(c) low pressure, high temperature and high pressure, high temperature

(d) low pressure, low temperature and high pressure, low temperature

50. What happens when an inert gas is added to an equilibrium keeping volume unchanged?
(a) More product will form
(b) Less product will form
(c) More reactant will form
(d) Equilibrium will remain unchanged

51. In a vessel N_2, H_2 and NH_3 are at equilibrium. Some helium gas is introduced into the vessel so that total pressure increases while temperature and volume remain constant. According to Le Chatelier's principle, the dissociation of NH_3
(a) increases (b) decreases
(c) remains unchanged (d) equilibrium is disturbed

52. Effect of a catalyst on a equilibrium reaction.
(i) A catalyst increases the rate of the chemical reaction by making available a new low energy pathway for the conversion of reactants to products.
(ii) It increases the rate of forward and reverse reactions that pass through the same transition state and does not affect equilibrium.
(iii) It lowers the activation energy for the forward and reverse reactions by exactly the same amount.
Which of the above statement(s) is/are correct ?
(a) Only (i) (b) (i) and (ii)
(c) (i), (ii) and (iii) (d) (ii) and (iii)

53. Which of the following is/are electrolytes?
(i) Sugar solution (ii) Sodium chloride
(iii) Acetic acid (iv) Starch solution
(a) (i) and (iv) (b) (ii) and (iv)
(c) (ii) and (iii) (d) (i) and (iii)

54. The geometry of hydronium ion is
(a) tetrahedral (b) linear
(c) trigonal pyramidal (d) trigonal planer

55. Which of the following statements are correct regarding Arrhenius theory of acid and base?
(a) This theory was applicable to only aqueous solutions
(b) This theory was applicable to all solutions
(c) This theory could not explain the basicity of substances like ammonia which do not possess a hydroxyl group
(d) Both (a) and (c)

56. Would gaseous HCl be considered as an Arrhenius acid ?
(a) Yes
(b) No
(c) Not known
(d) Gaseous HCl does not exist

57. A base, as defined by Bronsted theory, is a substance which can
(a) lose a pair of electrons
(b) donate protons
(c) gain a pair of electrons
(d) accept protons

58. BF_3 is an acid according to
(a) Arrhenius concept (b) Bronsted-Lowry concept
(c) Lewis Concept (d) Both (b) and (c)

59. Which of the following can act as both Bronsted acid and Bronsted base?
(a) Na_2CO_3 (b) OH^-
(c) HCO_3^- (d) NH_3

60. Conjugate acid of NH_2^- is :
(a) NH_4^+ (b) NH_3
(c) NH_2 (d) NH

61. Among boron trifluoride, stannic chloride and stannous chloride, Lewis acid is represented by
(a) only stannic chloride
(b) boron trifluoride and stannic chloride
(c) boron trifluoride and stannous chloride
(d) only boron trifluoride

62. Which of the following molecules acts as a Lewis acid ?
(a) $(CH_3)_2O$ (b) $(CH_3)_3P$
(c) $(CH_3)_3N$ (d) $(CH_3)_3B$

63. Which one of the following molecular hydrides acts as a Lewis acid?
(a) NH_3 (b) H_2O
(c) B_2H_6 (d) CH_4

64. Which of these is least likely to act as Lewis base?
(a) F^- (b) BF_3
(c) PF_3 (d) CO

65. Which one of the following is the correct statement ?
(a) HCO_3^- is the conjugate base of CO_3^{2-}.
(b) NH_2^- is the conjugate acid of NH_3.
(c) H_2SO_4 is the conjugate acid of HSO_4^-.
(d) NH_3 is the conjugate base of NH_2^-.

66. Water is well known amphoprotic solvent. In which chemical reaction water is behaving as a base?
(a) $H_2SO_4 + H_2O \longrightarrow H_3O^+ + HSO_4^-$
(b) $H_2O + H_2O \longrightarrow H_3O^+ + OH^-$
(c) $H_2O + NH_2^- \longrightarrow NH_3 + OH^-$
(d) $H_2O + NH_3 \longrightarrow NH_4^+ + OH^-$

67. An acid/ base dissociation equilibrium is dynamic involving a transfer of proton in forward and reverse directions. Now, with passage of time in which direction equilibrium is favoured ?
(a) in the direction of stronger base and stronger acid
(b) in the direction of formation of stronger base and weaker acid
(c) in the direction of formation of weaker base and weaker acid
(d) in the direction of formation of weaker base and stronger acid

68. Three reactions involving $H_2PO_4^-$ are given below:
(i) $H_3PO_4 + H_2O \rightarrow H_3O^+ + H_2PO_4^-$
(ii) $H_2PO_4^- + H_2O \rightarrow HPO_4^{2-} + H_3O^+$
(iii) $H_2PO_4^- + OH^- \rightarrow H_3PO_4 + O^{2-}$
In which of the above does $H_2PO_4^-$ act as an acid ?
(a) (ii) only (b) (i) and (ii)
(c) (iii) only (d) (i) only

69. The value of the ionic product of water
(a) depends on volume of water
(b) depends on temperature
(c) changes by adding acid or alkali
(d) always remains constant

70. A base when dissolved in water yields a solution with a hydroxyl ion concentration of 0.05 mol litre^{-1}. The solution is
(a) basic (b) acidic
(c) neutral (d) either (b) or (c)

71. pH scale was introduced by :
(a) Arrhenius (b) Sorensen
(c) Lewis (d) Lowry

72. pH of solution is defined by expression
(a) $\log[H^+]$ (b) $\log\left[\frac{1}{H^+}\right]$
(c) $\frac{1}{\log[H^+]}$ (d) $\frac{1}{-\log[H^+]}$

73. The pH of a 10^{-3} M HCl solution at 25°C if it is diluted 1000 times, will be –
(a) 3 (b) zero
(c) 5.98 (d) 6.02

74. How many litres of water must be added to 1 litre an aqueous solution of HCl with a pH of 1 to create an aqueous solution with pH of 2 ?
(a) 0.1 L (b) 0.9 L
(c) 2.0 L (d) 9.0 L

75. What is the approximate pH of a 1×10^{-3} M NaOH solution?
(a) 3 (b) 11
(c) 7 (d) 1×10^{-11}

76. Calculate the pOH of a solution at 25°C that contains 1×10^{-10} M of hydronium ions, i.e. H_3O^+.
(a) 4.000 (b) 9.0000
(c) 1.000 (d) 7.000

77. The pH value of a 10 M solution of HCl is
(a) less than 0 (b) equal to 0
(c) equal to 1 (d) equal to 2

78. What is the H^+ ion concentration of a solution prepared by dissolving 4 g of NaOH (Atomic weight of Na = 23 amu) in 1000 ml?
(a) 10^{-10} M (b) 10^{-4} M
(c) 10^{-1} M (d) 10^{-13} M

79. Calculate the pOH of a solution at 25°C that contains 1×10^{-10} M of hydronium ions, i.e. H_3O^+.
(a) 4.000 (b) 9.0000
(c) 1.000 (d) 7.000

80. The pH of 0.005 molar solution of H_2SO_4 is approximately:
(a) 0.010 (b) 1
(c) 2 (d) 0.005

81. Which solution has pH equal to 10 ?
(a) 10^{-4} M KOH (b) 10^{-10} M KOH
(c) 10^{-10} M HCl (d) 10^{-4} M HCl

82. Which of the following has highest pH ?
(a) $\frac{M}{4}$KOH (b) $\frac{M}{4}$NaOH
(c) $\frac{M}{4}NH_4OH$ (d) $\frac{M}{4}Ca(OH)_2$

83. A weak acid, HA, has a K_a of 1.00×10^{-5}. If 0.100 mole of this acid dissolved in one litre of water, the percentage of acid dissociated at equilbrium is closest to
(a) 1.00% (b) 99.9%
(c) 0.100% (d) 99.0%

84. A monobasic weak acid solution has a molarity of 0.005 and pH of 5. What is the percentage ionization in this solution?
(a) 2.0 (b) 0.2
(c) 0.5 (d) 0.25

85. Calculate the pH of a solution obtained by diluting 1 mL of 0.10 M weak monoacidic base to 100 mL at constant temperature if K_b of the base is 1×10^{-5} ?
(a) 8 (b) 9
(c) 10 (d) 11

86. The ionisation constant of an acid, K_a, is the measure of strength of an acid. The K_a values of acetic acid, hypochlorous acid and formic acid are 1.74×10^{-5}, 3.0×10^{-8} and 1.8×10^{-4} respectively. Which of the following orders of pH of 0.1 mol dm^{-3} solutions of these acids is correct?
(a) acetic acid > hypochlorous acid > formic acid
(b) hypochlorous acid > acetic acid > formic acid
(c) formic acid > hypochlorous acid > acetic acid
(d) formic acid > acetic acid > hypochlorous acid

87. The first and second dissociation constants of an acid H_2A are 1.0×10^{-5} and 5.0×10^{-10} respectively. The overall dissociation constant of the acid will be
(a) 0.2×10^5 (b) 5.0×10^{-5}
(c) 5.0×10^{15} (d) 5.0×10^{-15}.

88. Equimolar solutions of HF, HCOOH and HCN at 298 K have the values of K_a as 6.8×10^{-4} and 4.8×10^{-9} respectively. What is the observed trend of dissociation constants in successive stages ?
(a) HF > HCN > HCOOH (b) HF > HCOOH > HCN
(c) HCN > HF > HCOOH (d) HCOOH > HCN > HF

89. At 25°C, the dissociation constant of a base, BOH, is 1.0×10^{-12}. The concentration of hydroxyl ions in 0.01 M aqueous solution of the base would be
(a) 1.0×10^{-5} mol L^{-1} (b) 1.0×10^{-6} mol L^{-1}
(c) 2.0×10^{-6} mol L^{-1} (d) 1.0×10^{-7} mol L^{-1}

90. Which of the following pK_a value represents the strongest acid ?
(a) 10^{-4} (b) 10^{-8}
(c) 10^{-5} (d) 10^{-2}

91. The dissociation constant of two acids HA_1 and HA_2 are 3.14×10^{-4} and 1.96×10^{-5} respectively. The relative strength of the acids will be approximately
(a) 1 : 4 (b) 4 : 1
(c) 1 : 16 (d) 16 : 1

92. Given

$$HF + H_2O \xrightarrow{K_a} H_3O^+ + F^-$$

$$F^- + H_2O \xrightarrow{K_b} HF + OH^-$$

Which of the following reaction is correct

(a) $K_b = K_w$
(b) $K_b = \frac{1}{K_w}$
(c) $K_a \times K_b = K_w$
(d) $\frac{K_a}{K_b} = K_w$

93. At 298K a 0.1 M CH_3COOH solution is 1.34% ionized. The ionization constant K_a for acetic acid will be

(a) 1.82×10^{-5}
(b) 18.2×10^{-5}
(c) 0.182×10^{-5}
(d) None of these

94. For dibasic acid correct order is

(a) $K_{a_1} < K_{a_2}$
(b) $K_{a_1} > K_{a_2}$
(c) $K_{a_1} = K_{a_2}$
(d) not certain

95. For a polybasic acid, the dissociation constants have a different values for each step, e.g.,

$$H_3A \rightleftharpoons H^+ + H_2A^- \ ; \ K = K_{a_1}$$

$$H_2A^- \rightleftharpoons H^+ + HA^{2-} \ ; \ K = K_{a_2}$$

$$HA^{2-} \rightleftharpoons H^+ + A^{3-} \ ; \ K = K_{a_3}$$

What is the observed trend of dissociation constants in successive stages ?

(a) $K_{a_1} > K_{a_2} > K_{a_3}$
(b) $K_{a_1} = K_{a_2} = K_{a_3}$
(c) $K_{a_1} < K_{a_2} < K_{a_3}$
(d) $K_{a_1} = K_{a_2} + K_{a_3}$

96. K_{a_1}, K_{a_2} and K_{a_3} are the respective ionisation constants for the following reactions.

$$H_2S \rightleftharpoons H^+ + HS^-$$

$$HS^- \rightleftharpoons H^+ + S^{2-}$$

$$H_2S \rightleftharpoons 2H^+ + S^{2-}$$

The correct relationship between K_{a_1}, K_{a_2} and K_{a_3} is

(a) $K_{a_3} = K_{a_1} \times K_{a_2}$
(b) $K_{a_3} = K_{a_1} + K_{a_2}$
(c) $K_{a_3} = K_{a_1} - K_{a_2}$
(d) $K_{a_3} = K_{a_1} / K_{a_2}$

97. Cationic hydrolysis gives the following solution:

(a) acidic
(b) basic
(c) neutral
(d) amphoteric

98. In qualitative analysis, in III group NH_4Cl is added before NH_4OH because

(a) to increase the concentration of NH_4^+ions
(b) to increase concentration of Cl^- ions
(c) to reduce the concentration of OH^- ions
(d) to increase concentration of OH^- ions

99. The solubility of AgI in NaI solution is less than that in pure water because :

(a) the temperature of the solution decreases
(b) solubility product to AgI is less than that of NaI
(c) of common ion effect
(d) AgI forms complex with NaI

100. When sodium acetate is added to an aqueous solution of acetic acid :

(a) The pH of the solution decreases
(b) The pH of the solution increases
(c) The pH of the solution remains unchanged
(d) An acid salt is produced

101. Which of the following statements about pH and H^+ ion concentration is incorrect?

(a) Addition of one drop of concentrated HCl in NH_4OH solution decreases pH of the solution.
(b) A solution of the mixture of one equivalent of each of CH_3COOH and NaOH has a pH of 7
(c) pH of pure neutral water is not zero
(d) A cold and concentrated H_2SO_4 has lower H^+ ion concentration than a dilute solution of H_2SO_4

102. H_2S gas when passed through a solution of cations containing HCl precipitates the cations of second group of qualitative analysis but not those belonging to the fourth group. It is because

(a) presence of HCl decreases the sulphide ion concentration.
(b) solubility product of group II sulphides is more than that of group IV sulphides.
(c) presence of HCl increases the sulphide ion concentration.
(d) sulphides of group IV cations are unstable in HCl.

103. A salt 'X' is dissolved in water of pH = 7. The salt is made resulting solution becomes alkaline in nature. The salt is made

(a) A strong acid and strong base
(b) A strong acid and weak base
(c) A weak acid and weak base
(d) A weak acid and strong base

104. Aqueous solution of ferric chloride is acidic due to

(a) ionization
(b) polarization
(c) dissociation
(d) hydrolysis

105. The pK_a of a weak acid, HA, is 4.80. The pK_b of a weak base, BOH, is 4.78. The pH of an aqueous solution of the correspondng salt, BA, will be

(a) 9.58
(b) 4.79
(c) 7.01
(d) 9.22

106. The pK_a of a weak acid (HA) is 4.5. The pOH of an aqueous buffer solution of HA in which 50% of the acid is ionized is

(a) 7.0
(b) 4.5
(c) 2.5
(d) 9.5

107. A buffer solution is prepared in which the concentration of NH_3 is 0.30M and the concentration of NH_4^+ is 0.20 M. If the equilibrium constant, K_b for NH_3 equals 1.8×10^{-5}, what is the pH of this solution ? (log 2.7 = 0.433).

(a) 9.08
(b) 9.43
(c) 11.72
(d) 8.73

108. What is [H^+] in mol/L of a solution that is 0.20 M in CH_3COONa and 0.10 M in CH_3COOH ? K_a for CH_3COOH $= 1.8 \times 10^{-5}$.

(a) 3.5×10^{-4} (b) 1.1×10^{-5}
(c) 1.8×10^{-5} (d) 9.0×10^{-6}

109. Which of the following pairs constitutes a buffer?

(a) NaOH and NaCl (b) HNO_3 and NH_4NO_3
(c) HCl and KCl (d) HNO_2 and $NaNO_2$

110. Buffer solutions have constant acidity and alkalinity because

(a) these give unionised acid or base on reaction with added acid or alkali.
(b) acids and alkalies in these solutions are shielded from attack by other ions.
(c) they have large excess of H^+ or OH^- ions
(d) they have fixed value of pH

111. The buffering action of an acidic buffer is maximum when its pH is equal

(a) 5 (b) 7
(c) 1 (d) pK_a

112. When a buffer solution, sodium acetate and acetic acid is diluted with water :

(a) Acetate ion concentration increases
(b) H^+ ion concentration increases
(c) OH^- ion conc. increases
(d) H^+ ion concentration remains unaltered

113. The product of ionic concentration in a saturated solution of an electrolyte at a given temperature is constant and is known as

(a) Ionic product of the electrolyte
(b) Solubility product
(c) Ionization constant
(d) Dissociation constant

114. The K_{sp} for $Cr(OH)_3$ is 1.6×10^{-30}. The solubility of this compound in water is :

(a) $\sqrt[4]{1.6 \times 10^{-30}}$ (b) $\sqrt[4]{1.6 \times 10^{-30}/27}$
(c) $1.6 \times 10^{-30/27}$ (d) $\sqrt{1.6 \times 10^{-30}}$

115. At 25°C, the solubility product of $Mg(OH)_2$ is 1.0×10^{-11}. At which pH, will Mg^{2+} ions start precipitating in the form of $Mg(OH)_2$ from a solution of 0.001 M Mg^{2+} ions?

(a) 9 (b) 10
(c) 11 (d) 8

116. pH of a saturated solution of $Ba(OH)_2$ is 12. The value of solubility product (K_{sp}) of $Ba(OH)_2$ is :

(a) 3.3×10^{-7} (b) 5.0×10^{-7}
(c) 4.0×10^{-6} (d) 5.0×10^{-6}

117. If s and S are respectively solubility and solubility product of a sparingly soluble binary electrolyte then :

(a) $s = S$ (b) $s = S^2$
(c) $s = S^{1/2}$ (d) $s = \frac{1}{2}S$

118. Why only As^{+3} gets precipitated as As_2S_3 and not Zn^{+2} as ZnS when H_2S is passed through an acidic solution containing As^{+3} and Zn^{+2}?

(a) Solubility product of As_2S_3 is less than that of ZnS
(b) Enough As^{+3} are present in acidic medium
(c) Zinc salt does not ionise in acidic medium
(d) Solubility product changes in presence of an acid

119. Solid $Ba(NO_3)_2$ is gradually dissolved in a 1.0×10^{-4} M Na_2CO_3 solution. At which concentration of Ba^{2+}, precipitate of $BaCO_3$ begins to form ? (K_{sp} for $BaCO_3$ $= 5.1 \times 10^{-9}$)

(a) 5.1×10^{-5} M (b) 7.1×10^{-8} M
(c) 4.1×10^{-5} M (d) 8.1×1^{-7} M

120. Solubility product of silver bromide is 5.0×10^{-13}. The quantity of potassium bromide (molar mass taken as 120 g mol^{-1}) to be added to 1 litre of 0.05 M solution of silver nitrate to start the precipitation of AgBr is

(a) 1.2×10^{-10} g (b) 1.2×10^{-9} g
(c) 6.2×10^{-5} g (d) 5.0×10^{-8} g

121. At 25°C, the solubility product of $Mg(OH)_2$ is 1.0×10^{-11}. At which pH, will Mg^{2+} ions start precipitating in the form of $Mg(OH)_2$ from a solution of 0.001 M Mg^{2+} ions?

(a) 9 (b) 10
(c) 11 (d) 8

STATEMENT TYPE QUESTIONS

122. Read the following statements carefully and choose the correct answer

(i) Water and water vapour remain in equilibrium position at atmospheric pressure (1.013 bar) and at 100°C in a closed vessel.
(ii) The boiling point of water is 100°C at 1.013 bar pressure
(iii) Boiling point of the liquid depends on the atmospheric pressure.
(iv) Boiling point depends on the altitude of the place; at high altitude the boiling point increases.

(a) (i), (ii) and (iv) are correct
(b) (i), (iii) and (iv)
(c) (i), (ii) and (iii) are correct
(d) only (iii) is correct

123. You must have seen that when a soda water bottle is opened, some of the carbon dioxide gas dissolved in it fizzes out rapidly. There is equilibrium between the molecules in the gaseous state and the molecules dissolved in the liquid under pressure i.e.,

$$CO_2(gas) \rightleftharpoons CO_2(\text{in solution})$$

Which of the following statements is/are correct regarding this?

(i) The phenomenon arises due to difference in solubility of carbon dioxide at different pressures.
(ii) This equilibrium is governed by Henry's law.
(iii) The amount of CO_2 gas dissolved in liquid increases with decrease of temperature.
(iv) The amount of CO_2 gas dissolved in liquid decreases with increase of temperature.

(a) (i), (ii) and (iv) are correct
(b) (i), (iii) and (iv)
(c) (i), (ii) and (iii) are correct
(d) only (iii) is correct

124. Identify the CORRECT statements below regarding chemical equilibrium:

(i) All chemical reactions which are in equilibrium are irreversible.

(ii) Equilibrium is achieved when the forward reaction rate equals the reverse reaction rate.

(iii) Equilibrium is achieved when the concentrations of reactants and product remain constant.

(iv) Equilibrium is dynamic in nature

(a) (i), (ii) and (iv) are correct

(b) (i), (ii), (iii) and (iv) are correct

(c) (i), (ii) and (iii) are correct

(d) only (ii) is correct

125. Nobel gas is added to a reaction at equilibrium involving gaseous reactant and gaseous product.

Which of the following statement is true for above reaction?

Statement 1 : Reaction will proceed forward, as total pressure has increased due to addition of Nobel gas.

Statement 2 : Reaction will proceed backward, if Nobel gas react with reactant.

(a) Statement 1 and 2 are both correct.

(b) Statement 1 is correct but statement 2 is incorrect.

(c) Statement 1 is incorrect but statement 2 is correct.

(d) Statement 1 and 2 both are incorrect.

126 Read the following statements and choose the correct option.

(i) The value of equilibrium constant is independent of initial concentrations of the reactants and products.

(ii) Equilibrium constant is temperature dependent

(iii) The equilibrium constant for the reverse reaction is equal to the inverse of the equilibrium constant for the forward reaction.

(iv) The equilibrium constant for the reverse reaction is equal to the equilibrium constant for the forward reaction.

(a) (i), (ii) and (iv) are correct

(b) (i), (iii) and (iv)

(c) (i), (ii) and (iii) are correct

(d) only (iii) is correct

127. Read the following statements and choose the correct option

(i) The numerical value of the equilibrium constant for a reaction indicates the extent of the reaction.

(ii) An equilibrium constant give information about the rate at which the equilibrium is reached.

(iii) If $K_c > 10^3$, products predominate over reactants, i.e., if K_c is very large, the reaction proceeds nearly to completion.

(iv) If $K_c < 10^{-3}$, reactants predominate over products, i.e., if K_c is very small, the reaction proceeds rarely.

(a) (i), (ii) and (iv) are correct

(b) (i), (iii) and (iv)

(c) (i), (ii) and (iii) are correct

(d) only (iii) is correct

128. Which of the following statement(s) is/are correct ?

(i) ΔG is negative, then the reaction is spontaneous and proceeds in the forward direction.

(ii) ΔG is positive, then reaction is non-spontaneous

(iii) ΔG is 0, then reaction is at equilibrium

(a) (i), (ii) and (iii) are correct

(b) (i) and (ii)

(c) (ii) and (iii) are correct

(d) only (iii) is correct

129. Read the following statements and choose the correct option

(i) Most of the acids taste sour

(ii) Acids turns blue litmus paper into red

(iii) Bases turns red litmus paper blue

(iv) Bases taste bitter and feel soapy

(a) (i), (ii) and (iv) are correct

(b) (i), (iii) and (iv)

(c) (i), (ii) and (iii) are correct

(d) All statements are correct

130. Which of the following statements are correct ?

(i) Strong acids have very weak conjugate bases

(ii) Weak acids have very strong conjugate bases

(iii) Strong bases have strong conjugate acids

(iv) Weak bases have weak conjugate acids

(a) (i) and (ii) (b) (i) and (iii)

(c) (ii) and (iv) (d) (iii) and (iv)

131. Which of the following statement(s) is/are correct ?

(i) Water has ability to act both as an acid and a base

(ii) In pure water one H_2O molecule donate proton and acts an acid and another water molecule accepts a proton and acts as a base.

(a) Both (i) and (ii) (b) Neither (i) nor (ii)

(c) Only (i) (d) Only (ii)

132. Which of the following statements are correct ?

(i) Ionic product of water $(K_w) = [H^+][OH^-] = 10^{-14} M^2$

(ii) At 298K $[H^+] = [OH^-] = 10^{-7}$

(iii) K_w does not depends upon temperature

(iv) Molarity of pure water = 55.55M

(a) (i), (ii) and (iii) (b) (i), (ii) and (iv)

(c) (i) and (iv) (d) (ii) and (iii)

133. Read the following statements and choose the correct option

(i) K_a (ionization constant) is a measure of the strength of the acids

(ii) Smaller the value of K_a, the stronger is the acid

(iii) K_a is a dimensionless quantity

(a) Statements (i) and (ii) are correct

(b) Statements (ii) and (iii) are correct

(c) Statements (i), (ii) and (iii) are correct

(d) Statements (i) and (iii) are correct

134. Which of the following statement(s) is/are correct ?

(i) In a tribasic acid 2nd and 3rd (K_{a_2}, K_{a_3}) ionization constants are smaller than the first ionisation (K_{a_1})

(ii) It is difficult to remove a positively charged proton from a negative ion due to electrostatic force.

(a) Both (i) and (ii) (b) Neither (i) nor (ii)

(c) Only (i) (d) Only (ii)

135. Which of the following statements are correct ?

(i) The extent of dissociation of an acid depends on the strength and polarity of the H — A bond (where A is an electronegative element.)

(ii) As the strength of H–A bond increases, the energy required to break the bond decreases.

(iii) As the electronegativity difference between the atoms H and A increases, acidity increases

(a) (i) and (ii) (b) (ii) and (iii)
(c) (i) and (iii) (d) (i), (ii) and (iii)

MATCHING TYPE QUESTIONS

136. Match the columns

	Column-I		**Column-II**
(A)	$H_2O\,(l) \rightleftharpoons H_2O\,(vap)$	(p)	rate of melting = rate of freezing
(B)	I_2 (solid) $\rightleftharpoons$ I_2 (vapour)	(q)	rate of evaporation = rate of condensation
(C)	Ice $\rightleftharpoons$ water	(r)	rate of sublimation = rate of condensation

(a) A – (p), B – (q), C – (r)
(b) A – (r), B – (q), C – (p)
(c) A – (p), B – (r), C – (q)
(d) A – (q), B – (r), C – (p)

137. Match the Column-I with Column-II and mark the appropriate choice.

	Column-I		**Column-II**
(A)	Liquid $\rightleftharpoons$ Vapour	(p)	Saturated solution
(B)	Solid $\rightleftharpoons$ Liquid	(q)	Boiling point
(C)	Solid $\rightleftharpoons$ Vapour	(r)	Sublimation point
(D)	Solute (s) $\rightleftharpoons$ Solute (solution)	(s)	Melting point

(a) A – (p) ; B – (r) ; C – (q) ; D – (s)
(b) A – (q) ; B – (s) ; C – (r) ; D – (p)
(c) A – (s) ; B – (q) ; C – (p) ; D – (r)
(d) A – (r) ; B – (s) ; C – (q) ; D – (p)

138. Match the columns.

	Column-I (Reactions)		**Column-II (Effect of increase in pressure)**
(A)	$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$	(p)	Reaction proceed backward.
(B)	$CO(g) + \frac{1}{2}O_2(g) \rightleftharpoons CO_2(g)$	(q)	No effect on reaction.
(C)	$N_2O_4(g) \rightleftharpoons 2NO_2(g)$	(r)	Reaction proceed forward

(a) A – (q), B – (r), C – (p)
(b) A – (r), B – (q), C – (p)
(c) A – (p), B – (r), C – (q)
(d) A – (q), B – (p), C – (r)

139. Match the columns :

	Column-I		**Column-II**
(A)	$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)\ (t = 300°C)$	(p)	$\Delta n > 0$
(B)	$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)\ (t = 50°C)$	(q)	$K_P < K_C$
(C)	$C(s) + H_2O(g) \rightleftharpoons CO(g) + H_2(g)$	(r)	K_P not defined
(D)	$CH_3COOH(l) + C_2H_5OH(l) \rightleftharpoons CH_3COOC_2H_5(l) + H_2O(l)$	(s)	$\Delta n = 1$

(a) A – (q), B – (p), C – (s), D – (r)
(b) A – (p), B – (q), C – (r), D – (s)
(c) A – (r), B – (p), C – (s), D – (q)
(d) A – (s), B – (q), C – (p), D – (r)

140. Match the columns :

	Column-I		**Column-II**
(A)	For the equilibrium $NH_4I(s) \rightleftharpoons NH_3(g) + HI(g)$, if pressure is increased at equilibrium	(p)	Forward shift
(B)	For the equilibrium $N_2 + 3H_2 \rightleftharpoons 2NH_3$ If volume is increased at equilibrium	(q)	No change
(C)	For the equilibrium $H_2O(g) + CO(g) \rightleftharpoons H_2(g) + CO_2(g)$ inert gas is added at constant pressure at equilibrium	(r)	Backward shift
(D)	For the equilibrium $PCl_5 \rightleftharpoons PCl_3 + Cl_2$ what happens if more PCl_5 is added	(s)	More N_2 and H_2 is formed.

(a) A – (p), B – (q), C – (r), D – (s)
(b) A – (r), B – (s), C – (q), D – (p)
(c) A – (s), B – (p), C – (q), D – (r)
(d) A – (q), B – (s), C – (r), D – (p)

141. Match the columns

	Column-I		**Column-II**
(A)	$Q_c < K_c$,	(p)	Net reaction goes from right to left.
(B)	$Q_c > K_c$,	(q)	Net reaction goes from left to right.
(C)	$Q_c = K_c$,	(r)	No net reaction occurs.

(a) A – (p), B – (q), C – (r)
(b) A – (r), B – (q), C – (p)
(c) A – (p), B – (r), C – (q)
(d) A – (q), B – (p), C – (r)

142. Match the columns

	Column-I		Column-II
(A)	Hydrochloric acid	(p)	Lemon and orange
(B)	Acetic acid	(q)	Tamarind paste.
(C)	Citric and ascorbic acids	(r)	Digestive juice
(D)	Tartaric acid	(s)	Constituent of vinegar

(a) A – (q), B – (r), C – (p), D – (s)
(b) A – (r), B – (s), C – (p), D – (q)
(c) A – (s), B – (p), C – (q), D – (r)
(d) A – (r), B – (p), C – (s), D – (q)

143. Match the columns

	Column-I		Column-II
(A)	$HClO_4$	(p)	Strong base
(B)	HNO_2	(q)	Strong acid
(C)	NH_2^-	(r)	Weak base
(D)	HSO_4^-	(s)	Weak acid

(a) A – (s), B – (q), C – (p), D – (r)
(b) A – (q), B – (s), C – (p), D – (r)
(c) A – (r), B – (p), C – (q), D – (s)
(d) A – (s), B – (q), C – (p), D – (r)

ASSERTION-REASON TYPE QUESTIONS

Directions : Each of these questions contain two statements, Assertion and Reason. Each of these questions also has four alternative choices, only one of which is the correct answer. You have to select one of the codes (a), (b), (c) and (d) given below.

(a) Assertion is correct, reason is correct; reason is a correct explanation for assertion.
(b) Assertion is correct, reason is correct; reason is not a correct explanation for assertion
(c) Assertion is correct, reason is incorrect
(d) Assertion is incorrect, reason is correct.

144. Assertion : K_p can be less than, greater than or equal to K_c.
Reason : Relation between K_p and K_c depends on the change in number of moles of gaseous reactants and products (Δn).

145. Assertion : If a volume is kept constant and an inert gas such as argon is added which does not take part in the reaction, the equilibrium remains undisturbed.
Reason : It is because the addition of an inert gas at constant volume does not change the partial pressure or the molar concentrations of the substance involved in the reaction.

146. Assertion : Buffer system of carbonic acid and sodium bicarbonate is used for the precipitation of hydroxides of third group elements.
Reason : It maintains the pH to a constant value, about 7.4.

147. Assertion : Addition of silver ions to a mixture of aqueous sodium chloride and sodium bromide solution will first precipitate AgBr rather than AgCl.
Reason : K_{sp} of AgCl > K_{sp} of AgBr.

CRITICAL THINKING TYPE QUESTIONS

148. $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g), K_1$ (1)
$N_2(g) + O_2(g) \rightleftharpoons 2NO(g), K_2$ (2)
$H_2(g) + \frac{1}{2}O_2(g) \rightleftharpoons H_2O(g), K_3$ (3)

The equation for the equilibrium constant of the reaction
$2NH_3(g) + \frac{5}{2}O_2(g) \rightleftharpoons 2NO(g) + 3H_2O(g), (K_4)$ in terms of K_1, K_2 and K_3 is :

(a) $\frac{K_1.K_2}{K_3}$ (b) $\frac{K_1.K_3^2}{K_2}$
(c) $K_1 K_2 K_3$ (d) $\frac{K_2.K_3^3}{K_1}$

149. Two equilibria, $AB \rightleftharpoons A^+ + B^-$ and $AB + B^- \rightleftharpoons AB_2^-$ are simultaneously maintained in a solution with equilibrium constants, K_1 and K_2 respectively. The ratio of $[A^+]$ to $[AB_2^-]$ in the solution is
(a) directly proportional to $[B^-]$
(b) inversely proportional to $[B^-]$
(c) directly proportional to the square of $[B^-]$
(d) inversely proportional to the square of $[B^-]$

150. Equilibrium constant (K) for the reaction
$Ni(s) + 4CO(g) \rightleftharpoons Ni(CO)_4(g)$ can be written in terms of
(1) $Ni(s) + 2CO_2(g) + 2C(s) \rightleftharpoons Ni(CO)_4(g)$;
equilibrium constant = K_1.
(2) $CO_2(g) + C(s) \rightleftharpoons 2CO(g)$;
equilibrium constant = K_2.
What is the relation between K, K_2 and K_2 ?
(a) $K = (K_1)/(K_2)^2$ (b) $K = (K_1 . K_2)$
(c) $K = (K_1)(K_2)^2$ (d) $K = K_1/K_2$

151. K_1, K_2 and K_3 are the equilibrium constants of the following reactions (I), (II) and (III) respectively:
(I) $N_2 + 2O_2 \rightleftharpoons 2NO_2$
(II) $2NO_2 \rightleftharpoons N_2 + 2O_2$
(III) $NO_2 \rightleftharpoons \frac{1}{2}N_2 + O_2$

The correct relation from the following is

(a) $K_1 = \frac{1}{K_2} = \frac{1}{K_3}$ (b) $K_1 = \frac{1}{K_2} = \frac{1}{(K_3)^2}$
(c) $K_1 = \sqrt{K_2} = K_3$ (d) $K_1 = \frac{1}{K_2} = K_3$

152. For the following three reactions a, b and c, equilibrium constants are given:

(i) $CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g); K_1$

(ii) $CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g); K_2$

(iii) $CH_4(g) + 2H_2O(g) \rightleftharpoons CO_2(g) + 4H_2(g); K_3$

(a) $K_1\sqrt{K_2} = K_3$ (b) $K_2K_3 = K_1$

(c) $K_3 = K_1 K_2$ (d) $K_3.K_2^3 = K_1^2$

153. The value of equilibrium constant of the reaction

$HI(g) \rightleftharpoons \frac{1}{2}H_2(g) + \frac{1}{2}I_2$ is 8.0

The equilibrium constant of the reaction

$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$ will be:

(a) $\frac{1}{16}$ (b) $\frac{1}{64}$

(c) 16 (d) $\frac{1}{8}$

154. For the reversible reaction,

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ at 500°C, the value of K_p is 1.44×10^{-5} when partial pressure is measured in atmospheres. The corresponding value of K_C, with concentration in mole litre^{-1}, is

(a) $\frac{1.44\times10^{-5}}{(0.082\times500^{-2})}$ (b) $\frac{1.44\times10^{-5}}{(8.314\times773^{-2})}$

(c) $\frac{1.44\times10^{-5}}{(0.082\times773^{2})}$ (d) $\frac{1.44\times10^{-5}}{(0.082\times773^{-2})}$

155. Two moles of PCl_5 were heated in a closed vessel of 2L. At equilibrium 40% of PCl_5 is dissociated into PCl_3 and Cl_2. The value of equilibrium constant is

(a) 0.53 (b) 0.267

(c) 2.63 (d) 5.3

156. PCl_5 is dissociating 50% at 250°C at a total pressure of P atm. If equilibrium constant is K_p, then which of the following relation is numerically correct ?

(a) $K_p = 3P$ (b) $P = 3K_p$

(c) $P = \frac{2K_P}{3}$ (d) $K_p = \frac{2P}{3}$

157. For the decomposition of the compound, represented as

$NH_2COONH_4(s) \rightleftharpoons 2NH_3(g) + CO_2(g)$

the $K_p = 2.9 \times 10^{-5}$ atm^3.

If the reaction is started with 1 mol of the compound, the total pressure at equilibrium would be :

(a) 1.94×10^{-2} atm (b) 5.82×10^{-2} atm

(c) 7.66×10^{-2} atm (d) 38.8×10^{-2} atm

158. The values of Kp_1 and Kp_2 for the reactions

$X \rightleftharpoons Y + Z$ ...(1)

and $A \rightleftharpoons 2B$ ...(2)

are in the ratio of 9 : 1. If degree of dissociation of X and A be equal, then total pressure at equilibrium (1) and (2) are in the ratio :

(a) 3 : 1 (b) 1 : 9

(c) 36 : 1 (d) 1 : 1

159. The dissociation equilibrium of a gas AB_2 can be represented as :

$2AB_2(g) \rightleftharpoons 2AB(g) + B_2(g)$

The degree of dissociation is 'x' and is small compared to 1. The expression relating the degree of dissociation (x) with equilibrium constant K_p and total pressure P is :

(a) $(2K_p/P)$ (b) $(2K_p/P)^{1/3}$

(c) $(2K_p/P)^{1/2}$ (d) (K_p/P)

160. On increasing the pressure, the gas phase reaction proceed forward to re-establish equilibrium, as predicted by applying the Le Chatelier's principle. Consider the reaction.

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

Which of the following is correct, if the total pressure at which the equilibrium is established, is increased without changing the temperature?

(a) K will remain same

(b) K will decrease

(c) K will increase

(d) K will increase initially and decrease when pressure is very high

161. The exothermic formation of ClF_3 is represented by the equation :

$Cl_2(g) + 3F_2(g) \rightleftharpoons 2ClF_3(g)$;

$\Delta H = -329$ kJ

Which of the following will increase the quantity of ClF_3 in an equilibrium mixture of Cl_2, F_2 and ClF_3 ?

(a) Adding F_2

(b) Increasing the volume of the container

(c) Removing Cl_2

(d) Increasing the temperature

162. When hydrochloric acid is added to cobalt nitrate solution at room temperature, the following reaction takes place out the reaction mixture becomes blue. On cooling the mixture it becomes pink. On the basis of this information mark the correct answer.

$$\underset{\text{(pink)}}{[CO(H_2O_6]^{3+}}(aq) + 4Cl^-(aq) \rightleftharpoons \underset{\text{(blue)}}{[COCl_4]^{2-}}(aq) + 6H_2O(l)$$

(a) $\Delta H > 0$ for the reaction

(b) $\Delta H < 0$ for the reaction

(c) $\Delta H = 0$ for the reaction

(d) The sign of ΔH cannot be predicted on the basis of this information.

163. In HS^-, I^-, RNH_2 and NH_3, order of proton accepting tendency will be
(a) $I^- > NH_3 > RNH_2 > HS^-$
(b) $HS^- > RNH_2 > NH_3 > I^-$
(c) $RNH_2 > NH_3 > HS^- > I^-$
(d) $NH_3 > RNH_2 > HS^- > I^-$

164. Which equilibrium can be described as an acid-base reaction using the Lewis acid-base definition but not using the Bronsted-Lowry definition?
(a) $2NH_3 + H_2SO_4 \rightleftharpoons 2NH_4^+ + SO_4^{2-}$
(b) $NH_3 + CH_3COOH \rightleftharpoons NH_4^+ + CH_3COO^-$
(c) $H_2O + CH_3COOH \rightleftharpoons H_3O^+ + CH_3COO^-$
(d) $[Cu(H_2O)_4]^{2-} + 4NH_3 \rightleftharpoons [Cu(NH_3)_4]^{2+} + 4H_2O$

165. Equal volumes of three acid solutions of pH 3, 4 and 5 are mixed in a vessel. What will be the H^+ ion concentration in the mixture ?
(a) 1.11×10^{-4} M (b) 3.7×10^{-4} M
(c) 3.7×10^{-3} M (d) 1.11×10^{-3} M

166. The pH of 10^{-10} M NaOH solution is nearest to:
(a) 6 (b) – 10
(c) 4 (d) 7

167. 100 mL of 0.04 N HCl aqueous solution is mixed with 100 mL of 0.02 N NaOH solution. The pH of the resulting solution is:
(a) 1.0 (b) 1.7
(c) 2.0 (d) 2.3

168. Equal volumes of three acid solutions of pH 3, 4 and 5 are mixed in a vessel. What will be the H^+ ion concentration in the mixture ?
(a) 1.11×10^{-4} M (b) 3.7×10^{-4} M
(c) 3.7×10^{-3} M (d) 1.11×10^{-3} M

169. At 100°C the K_w of water is 55 times its value at 25°C. What will be the pH of neutral solution? (log 55 = 1.74)
(a) 6.13 (b) 7.00
(c) 7.87 (d) 5.13

170. Ionisation constant of CH_3COOH is 1.7×10^{-5} if concentration of H^+ ions is 3.4×10^{-4}M, then find out initial concentration of CH_3COOH molecules
(a) 3.4×10^{-4}M (b) 3.4×10^{-3}M
(c) 6.8×10^{-3}M (d) 6.8×10^{-4}M

171. Values of dissociation constant, K_a are given as follows :

Acid	K_a
HCN	6.2×10^{-10}
HF	7.2×10^{-4}
HNO_2	4.0×10^{-4}

Correct order of increasing base strength of the base CN^-, F^- and NO_2^- will be :
(a) $F^- < CN^- < NO_2^-$ (b) $NO_2^- < CN^- < F^-$
(c) $F^- < NO_2^- < CN^-$ (d) $NO_2^- < F^- < CN^-$

172. The dissociation constants for acetic acid and HCN at 25°C are 1.5×10^{-5} and 4.5×10^{-10} respectively. The equilibrium constant for the equilibrium
$CN^- + CH_3COOH \rightleftharpoons HCN + CH_3COO^-$ would be:
(a) 3.0×10^{-5} (b) 3.0×10^{-4}
(c) 3.0×10^{4} (d) 3.0×10^{5}

173. If degree of dissociation of pure water at 100°C is 1.8×10^{-8}, then the dissociation constant of water will be (density of H_2O = 1 gm/cc)
(a) 1×10^{-12} (b) 1×10^{-14}
(c) 1.8×10^{-12} (d) 1.8×10^{-14}

174. Ionisation of weak acid can be calculated by the formula
(a) $100\sqrt{\frac{K_a}{c}}$ (b) $\frac{100}{1+10^{(pK_a-pH)}}$
(c) Both (a) and (b) (d) None of these

175. Equimolar solutions of the following were prepared in water separately. Which one of the solutions will record the highest pH ?
(a) $SrCl_2$ (b) $BaCl_2$
(c) $MgCl_2$ (d) $CaCl_2$

176. Solubility product constant (K_{sp}) of salts of types MX, MX_2 and M_3X at temperature T are 4.0×10^{-8}, 3.2×10^{-14} and 2.7×10^{-15}, respectively. Solubilities (mol dm^{-3}) of the salts at temperature 'T' are in the order –
(a) $MX > MX_2 > M_3X$ (b) $M_3X > MX_2 > MX$
(c) $MX_2 > M_3X > MX$ (d) $MX > M_3X > MX_2$

177. In qualitative analysis, the metals of Group I can be separated from other ions by precipitating them as chloride salts. A solution initially contains Ag^+ and Pb^{2+} at a concentration of 0.10 M. Aqueous HCl is added to this solution until the Cl^- concentration is 0.10 M. What will the concentrations of Ag^+ and Pb^{2+} be at equilibrium?
(K_{sp} for AgCl = 1.8×10^{-10}, K_{sp} for $PbCl_2 = 1.7 \times 10^{-5}$)
(a) $[Ag^+] = 1.8 \times 10^{-7}$ M ; $[Pb^{2+}] = 1.7 \times 10^{-6}$ M
(b) $[Ag^+] = 1.8 \times 10^{-11}$ M ; $[Pb^{2+}] = 8.5 \times 10^{-5}$ M
(c) $[Ag^+] = 1.8 \times 10^{-9}$ M ; $[Pb^{2+}] = 1.7 \times 10^{-3}$ M
(d) $[Ag^+] = 1.8 \times 10^{-11}$ M ; $[Pb^{2+}] = 8.5 \times 10^{-4}$ M

178. The solubility product (K_{sp}) of the following compounds are given at 25°C.

Compound	K_{sp}
AgCl	1.1×10^{-10}
AgI	1.0×10^{-16}
$PbCrO_4$	4.0×10^{-14}
Ag_2CO_3	8.0×10^{-12}

The most soluble and least soluble compounds are respectively.
(a) AgCl and $PbCrO_4$ (b) AgI and Ag_2CO_3
(c) AgCl and Ag_2CO_3 (d) Ag_2CO_3 and AgI

179. What is the molar solubility of $Fe(OH)_3$ if $K_{sp} = 1.0 \times 10^{-38}$?
(a) 3.16×10^{-10} (b) 1.386×10^{-10}
(c) 1.45×10^{-9} (d) 1.12×10^{-11}

HINTS AND SOLUTIONS

FACT/DEFINITION TYPE QUESTIONS

1. **(c)** **2.** **(c)** **3.** **(b)**

4. **(d)** The time taken for complete evaporation depends on (i) the nature of the liquid, (ii) the amount of the liquid and (iii) the temperature.

5. **(c)** When the watch glass is open to the atmosphere, the rate of evaporation remains constant but the molecules are dispersed into large volume of the room. As a consequence the rate of condensation from vapour to liquid state is much less than the rate of evaporation.

6. **(c)** Ice melts with a reduction in volume. So Increase in pressure shifts equilibrium to water side, result in melting of ice according to Lechatelier's principle.

7. **(a)** A reaction is said to be in equilibrium when rate of forward reaction is equal to the rate of backward reaction.

8. **(c)**

9. **(b)** The reaction mixtures starting either with H_2 or D_2 reach equilibrium with the same composition, except that D_2 and ND_3 are present instead of H_2 and NH_3.

10. **(a)** Equilibrium can be attained by either side of the reactions of equilibrium.

11. **(d)** According to the idea of dynamic equilibrium there is possibility of formation of all product.

12. **(b)** At equilibrium, the rate of forward and backward reactions is equal.

13. **(a)** For reation (1)

$$K_1 = \frac{[NO]^2}{[N_2][O_2]}$$

and for reaction (2)

$$K_2 = \frac{[N_2]^{1/2}[O_2]^{1/2}}{[NO]} \text{ therefore } K_1 = \frac{1}{K_2^2}$$

14. **(c)** $N_2 + 3H_2 \rightleftharpoons 2NH_3$

$\therefore\ K = [NH_3]^2 / [N_2][H_2]^3$ ....(i)

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

$\therefore\ K' = [NH_3]/[N_2]^{1/2}[H_2]^{3/2}$ ....(ii)

Dividing equation (i) by equation (ii), we get $K' = \sqrt{K}$

15. **(b)** Given reaction, $2A \rightleftharpoons B + C$

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

$$K_c = \frac{2\times10^{-3}\times3\times10^{-3}}{(10^{-3})^2} = 6$$

16. **(c)** $A_2 + B_2 \rightleftharpoons 2AB \quad K_c = \frac{[AB]^2}{[A_2][B_2]}$

$$K_c = \frac{(2.8\times10^{-3})^2}{3\times10^{-3}\times4.2\times10^{-3}} = \frac{(2.8)^2}{3\times4.2} = 0.62$$

17. **(c)**

$$\begin{array}{lcccc} & A & + B & \rightleftharpoons C & + D \\ \text{At eqb.} & x & x & 2x & 2x \end{array}$$

$$K_c = \frac{2x.2x}{x.x} = 4$$

18. **(a)** For $A + B \rightleftharpoons C,\ \Delta n = 1 - 2 = -1$

$$\text{Unit of } K_c = \left[\frac{mol}{litre}\right]^{\Delta n} = \left[\frac{mol}{litre}\right]^{-1}$$

$$= \text{Litre mole}^{-1}$$

19. **(c)** $K_p = \frac{P^2CO}{PCO_2}; K_p = \frac{4\times4}{2} = 8;\ C(s) = 1;$

The concentration of solids and liquids are taken as unity.

20. **(d)** $2C(s) + O_2(g) \rightleftharpoons 2CO_2(g)$

$\Delta n = 2 - 1 = +1$

$\therefore$ K_c and K_p are not equal.

21. **(b)** For a gaseous phase reaction K_p and K_c are related as

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

For the given reaction,

$$CO(g) + \frac{1}{2}O_2(g) \rightarrow CO_2(g)$$

$$\Delta n_g = 1 - (1 + 0.5) = -0.5 \text{ or } -\frac{1}{2}$$

$$\therefore\ K_p = K_c(RT)^{-\frac{1}{2}}$$

$$\text{or } \frac{K_p}{K_c} = (RT)^{-\frac{1}{2}}$$

22. **(c)** Using the relation $K_P = K_C.(RT)^{\Delta n}$, we get

$$\frac{K_P}{K_C} = (RT)^{\Delta n}$$

Thus $\frac{K_P}{K_C}$ will be highest for the reaction having highest value of Δn.

The Δn values for various reactions are

(a) $\Delta n = 1 - \left(1 + \frac{1}{2}\right) = -\frac{1}{2}$

(b) $\Delta n = 2 - (1+1) = 0$

(c) $\Delta n = (1+1) - 1 = 1$

(d) $\Delta n = (2+4) - (7+2) = -3$

Thus maximum value of $\Delta n = 1$

23. **(c)** As $K_p = K_c\ RT^{\Delta n_g}$
Here $\Delta n_g = 1$
So, $K_p = K_c$ when RT = 1
Thus T = 12.5 K

24. **(b)** $3Fe(s) + 4H_2O\,(steam) \rightleftharpoons Fe_3O_4\,(s) + 4\,H_2\,(g)$

$K_p = \frac{(p_{H_2})^4}{(p_{H_2O})^4}$ only gaseous products and reactants.

25. **(b)** $C(s) + CO_2(g) \longrightarrow 2CO(g)$
Apply law of mass action,

$$K_P = \frac{(P_{CO})^2}{P_{CO_2}} \text{ or } 63 = \frac{(10P_{CO_2})^2}{P_{CO_2}}$$

(Given $K_P = 65$) and $P_{CO} = 10P_{CO_2}$

$$\text{or } 63 = \frac{100(P_{CO_2})^2}{P_{CO_2}} \text{ or } 63 = 100\ P_{CO_2}$$

$$P_{CO_2} = \frac{63}{100} = 0.63 \text{ atm}$$

$$P_{CO} = 10P_{CO_2} = 10 \times 0.63 = 6.3 \text{ atm}$$

$$P_{total} = P_{CO_2} + P_{CO} = 0.63 + 6.3 = 6.93 \text{ atm.}$$

26. **(d)** Rate constant of forward reaction (K_f) = 1.1×10^{-2} and rate constant of backward reaction (K_b) = 1.5×10^{-3} per minute.

Equilibrium constant (K_c) $= \frac{K_f}{K_b} = \frac{1.1 \times 10^{-2}}{1.5 \times 10^{-3}} = 7.33$

27. **(a)** $MgCO_3(s) \rightarrow MgO(s) + CO_2(g)$
MgO & $MgCO_3$ are solid and they donot exert any pressure and hence only pressure exerted is by CO_2.
Therefore $K_P = P_{CO_2}$

28. **(a)** All the reactants and products are in same physical state.

29. **(a)** $K = \frac{[Ni(CO)_4]}{[CO]^4} = \frac{mol\ l^{-1}}{(mol\ l^{-1})^4} = (mol\ l^{-1})^{-3}$

30. **(b)** For the reaction
$CaCO_3\,(s) \rightleftharpoons CaO\,(s) + CO_2\,(g)$
On the basis of the stoichiometric equation, we can write,
K_c=[CaO(s)] [CO_2(g)/[$CaCO_3$(s)]
Since [$CaCO_3$(s)] and [CaO(s)] are both constant, therefore modified equilibrium constant for the thermal decomposition of calcium carbonate will be
$K_c' = [CO_2(g)]$
$K p = [p\, CO_2(g)]$

31. **(d)** Equilibrium constant (K) is independent of concentrations of reactions and products.

32. **(a)** Equilibrium constant is not effected by change in conditions like P and V. These changes can change only the time required to attain equilibrium.

33. **(b)** Reaction proceed forward according to Le-chatelier's principle.

34. **(b)**

35. **(d)** For reaction to proceed from right to left
$Q > K_c$ i.e the reaction will be fast in backward direction i.e $r_b > r_f$

36. **(b)** The equilibrium constant helps in predicting the direction in which a given reaction will proceed at any stage. For this purpose, we calculate the reaction quotient Q. The reaction quotient Q (Q_c with molar concentration and Q_p with partial pressures) is defined in the same way as the equilibrium constant K_c except that the concentrations in Q_c are not necessary equilibrium values.

37. **(d)**

38. **(c)** Both (a) and (b) are correct for the equation,
$K = e^{-\Delta G^{\ominus}/RT}$

39. **(c)** $\Delta G = -2.303\ RT \log K$
$-nFE° = -2.303\ RT \log K$

$$\log K = \frac{nFE°(I)}{2.303\ RT}$$

$$= 0.4342 \frac{nFE°}{RT} \qquad \text{........ (i)}$$

$$\ln K = \frac{nFE°}{RT}$$

$$K = e^{\frac{-nFE°}{RT}} \qquad \text{....... (ii)}$$

40. **(d)** Solid $\rightleftharpoons$ Liquid
It is an endothermic process. So when temperature is raised, more liquid is formed. Hence adding heat will shift the equilbrium in the forward direction.

41. **(d)** According to Le-chatelier's principle" whenever a constraint is applied to a system in equilibrium, the system tends to readjust so as to nullify the effect of the constraint.

42. **(b)** The most favourable conditions are :
(i) High pressure ($\Delta n < 0$)
(ii) Low temperature (Exothermic reaction)
(iii) Catalyst Fe is presence of Mo.

43. **(c)** As in this no. of moles are increasing hence low pressure will favour the forward direction.
$\Delta n = (1+1) - 1 = 1$

44. **(a)** For $\Delta n = 0$, no effect of pressure.

45. **(a)** Melting of ice involve absorption of heat i.e Endothermic hence high temperature favour the process.

Further for a given mass volume of water is less than ice thus high pressure favour the process. High pressure and high temperature convert ice into liquid.

46. **(d)**

47. **(b)** Le chatelier principle is not applicable to solid-solid equilibrium.

48. **(c)** Effect of increase of temperature on equilibrium constant depends on the fact that whether the reaction is exothermic, or endothermic. If the reaction is exothermic, it is favoured by low temperature and if the reaction is endothermic, it is favoured by high temperature.

49. **(d)** $A_2(g)+B_2(g) \underset{\text{step-1}}{\rightleftharpoons} 3C(g) \underset{\text{step-2}}{\rightleftharpoons} D(g)$

since the steps 1 and 2 are exothermic hence low temprature will favour both the reactions. In step - 1 moles are increasing hence low pressure will favour it. In step 2 moles are decreasing, hence high pressure will favour it.

50. **(a)** On adding inert gas at constant volume the total pressure of the system is increased, but the partial pressure of each reactant and product remains the same. Hence no effect on the state of equilibrium.

51. **(c)** The backward reaction is not favoured at high pressure.

52. **(c)** A catalyst increases the rate of the chemical reaction by making available a new low energy pathway for the conversion of reactants to products. It increases the rate of forward and reverse reaction that pass through the same transition state and does not affect equilibrium.

Catalyst lowers the activation energy for the forward and reverse reactions by exactly the same amount.

53. **(c)** An aqueous solution of sodium chloride is comprised entirely of sodium ions and chloride ions, while that of acetic acid mainly contains unionized acetic acid molecules and only some acetate ions and hydronium ions. This is because there is almost 100% ionization in case of sodium chloride which is a strong electrolyte as compared to less than 5% ionization of acetic acid which is a weak electrolyte.

54. **(c)** The hydronium ion has a trigonal pyramidal geometry and is composed of three hydrogen atoms and one oxygen atom. There is a lone pair of electrons on the oxygen giving it this shape. The bond angle between the atoms is 113°.

55. **(d)**

56. **(b)** According to Arrhenius, acids are those substances which give proton in aqueous solution, hence gaseous HCl is not an Arrhenius acid.

57. **(d)** Base accepts protons and acid donates protons.

58. **(c)** Lewis concept.

59. **(c)** $H_2CO_3 \rightleftharpoons H^+ + HCO_3^- \rightleftharpoons H^+ + CO_3^{-\cdot}$

HCO_3^- can donate and accept H^+.

60. **(b)** Because NH_3 after losing a proton (H^+) gives NH_2^-

$NH_3 + H_2O \rightleftharpoons NH_2^- + H_3O^+$

(Conjugate acid-base pair differ only by a proton)

61. **(c)** Lewis acid is that compound which have electron deficiency. eg. BF_3, $SnCl_2$.

62. **(d)** $(CH_3)_3$ B - is an electron deficient, thus behave as a lewis acid.

63. **(c)** Boron in B_2H_6 is electron deficient

64. **(b)** BF_3 is Lewis acid (e^- pair acceptor)

65. **(c)** HSO_4^- accepts a proton to form H_2SO_4.

Thus H_2SO_4 is the conjugate acid of HSO_4^-.

$$\underset{\text{base}}{HSO_4^-} \xrightarrow{+H^+} \underset{\substack{\text{conjugate acid}\\ \text{of } HSO_4^-}}{H_2SO_4}$$

66. **(a)** Bronsted base is a substance which accepts proton. In option (a), H_2O is accepting proton, i.e., acting as a base.

67. **(c)**

68 **(a)** (i) $\underset{\text{acid}_1}{H_3PO_4} + \underset{\text{base}_2}{H_2O} \longrightarrow \underset{\text{acid}_2}{H_3O^+} + \underset{\text{base}_1}{H_2PO_4^-}$

(ii) $\underset{\text{acid}_1}{H_2PO_4^-} + \underset{\text{base}_2}{H_2O} \longrightarrow \underset{\text{base}_1}{HPO_4^{--}} + \underset{\text{acid}_2}{H_3O^+}$

(iii) $\underset{\text{base}_1}{H_2PO_4^-} + \underset{\text{acid}_2}{OH^-} \longrightarrow \underset{\text{acid}_1}{H_3PO_4} + \underset{\text{base}_2}{O^{--}}$

Hence only in (ii) reaction $H_2PO_4^-$ is acting as an acid.

69. **(b)** The value of ionic product of water changes with the temperature.

70. **(a)** **Given :** Hydroxyl ion concentration

$[OH^-] = 0.05 \text{ mol L}^{-1}$. We know that

$[H^+][OH^-] = 1 \times 10^{-14}$

or $[H^+] = \dfrac{1\times10^{-14}}{0.05} = 2\times10^{-13} \text{ mol L}^{-1}$

We also know that

$$pH = -\log[H^+] = -\log[2\times10^{-13}]$$

$$= -\log 2 - \log 10^{-13} = -\log 2 - (-13)\log 10$$

$$= -0.3010 + 13.0000 = 12.6990.$$

Since the value of pH > 7, therefore the solution is basic.

71. **(b)**

72. **(b)** $pH = -\log[H^+] = \log\left[\dfrac{1}{H^+}\right]$

73. **(c)** On dilution $[H^+] = 10^{-6}\,M = 10^{-6}$ mol

Now dissociation of water cannot be neglected,

Total $[H^+] = 10^{-6} + 10^{-7} = 11 \times 10^{-7}$

$pH = -\log[H^+]$

$= -\log(11\times10^{-7}) = 5.98$

74. **(d)** $\because pH = 1\ ;\ H^+ = 10^{-1} = 0.1\ M$

$pH = 2\ ; H^+ = 10^{-2} = 0.01\ M$

$\therefore M_1 = 0.1 \quad V_1 = 1$

$M_2 = 0.01 \quad V_2 = ?$

From
$M_1V_1 = M_2V_2$
$0.1 \times 1 = 0.01 \times V_2$
$V_2 = 10$ litres
$\therefore$ Volume of water added $= 10 - 1 = 9$ litres

75. **(b)** Given $[OH^-] = 10^{-3}$
$\therefore \quad pOH = 3$
$\because pH + pOH = 14$
$\therefore pH = 14 - 3 = 11$

76. **(a)** Given $[H_3O^+] = 1 \times 10^{-10}$ M
at 25° $[H_3O^+][OH^-] = 10^{-14}$

$$\therefore [OH^-] = \frac{10^{-14}}{10^{-10}} = 10^{-4}$$

Now, $[OH^-] = 10^{-p^{OH}} = 10^{-4} = 10^{-p^{OH}}$
$\therefore p^{OH} = 4$

77. **(a)** Molarity (M) = 10M. HCl is a strong acid and it is completely dissociated in aqueous solutions as : HCl (10) $\rightleftharpoons H^+(10) + Cl^-$.
So, for every moles of HCl, there is one H^+. Therefore $[H^+] = [HCl]$ or $[H^+] = 10$.
$pH = -\log[H^+] = -\log[10] = -1$.

78. **(d)** No. of moles of NaOH $= \dfrac{4}{40} = 0.1$
[Molecular weight of NaOH = 40]
No. of moles of $OH^- = 0.1$

$$\text{Concentration of } OH^- = \frac{0.1}{1 \text{ litre}} = 0.1 \text{Mole/L}$$

As we know that, $[H^+][OH^-] = 10^{-14}$

$\therefore [H^+] = 10^{-13} \qquad (\because OH^- = 10^{-1})$

79. **(a)** Given $[H_3O^+] = 1 \times 10^{-10}$ M
at 25° $[H_3O^+][OH^-] = 10^{-14}$

$$\therefore [OH^-] = \frac{10^{-14}}{10^{-10}} = 10^{-4}$$

Now, $[OH^-] = 10^{-p^{OH}} = 10^{-4} = 10^{-p^{OH}}$
$\therefore p^{OH} = 4$

80. **(c)** $H_2SO_4 \rightleftharpoons 2H^+ + SO_4^{2-}$
Given concentration of $H_2SO_4 = 0.005$ M
$\therefore \quad [H^+] = 0.005 \times 2 = 0.01 = 10^{-2}$
$pH = -\log[H^+] = -\log 10^{-2} = 2$

81. **(a)** $pOH = -\log[OH^-]$
$pH + pOH = 14$
For 10^{-4} KOH, $[OH^-] = 10^{-4}$
$pOH = -\log[OH^-] = -\log 10^{-4} = 4$
$pH = 14 - pOH = 10$

82. **(d)** Among M/4 KOH, M/4 NaOH, M/4 NH_4OH and M/4 $Ca(OH)_2$, $Ca(OH)_2$ furnishes highest number of OH^- ions $\quad (\because Ca(OH)_2 \longrightarrow Ca^{2+} + 2OH^-)$.
So pH of M/4 $Ca(OH)_2$ is highest.

83. **(a)** Given $K_a = 1.00 \times 10^{-5}$, C = 0.100 mol
for a weak electrolyte,
degree of dissociation

$$(\alpha) = \sqrt{\frac{K_a}{C}} = \sqrt{\frac{1 \times 10^{-5}}{0.100}} = 10^{-2} = 1\%$$

84. **(b)** $HA \longrightarrow H^+ + A^-$

$$K_a = \frac{[H^+][A^-]}{[HA]}, \quad \because [H^+] = 10^{-pH}$$

$\therefore [H^+] = 10^{-5}$; and at equilibrium $[H^+] = [A^-]$

$$\therefore K_a = \frac{10^{-5} \times 10^{-5}}{0.0015} = 2 \times 10^{-8}$$

$$\alpha = \sqrt{\frac{K_a}{C}} = \sqrt{\frac{2 \times 10^{-8}}{.005}} = \sqrt{4 \times 10^{-6}} = 2 \times 10^{-3}$$

Percentage ionization = 0.2

85. **(c)** $M_1V_1 = M_2V_2$
$1 \times 0.10 = M_2 \times 100$
$M_2 = 0.001 = 10^{-3}$

$$\begin{array}{ccc} BOH & \rightleftharpoons & B^+ + OH^- \\ C & & 0 \quad\ \ 0 \\ C(1-\alpha) & & C\alpha \quad C\alpha \end{array}$$

$$K_b = \frac{C\alpha \times C\alpha}{C(1-\alpha)}$$

$K_b = C\alpha^2 \qquad (\because 1 - \alpha \approx 1)$

$\alpha = \sqrt{K_b / C}$

$$[OH^-] = C\alpha = \sqrt{\frac{K_b}{C}} \times C = \sqrt{K_bC}$$

$= \sqrt{10^{-5} \times 10^{-3}} = 10^{-4}$
$\therefore pH + pOH = 14$
$\therefore pH = 14 - 4 = 10$

86. **(d)**

87. **(d)** $H_2A \rightleftharpoons H^+ + HA^-$

$$\therefore K_1 = 1.0 \times 10^{-5} = \frac{[H^+][HA^-]}{[H_2A]} \text{(Given)}$$

$HA^- \longrightarrow H^+ + A^{--}$

$$\therefore K_2 = 5.0 \times 10^{-10} = \frac{[H^+][A^{--}]}{[HA^-]} \text{(Given)}$$

$$K = \frac{[H^+]^2[A^{2-}]}{[H_2A]} = K_1 \times K_2$$

$= (1.0 \times 10^{-5}) \times (5 \times 10^{-10}) = 5 \times 10^{-15}$

88. **(b)** Acidic strength $\propto \sqrt{K_a}$

89. **(d)** Given $K_b = 1.0 \times 10^{-12}$

$[BOH] = 0.01\,M \qquad [OH] = ?$

$$\begin{array}{lccc} & BOH & \rightleftharpoons B^+ + & OH^- \\ t=o & c & 0 & 0 \\ t_{eq} & c(1-x) & cx & cx \end{array}$$

$$K_b = \frac{c^2x^2}{c(1-x)} = \frac{cx^2}{(1-x)} \Rightarrow 1.0 \times 10^{-12} = \frac{0.01x^2}{(1-x)}$$

On calculation, we get, $x = 1.0 \times 10^{-5}$

Now, $[OH^-] = cx = 0.01 \times 10^{-5} = 1 \times 10^{-7}\,\text{mol L}^{-1}$

90. **(b)** $pK_a = -\log K_a$

Smaller the value of pK_a, stronger will be acid

$\therefore$ Acid having pK_a value of 10^{-8} is strongest acid.

91. **(b)** $\frac{\alpha_1}{\alpha_2} = \sqrt{\frac{K_{a_1}}{K_{a_2}}} = \sqrt{\frac{3.14 \times 10^{-4}}{1.96 \times 10^{-5}}} = 4:1$

92. **(c)** $K_a = \frac{[H_3O^+][F^-]}{[HF]}$ ...(i)

$K_b = \frac{[HF][OH^-]}{[F^-]}$ ...(ii)

From (i) and (ii), $K_aK_b = [H_3O^+][OH^-] = K_w$
(ionic product of water)

93. **(a)** $K = c\alpha^2 = 0.1 \times \left(\frac{1.34}{100}\right)^2 = 1.8 \times 10^{-5}$

94. **(b)** In polyprotic acids the loss of second proton occurs much less readily than the first. Usually the K_a values for successive loss of protons from these acids differ by at least a factor of 10^{-3} i.e., $K_{a_1} > K_{a_2}$

$H_2X \rightleftharpoons H^+ + HX^- \ (K_{a_1})$

$HX^- \rightleftharpoons H^+ + X^{2-} \ (K_{a_2})$

95. **(a)** The values of dissociation constants for successive stages decrease.

96. **(a)**

97. **(a)** $NH_4Cl + H_2O \rightarrow NH_4OH + HCl$

or

$Cl^- + H_2O \rightleftharpoons HCl + H^+$ i.e., acidic

98. **(c)** Due to common ion effect addition of NH_4Cl in group (III) suppresses the ionisation of NH_4OH with the result concentration of OH^- decreases.

99. **(c)** Solubility of weak electrolyte decreases in solvent having common ion. So solubility of AgI in NaI solution is less than in pure water because of common ion effect.

100. **(b)** Dissociation of CH_3COOH is suppressed by the addition of sodium acetate (CH_3COONa) due to common ion (CH_3COO^-) effect. The $[H^+]$ decreases raising the pH of the acid solution.

Note : After the addition of CH_3COONa to CH_3COOH, a buffer solution is formed which has reserved pH value.

101. **(b)** CH_3COOH is weak acid while NaOH is strong base, so one equivalent of NaOH can not be neutralized with one equivalent of CH_3COOH. Hence the solution of one equivalent of each does not have pH value as 7. Its pH will be towards basic side as NaOH is a strong base hence conc. of OH^- will be more than the conc. of H^+.

102. **(a)** IVth group needs higher S^{2-} ion concentration. In presence of HCl, the dissociation of H_2S decreases hence produces less amount of sulphide ions due to common ion effect, thus HCl decreases the solubility of H_2S which is sufficient to precipitate IInd group radicals.

103. **(d)** A salt of strong base with weak acid undergoes anionic hydrolysis to give basic solution.

104. **(d)** Ferric chloride is the salt of a strong acid and a weak base, hence on hydrolysis it yields a mixture of weak base and strong acid

$$FeCl_3 + 3H_2O \rightarrow \underset{\text{weak base}}{Fe(OH)_3} + \underset{\text{strong acid}}{3HCl}$$

Due to this, there is predominance of H^+ ions in solution, hence the solution is acidic.

105. **(c)** In aqueous solution BA(salt) hydrolyses to give

$$BA + H_2O \rightleftharpoons \underset{\text{Base}}{BOH} + \underset{\text{acid}}{HA}$$

Now pH is given by

$$pH = \frac{1}{2}pK_w + \frac{1}{2}pKa - \frac{1}{2}pK_b$$

substituting given values, we get

$$pH = \frac{1}{2}(14 + 4.80 - 4.78) = 7.01$$

106. **(d)** For acidic buffer $pH = pK_a + \log\left[\frac{\text{salt}}{\text{acid}}\right]$

or $pH = pK_a + \log\frac{[A^-]}{[HA]}$

Given $pK_a = 4.5$ and acid is 50% ionised.

$[HA] = [A^-]$ (when acid is 50% ionised)

$\therefore pH = pK_a + \log 1$

$\therefore pH = pK_a = 4.5$

$pOH = 14 - pH = 14 - 4.5 = 9.5$

107. **(b)** Given $[NH_3] = 0.3\,M$, $[NH_4^+] = 0.2\,M$, $K_b = 1.8 \times 10^{-5}$.

$pOH = pK_b + \log\frac{[\text{salt}]}{[\text{base}]} \qquad [pK_b = -\log K_b;$

$pK_b = -\log 1.8 \times 10^{-5}]$

$\therefore pK_b = 4.74$

$$= 4.74 + \log\frac{0.2}{0.3} = 4.74 + 0.3010 - 0.4771 = 4.56$$

$pH = 14 - 4.56 = 9.436$

108. **(d)** $pH = pK_a + \log\left[\frac{\text{Salt}}{\text{Acid}}\right]$

$\log[H^+] = \log K_a - \log\left[\frac{\text{Salt}}{\text{Acid}}\right]$

$$\log\left[H^+\right] = \log K_a + \log\left[\frac{\text{Acid}}{\text{Salt}}\right]$$

$$\left[H^+\right] = K_a\left[\frac{\text{Acid}}{\text{Salt}}\right]$$

$$= 1.8 \times 10^{-5} \times \frac{0.1}{0.2} = 9 \times 10^{-6}\,\text{M}$$

109. (d) HNO_2 is a weak acid and $NaNO_2$ is salt of that weak acid and strong base (NaOH).

110. (a) Lets take an example of an acidic buffer CH_3COOH and CH_3COONa.

$CH_3COOH \rightleftharpoons CH_3COO^- + H^+$;

$CH_3COONa \rightleftharpoons CH_3COO^- + Na^+$

when few drops of HCl are added to this buffer, the H^+ of HCl immediatly combine with CH_3COO^- ions to form undissociated acetic acid molecules. Thus there will be no appreciable change in its pH value. Like wise if few drops of NaOH are added, the OH^- ions will combine with H^+ ions to form unionised water molecule. Thus pH of solution will remain constant.

111. (d) Buffering action is maximum when

$[\text{Salt}] = [\text{Acid}]$

i.e., $pH = pK_a$

112. (d) pH or $[H^+]$ of a buffer does not change with dilution.

113. (b) Solubility product is the product of ionic concentration in a saturated solution of an electrolyte at a given temperature.

114. (b) $Cr(OH)_3(s) \rightleftharpoons \underset{s}{Cr^{3+}(aq.)} + \underset{3s}{3OH^-(aq.)}$

$(s)\,(3s)^3 = K_{sp}$

$27S^4 = K_{sp}$

$$s = \left(\frac{K_{sp}}{27}\right)^{1/4} = \left(\frac{1.6 \times 10^{-30}}{27}\right)^{1/4}$$

115. (b) $Mg(OH)_2 \rightleftharpoons Mg^{++} + 2OH^-$

$K_{sp} = [Mg^{++}][OH^-]^2$

$1.0 \times 10^{-11} = 10^{-3} \times [OH^-]^2$

$$[OH^-] = \sqrt{\frac{10^{-11}}{10^{-3}}} = 10^{-4}$$

$\therefore$ pOH = 4

$\therefore$ pH + pOH = 14

$\therefore$ pH = 10

116. (b) Given pH = 12

or $[H^+] = 10^{-12}$

Since, $[H^+][OH^-] = 10^{-14}$

$$\therefore\ [OH^-] = \frac{10^{-14}}{10^{-12}} = 10^{-2}$$

$$Ba(OH)_2 \rightleftharpoons \underset{s}{Ba^{2+}} + \underset{2s}{2OH^-}$$

$[OH^-] = 10^{-2}$

$2s = 10^{-2}$

$$s = \frac{10^{-2}}{2}$$

$K_{sp} = 4s^3$

$$= 4 \times \left(\frac{10^{-2}}{2}\right)^3$$

$= 5 \times 10^{-7}$

117. (c) Let binary electrolyte be AB

$$\underset{s}{AB} \rightleftharpoons \underset{s}{A^+} + \underset{s}{B^-}$$

Hence, solubility product of AB

$K_{sp} = [A^+][B^-]$

$S = [s.]\,[s] \Rightarrow s = S^{1/2}$

118. (a) K_{sp} of As_2S_3 is less than ZnS. In acid medium ionisation of H_2S is suppresed (common ion effect) and K_{sp} of ZnS does not exceed.

119. (a) Given $Na_2CO_3 = 1.0 \times 10^{-4}\,M$

$\therefore\ [CO_3^{--}] = 1.0 \times 10^{-4}\,M$

i.e. $S = 1.0 \times 10^{-4}\,M$

At equilibrium

$[Ba^{++}][CO_3^{--}] = K_{sp}$ of $BaCO_3$

$$[Ba^{++}] = \frac{K_{sp}}{[CO_3^{--}]} = \frac{5.1 \times 10^{-9}}{1.0 \times 10^{-4}} = 5.1 \times 10^{-5}\,M$$

120. (b) $AgBr \rightleftharpoons Ag^+ + Br^-$

$K_{sp} = [Ag^+][Br^-]$

For precipitation to occur

Ionic product > Solubility product

$$[Br^-] = \frac{K_{sp}}{[Ag^+]} = \frac{5 \times 10^{-13}}{0.05} = 10^{-11}$$

i.e., precipitation just starts when 10^{-11} moles of KBr is added to 1ℓ $AgNO_3$ solution

$\therefore$ Number of moles of Br^- needed from

KBr = 10^{-11}

$\therefore$ Mass of KBr = $10^{-11} \times 120 = 1.2 \times 10^{-9}$ g

121. (b) $Mg(OH)_2 \rightleftharpoons Mg^{++} + 2OH^-$

$K_{sp} = [Mg^{++}][OH^-]^2$

$1.0 \times 10^{-11} = 10^{-3} \times [OH^-]^2$

$$[OH^-] = \sqrt{\frac{10^{-11}}{10^{-3}}} = 10^{-4}$$

$\therefore$ pOH = 4

$\therefore$ pH + pOH = 14 $\therefore$ pH = 10

STATEMENT TYPE QUESTIONS

122. (c) Boiling point depends on the altitude of the place; at high altitude the boiling point decreases.

123. (a)

124. (b) Chemical reactions which are in equilibrium are reversible

125. (c) Since equilibrium constant is related to the partial pressure of reactant and product therefore if nobel gas is added, no change is observed, Statement 1 is incorrect.

If Nobel gas react with reactant, concentration of reactant will decrease and therefore reaction will proceed backword according to Le– chatelier's principle.

126. (c) Equilibrium constant is temperature dependent having one unique value for a particular reaction represented by a balanced equation at a given temperature.

127. (b) An equilibrium constant does not give any information about the rate at which the equilibrium is reached.

128. (a) **129. (d)**

130. (a) As strong acid dissociate completely in water hence resulting base formed would be very weak. On the other hand a weak acid is only partially dissociated in aqueous solution, hence resulting base formed would be strong.

131. (a) $\underset{\text{acid}}{H_2O(l)} + \underset{\text{base}}{H_2O(l)} \rightleftharpoons \underset{\text{conjugate acid}}{H_3O^+(aq)} + \underset{\text{conjugate base}}{OH^-(aq)}$

132. (c) K_w depends upon temperature as it is an equilibrium constant.

133. (d) Larger the value of K_a, the stronger is the acid.

134. (a)

135. (c) Bond energy being directly related to bond strength increases with increase in bond strength

MATCHING TYPE QUESTIONS

136. (d)

137. (b) (A) Liquid $\rightleftharpoons$ Vapour equilibrium exists at the boiling point.

(B) Solid $\rightleftharpoons$ Liquid equilibrium exists at the melting point.

(C) Solid $\rightleftharpoons$ Vapour equilibrium exists at the sublimation point.

(D) Solute $\rightleftharpoons$ Solute (solution) equilibrium exists in a saturated solution.

138. (a) In case of A no. of moles of product and reactant are same, in case of B no. of moles of reactant are greater so reaction go forward, in case of C the no. of moles of product are greater than no. of moles of reactant.

139. (a)

(A) $K_P = K_C (RT)^{\Delta n}$

$$\frac{K_P}{K_C} = (RT)^{\Delta n} \text{ as } \Delta n = -ve \Rightarrow K_P < K_C$$

(B) $\Delta n > 0$

(C) $\Delta n = 2 - 1 = 1$

(D) As the reaction is not containing any gaseous component therefore K_P is not defined for this.

140. (b)

(A) As $\Delta n > 0$ therefore if P ↑, reaction will go in the backward direction.

(B) As $\Delta n < 0$ therefore if V ↑, P ↓ reaction will go in the direction in which more number of gaseous moles are formed i.e. backward direction.

(C) As $\Delta n = 0$ hence no effect.

(D) If concentration of reactant is increased reaction will go in the forward direction.

141. (d) **142. (b)**

143. (b) $HClO_4$ is a strong acid

HNO_2 is a weak acid.

NH_2^- is a very good proton acceptor and thus, it is a base.

H_2SO_4 is a strong acid hence its conjugate base (HSO_4^-) will be a weak base.

ASSERTION-REASON TYPE QUESTIONS

144. (a) $K_p = K_c(RT)^{\Delta n}$

145. (a) If the volume is kept constant and an inert gas such as argon is added which does not take part in the reaction, the equilibrium remains undisturbed. It is because the addition of an inert gas at constant volume does not change the partial pressure or the molar concentration of the substance involved in the reaction. The reaction quotient changes only if the added gas is reactant or product involved in the reaction.

146. (d) In biological systems buffer system of carbonic acid and sodium bicarbonate is found in our blood. It maintains the pH of blood to a constant value of about 7.4.

147. (a) Ionic product of AgBr is greater than that of AgCl in comparison with there solubility product AgBr will precipitate first rather than that of AgCl.

CRITICAL THINKING TYPE QUESTIONS

148. (d) To calculate the value of K_4 in the given equation we should apply :

eqn. (2) + eqn.(3) × 3 – eqn. (1)

$$\text{hence } K_4 = \frac{K_2 K_3^3}{K_1}$$

149. (d) Given,

$$AB \xrightleftharpoons{K_1} A^+ + B^{-1}$$

$$K_1 = \frac{[A^+][B^-]}{[AB]}$$

$$AB + B^- \xrightleftharpoons{K_2} AB_2^-$$

$$K_2 = \frac{[AB_2^-]}{[AB][B^-]}$$

Dividing K_1 and K_2, we get

$$K = \frac{K_1}{K_2} = \frac{[A^+][B^-]^2}{[AB_2^-]}$$

$$\therefore \frac{[A^+]}{[AB_2^-]} = \frac{K}{[B^-]^2}$$

150. (a) $K_1 = \frac{Ni(CO)_4}{[CO_2]^2}$; $K_2 = \frac{[CO]^2}{[CO_2]}$

$$K = \frac{[Ni(CO)_4]}{[CO]^4}$$

$$K = \frac{[Ni(CO)_4]}{[CO_2]^2} \times \left(\frac{[CO_2]}{[CO]^2}\right)^2$$

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

151. (b) (I) $N_2 + 2O_2 \xrightleftharpoons{K_1} 2NO_2$

$$K_1 = \frac{[NO_2]^2}{[N_2][O_2]^2} \quad \text{...(i)}$$

(II) $2NO_2 \xrightleftharpoons{K_2} N_2 + 2O_2$

$$K_2 = \frac{[N_2][O_2]^2}{[NO_2]^2} \quad \text{...(ii)}$$

(III) $NO_2 \xrightleftharpoons{K_3} \frac{1}{2}N_2 + O_2$

$$K_3 = \frac{[N_2]^{1/2}[O_2]}{[NO_2]}$$

$$\therefore (K_3)^2 = \frac{[N_2][O_2]^2}{[NO_2]^2} \quad \text{...(iii)}$$

$\therefore$ from equations (i), (ii) and (iii)

$$K_1 = \frac{1}{K_2} = \frac{1}{(K_3)^2}$$

152. (c) Reaction (c) can be obtained by adding reactions (a) and (b) therefore $K_3 = K_1 . K_2$
Hence (c) is the correct answer.

153. (b) **Given:** Equilibrium constant (K_1) for the reaction

$$HI(g) \xrightleftharpoons{K_1} \frac{1}{2}H_2(g) + \frac{1}{2}I_2(g);\ K_1 = 8; \quad \text{.........(i)}$$

To find equilibrium constant for the following reaction

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g);\ K_2 = ? \quad \text{.....(ii)}$$

For this multiply (i) by 2, we get

$$2HI(g) \rightleftharpoons H_2(g) + I_2(g);\ K_1 = 8^2 = 64 \quad \text{.....(iii)}$$

[**Note:** When the equation for an equilibrium is multiplied by a factor, the equilibrium constant must be raised to the power equal to the factor]

Now reverse equation (iii), we get

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g); K = \frac{1}{64} \quad \text{.....(iv)}$$

[**Note:** For a reversible reaction, the equilibrium constant of the backward reaction is inverse of the equilibrium constant for the forward reaction.]

Equation (iv) is the same as the required equation (ii), thus K_2 for equation (ii) is $\frac{1}{64}$ i.e. option (b) is correct.

154. (d) $K_c = \frac{K_p}{(RT)^{\Delta n}}$

$$= \frac{1.44 \times 10^{-5}}{(0.082 \times 773)^{-2}} \text{ (R in L. atm. K}^{-1}\text{ mole}^{-1}\text{)}.$$

155. (b) $\underset{a(1-x)}{PCl_5} \rightleftharpoons \underset{ax}{PCl_3} + \underset{ax}{Cl_2}$

$a = 2, x = 0.4, V = 2\text{ L}$

$$\therefore [PCl_5] = \frac{2(1-0.4)}{2} = 0.6 \text{ mol L}^{-1}$$

$$[PCl_3] = [Cl_2] = \frac{2 \times 0.4}{2} = 0.4 \text{ mol L}^{-1}$$

$$\therefore K_c = \frac{0.4 \times 0.4}{0.6} = 0.267$$

156. (b) $PCl_5 \rightleftharpoons PCl_3 + Cl_2$

Moles at equilibrium

$\frac{1}{2} \qquad \frac{1}{2} \qquad \frac{1}{2}$

Mole fraction at equilibrium

$\frac{1}{3} \qquad \frac{1}{3} \qquad \frac{1}{3}$

Partial pressure at equilibrium

$\frac{P}{3} \qquad \frac{P}{3} \qquad \frac{P}{3}$

$$K_p = \frac{\frac{P}{3} \times \frac{P}{3}}{P/3} = \frac{P}{3}$$

157. (b) $NH_2COONH_4(s) \rightleftharpoons 2NH_3(g) + CO_2(g)$

$$K_P = \frac{(P_{NH_3})^2 \times (P_{CO_2})}{P_{NH_2COONH_4}(s)} = (P_{NH_3})^2 \times (P_{CO_2})$$

As evident by the reaction, NH_3 and CO_2 are formed in molar ratio of 2 : 1. Thus if P is the total pressure of the system at equilibrium, then

$$P_{NH_3} = \frac{2 \times P}{3} \quad P_{CO_2} = \frac{1 \times P}{3}$$

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

Given $K_P = 2.9 \times 10^{-5}$

$$\therefore 2.9 \times 10^{-5} = \frac{4P^3}{27}$$

$$P^3 = \frac{2.9 \times 10^{-5} \times 27}{4}$$

$$P = \left(\frac{2.9 \times 10^{-5} \times 27}{4}\right)^{1/3} = 5.82 \times 10^{-2} \text{ atm}$$

158. (c) Given reaction are

$X \rightleftharpoons Y + Z$ ..... (i)

and $A \rightleftharpoons 2B$ ......(ii)

Let the total pressure for reaction (i) and (ii) be P_1 and P_2 respectively, then

$$\frac{K_{P_1}}{KP_2} = \frac{9}{1} \qquad \text{(given)}$$

After dissociation,

$$X \rightleftharpoons Y + Z$$

At equilibrium $(1-\alpha)$ α α

[Let 1 mole of X dissociate with α as degree of dissociation]

Total number of moles $= 1-\alpha+\alpha+\alpha$

$= (1+\alpha)$

$$\text{Thus } P_X = \left(\frac{1-\alpha}{1+\alpha}\right).P_1 ; P_Y = \left(\frac{\alpha}{1+\alpha}\right)P_1;$$

$$P_Z = \left(\frac{\alpha}{1+\alpha}\right).P_1$$

$$\therefore K_{P_1} = \left(\frac{\alpha}{1+\alpha}\right).P_1 \times \frac{\alpha}{(1+\alpha})$$

$$P_1 / \left(\frac{1-\alpha}{1+\alpha}\right).P_1 \qquad \text{...(i)}$$

Similarly for $A \rightleftharpoons 2B$

At equilibrium $(1-\alpha)$ 2α

We have,

$$K_{P_2} = \left(\frac{2\alpha P_2}{1+\alpha}\right)^2 / \left(\frac{1-\alpha}{1+\alpha}\right)P_2 \qquad \text{...(ii)}$$

Dividing (i) by (ii), we get

$$\frac{K_{P1}}{K_{P_2}} = \frac{\alpha^2.P_1}{4\alpha^2.P_2} \text{ or } \frac{K_{P1}}{K_{P_2}} = \frac{1}{4}.\frac{P_1}{P_2}$$

$$\text{or } 9 = \frac{1}{4}.\frac{P_1}{P_2} \qquad \left[\therefore \frac{K_{P_1}}{K_{P_2}} = \frac{9}{1}\right]$$

$$\text{or } \frac{P_1}{P_2} = \frac{36}{1} \text{ or } P_1 : P_2 = 36 : 1$$

159. (b) For the reaction

$$\underset{\text{at equi}}{} \underset{2(1-x)}{2AB_2(g)} \rightleftharpoons \underset{2x}{2AB(g)} + \underset{x}{B_2(g)}$$

$$K_c = \frac{[AB]^2[B_2]}{[AB_2]^2} \text{ or } K_c = \frac{(2x)^2 \times x}{\{2(1-x)\}^2}$$

$= x^3$ [(1–x) can be neglected in denominator $(1-x) \simeq 1$]

The partial pressure at equilibrium are calculated on the basis of total number of moles at equilibrium.

Total number of moles

$= 2(1-x) + 2x + x = (2+x)$

$\therefore P_{AB_2} = \frac{2(1-x)}{(2+x)} \times P$ where P is the total pressure.

$$P_{AB} = \frac{2x}{(2+x)} \times P, \; P_{B_2} = \frac{x}{(2+x)} \times P$$

Since x is very small so can be neglected in denominator

Thus, we get

$P_{AB_2} = (1-x) \times P$ $\qquad P_{AB} = x \times P$

$$P_{B_2} = \frac{x}{2} \times P$$

$$\text{Now, } K_P = \frac{(P_{AB})^2 (P_{B_2})}{(P_{AB_2})^2}$$

$$= \frac{(x)^2 \times P^2.P \times \frac{x}{2}}{(1-x)^2 \times P^2}$$

$$= \frac{x^3.P^3}{2 \times 1 \times P^2} \qquad [\therefore 1-x \simeq 1]$$

$$= \frac{x^3.P}{2} \text{ or } x^3 = \frac{2.K_p}{P} \text{ or } x = \left(\frac{2K_p}{P}\right)^{\frac{1}{3}}$$

160. (a) Justification : According to Le-Chatelier's principle, at constant temperature, the equilibrium composition will change but K will remain same.

161. (a) The reaction given is an exothermic reaction thus according to Lechatalier's principle lowering of temperature, addition of F_2 and / or Cl_2 favour the for ward direction and hence the production of ClF_3.

162. (a)

163. (c) Strong base has higher tendency to accept the proton. Increasing order of base and hence the order of accepting tendency of proton is

$$I^- < HS^- < NH_3 < RNH_2$$

164. (d) $[Cu(H_2O)_4]^{2+} + 4NH_3 \rightleftharpoons [Cu(NH_3)_4]^{2+} + 4H_2O$ involves lose and gain of electrons. H_2O is coordinated to Cu by donating electrons (LHS). It is then removed by withdrawing electrons.

165. (b) $[H_3O]^+$ for a solution having pH = 3 is given by

$[H_3O]^+ = 1 \times 10^{-3}$ moles/litre

$[\therefore [H_3O]^+ = 10^{-pH}]$

Similarly for solution having pH = 4,

$[H_3O]^+ = 1 \times 10^{-4}$ moles/ litre and for pH = 5

$[H_3O^+] = 1 \times 10^{-5}$ moles/ litre

Let the volume of each solution in mixture be IL, then total volume of mixture solution $L = (1+1+1)L = 3L$

Total $[H_3O]^+$ ion present in mixture solution $= (10^{-3} + 10^{-4} + 10^{-5})$ moles

Then $[H_3O]^+$ ion concentration of mixture solution

$$= \frac{10^{-3} + 10^{-4} + 10^{-5}}{3} M = \frac{0.00111}{3} M$$

$= 0.00037\,M = 3.7 \times 10^{-4}\,M.$

166. (d) Given concentration of NaOH $= 10^{-10}$ M

$\mathrm{NaOH} \longrightarrow \mathrm{Na^+ + OH^-}$

10^{-10} M $\qquad 10^{-10}$

$\therefore$ $[\mathrm{OH^-}]$ from NaOH $= 10^{-10}$

We have to consider dissociation of H_2O

$[\mathrm{OH^-}]$ from $H_2O = 10^{-7}$

Total $[\mathrm{OH^-}] = 10^{-7} + 10^{-10}$

$$= 10^{-7}(0.001+1) = 10^{-7}\left(\frac{1001}{1000}\right) = 10^{-10} \times 1001$$

$\therefore$ pOH $= -\log\,[\mathrm{OH^-}]$

$= -(\log 1001 \times 10^{-10}) = -3.004 + 10 = 6.9996$

pH $= 14 - $ pOH $= 14 - 6.996 = 7.004$

$\therefore$ pH of 10^{-10} M NaOH solution is nearest to 7.

167. (c) Number of meq. of the acid $= 0.04 \times 100 = 4$

Number of meq. of the base $= 0.02 \times 100 = 2$

$\therefore$ Number of meq. of the acid left on mixing $= 4 - 2 = 2$

Total volume of the solution $= 200$ mL

$\therefore$ No. of meq of the acid present in 1000 mL of the solution $= 10$

or No. of eq. of the acid in 1000 mL of the solution

$$= \frac{10}{1000} = 0.01$$

Since the acid is monobasic and completely ionises in solution

0.01 N HCl = 0.01 M HCl

Thus $[\mathrm{H^+}] = 0.01$

$\therefore$ pH $= -\log(0.01) = -(-2) = 2$

168. (b) $[\mathrm{H_3O}]^+$ for a solution having pH $= 3$ is given by

$[\mathrm{H_3O}]^+ = 1 \times 10^{-3}$ moles/litre

$[\therefore\ [\mathrm{H_3O}]^+ = 10^{-\mathrm{pH}}]$

Similarly for solution having pH $= 4$,

$[\mathrm{H_3O}]^+ = 1 \times 10^{-4}$ moles/ litre and for pH=5

$[\mathrm{H_3O^+}] = 1 \times 10^{-5}$ moles/ litre

Let the volume of each solution in mixture be IL, then total volume of mixture solution L = (1 + 1 + 1) L = 3L

Total $[\mathrm{H_3O}]^+$ ion present in mixture solution

$= (10^{-3} + 10^{-4} + 10^{-5})$ moles

Then $[\mathrm{H_3O}]^+$ ion concentration of mixture solution

$$= \frac{10^{-3} + 10^{-4} + 10^{-5}}{3}\,\mathrm{M} = \frac{0.00111}{3}\,\mathrm{M}$$

$= 0.00037$ M $= 3.7 \times 10^{-4}$ M.

169. (a) K_w at 25°C $= 1 \times 10^{-14}$

At 25ºC

$K_w = [\mathrm{H^+}]\,[\mathrm{OH^-}] = 10^{-14}$

At 100°C (given)

$K_w = [\mathrm{H^+}]\,[\mathrm{OH^-}] = 55 \times 10^{-14}$

$\because$ for a neutral solution

$[\mathrm{H^+}] = [\mathrm{OH^-}]$

$\therefore$ $[\mathrm{H^+}]^2 = 55 \times 10^{-14}$

or $[\mathrm{H^+}] = (55 \times 10^{-14})^{1/2}$

$\because$ pH $= -\log\,[\mathrm{H^+}]$

On taking log on both side

$-\log\,[\mathrm{H^+}] = -\log\,(55 \times 10^{-14})^{1/2}$

$$\mathrm{pH} = -\frac{1}{2}\log 55 + 7 \log 10$$

pH $= -0.87 + 7$

$= 6.13$

170. (c) $\mathrm{CH_3COOH \rightleftharpoons CH_3COO^- + H^+}$

$$K_a = \frac{[\mathrm{CH_3COO^-}][\mathrm{H^+}]}{[\mathrm{CH_3COOH}]}$$

Given that,

$[\mathrm{CH_3COO^-}] = [\mathrm{H^+}] = 3.4 \times 10^{-4}$ M

K_a for $\mathrm{CH_3COOH} = 1.7 \times 10^{-5}$

$\mathrm{CH_3COOH}$ is weak acid, so in it $[\mathrm{CH_3COOH}]$ is equal to initial concentration. Hence

$$1.7 \times 10^{-5} = \frac{(3.4 \times 10^{-4})(3.4 \times 10^{-4})}{[\mathrm{CH_3COOH}]}$$

$$[\mathrm{CH_3COOH}] = \frac{3.4 \times 10^{-4} \times 3.4 \times 10^{-4}}{1.7 \times 10^{-5}}$$

$= 6.8 \times 10^{-3}$M

171. (c) Higher the value of K_a lower will be the value of pK_a i.e. higher will be the acidic nature. Further since $\mathrm{CN^-}$, $\mathrm{F^-}$ and $\mathrm{NO_2^-}$ are conjugate base of the acids HCN, HF and $\mathrm{HNO_2}$ respectively hence the correct order of base strength will be

$\mathrm{F^- < NO_2^- < CN^-}$

($\because$ stronger the acid weaker will be its conjugate base)

172. (c) Given, $\mathrm{CH_3COOH \rightleftharpoons CH_3COO^- + H^+}$;

$K_{a_1}, = 1.5 \times 10^{-5}$ ....(i)

$\mathrm{HCN \rightleftharpoons H^+ + CN^-}$; $K_{a_2} = 4.5 \times 10^{-10}$

or $\mathrm{H^+ + CN^- \rightleftharpoons HCN}$;

$$K'_{a_2} = \frac{1}{K_{a_2}} = \frac{1}{4.5 \times 10^{-10}} \quad \text{...(ii)}$$

$\therefore$ From (i) and (ii), we find that the equilibrium constant (K_a) for the reaction,

$\mathrm{CN^- + CH_3COOH \rightleftharpoons CH_3COO^- + HCN}$, is

$K_a = K_{a_1} \times K'_{a_2}$

$$= \frac{1.5 \times 10^{-5}}{4.5 \times 10^{-10}} = \frac{1}{3} \times 10^5 = 3.33 \times 10^4$$

173. (d) As, molarity, $= \dfrac{\text{wt. of solute per litre of solution}}{\text{Mol. wt. of solute}}$

Molarity of $H_2O = \dfrac{1000}{18}$ mole/litre

$$\begin{array}{ccccc} \mathrm{H_2O} & \rightleftharpoons & \mathrm{H^+} & + & \mathrm{OH^-} \\ c(1-\alpha) & & c\alpha & & c\alpha \end{array}$$

Thus, $K_a = \dfrac{c\alpha^2}{1-\alpha} = c\alpha^2 = 1.8 \times 10^{-14}$

174. (c) For weak acid dissociation equilibria, degree of dissociation α is given as :

$$\alpha = \sqrt{\frac{K_a}{c}} \quad \therefore \ \%\alpha = 100\sqrt{\frac{K_a}{c}}$$

$$\text{Also, } K_a = \frac{[H^+][A^-]}{[HA]} = \frac{[H^+]c\alpha}{c(1-\alpha)} = \frac{[H^+]\alpha}{(1-\alpha)}$$

$$\log K_a = \log H^+ + \log\frac{\alpha}{1-\alpha}$$

$$\text{or } pK_a = pH + \log\frac{1-\alpha}{\alpha}$$

$$pK_a - pH = \log\frac{1-\alpha}{\alpha}$$

$$\frac{1-\alpha}{\alpha} = 10^{pK_a - pH}$$

$$\text{or, } \frac{1}{\alpha} = 10^{pK_a - pH} + 1$$

$$\therefore \quad \alpha = \frac{1}{[1 + 10^{pK_a - pH}]}$$

175. (b) The highest pH will be recorded by the most basic solution. The basic nature of hydroxides of alkaline earth metals increase as we move from Mg to Ba and thus the solution of $BaCl_2$ in water will be most basic and so it will have highest pH.

176. (d) $MX \rightleftharpoons \underset{s}{M^+} + \underset{s}{X^-}$ (Where s is the solubility)

$$\text{Then } K_{sp} = s^2 \quad \text{or} \quad s = \sqrt{K_{sp}}$$

$$\text{Similarly for } MX_2 \longrightarrow \underset{s}{M^{2+}} + \underset{2s}{2X^-}$$

$$K_{sp} = s \times (2s)^2 = 4s^3 \quad \text{or} \quad s = \left[\frac{K_{sp}}{4}\right]^{\frac{1}{3}}$$

$$\text{and for } M_3X \rightleftharpoons \underset{3s}{3M^+} + \underset{s}{X^{-3}}$$

$$K_{sp} = (3s)^3 \times s = 27s^4 \quad \text{or} \quad s = \left[\frac{K_{sp}}{27}\right]^{\frac{1}{4}}$$

From the given values of K_{sp} for MX, MX_2 and M_3 X, we can find the solubilities of those salts at temperature, T.

$$\text{Solubility of } MX = \sqrt{4 \times 10^{-8}} = 2 \times 10^{-4}$$

$$\text{Solubility of } MX_2 = \left[\frac{3.2 \times 10^{-14}}{4}\right]^{\frac{1}{3}} \text{ or } \left[\frac{32}{4} \times 10^{-15}\right]^{\frac{1}{3}}$$

$$= \left[8 \times 10^{-15}\right]^{\frac{1}{3}} \quad \text{or} \quad 2 \times 10^{-5}$$

$$\text{Solubility of } M_3X = \left[\frac{2.7 \times 10^{-15}}{27}\right]^{\frac{1}{4}}$$

$$= \left[10^{-16}\right]^{\frac{1}{4}} \text{ or } 10^{-4}$$

Thus the solubilities are in the order $MX > M_3X > MX_2$ i.e the correct answer is (d).

177. (c) $K_{sp} = [Ag^+][Cl^-]$

$1.8 \times 10^{-10} = [Ag^+][0.1]$

$[Ag^+] = 1.8 \times 10^{-9}$ M

$K_{sp} = [Pb^{+2}][Cl^-]^2$

$1.7 \times 10^{-5} = [Pb^{+2}][0.1]^2$

$[Pb^{+2}] = 1.7 \times 10^{-3}$ M

178. (d) The solubility equilibrium for AgI is

$AgI\,(aq) \rightleftharpoons Ag^+(aq) + I^-(aq)$;

$K_{sp} = [Ag^+][I^-]$

Let solubility of AgI be S moles per litre,

$[Ag^+] = S, [I^-] = S$

$K_{sp} = [Ag^+][I^-]$

$1 \times 10^{-16} = (S) \times (S) = S^2$

$S = \left(1 \times 10^{-16}\right)^{\frac{1}{2}} = 1 \times 10^{-8}$

On calculating solubility of all given compounds

Compound	Solubility
AgCl	1×10^{-5}
AgI	1×10^{-8}
$PbCrO_4$	2×10^{-7}
Ag_2CO_3	1.26×10^{-4}

∴ Ag_2CO_3 is most soluble and AgI is least soluble.

179. (b) $K_{sp} = [Fe^{3+}].[3OH^-]$

So molar solubility of $Fe^{3+} = S$ and $[3OH^-] = 3S$

$Fe(OH)_3 \rightleftharpoons \underset{[S]}{Fe^{3\oplus}} + \underset{[3S]}{3OH^-}$

$1.0 \times 10^{-38} = [S][3S]^3$

$1.0 \times 10^{-38} = S^4 \times 27$

$$S^4 = \frac{1.0 \times 10^{-38}}{27}$$

$$S^4 = 3.703 \times 10^{-40}$$

$$S = \left(3.703 \times 10^{-40}\right)^{1/4} = 1.386 \times 10^{-10}$$