

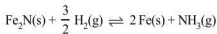


# Equilibrium

## TOPIC 1 Law of Mass Action, Equilibrium Constant ( $K_c$ and $K_p$ ) and its Application

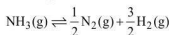


1. For the reaction [Sep. 06, 2020 (I)]



(a)  $K_c = K_p(RT)$  (b)  $K_c = K_p(RT)^{-\frac{1}{2}}$   
 (c)  $K_c = K_p(RT)^{\frac{1}{2}}$  (d)  $K_c = K_p(RT)^{\frac{3}{2}}$

2. The value of  $K_c$  is 64 at 800 K for the reaction  $\text{N}_2(g) + 3\text{H}_2(g) \rightleftharpoons 2\text{NH}_3(g)$ . The value of  $K_c$  for the following reaction is: [Sep. 06, 2020 (II)]

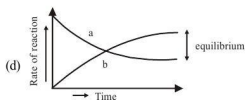
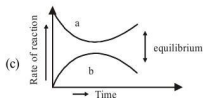
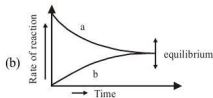
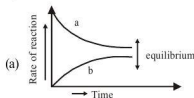


(a) 1/64 (b) 8 (c) 1/4 (d) 1/8

3. For a reaction  $X + Y \rightleftharpoons 2Z$ , 1.0 mol of X, 1.5 mol of Y and 0.5 mol of Z were taken in a 1 L vessel and allowed to react. At equilibrium, the concentration of Z was 1.0 mol L<sup>-1</sup>.

The equilibrium constant of the reaction is  $\frac{x}{15}$ . The value of x is \_\_\_\_\_ [NV, Sep. 05, 2020 (II)]

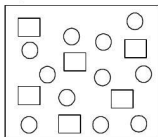
4. For the equilibrium  $A \rightleftharpoons B$ , the variation of the rate of the forward (a) and reverse (b) reaction with time is given by: [Sep. 04, 2020 (I)]



5. If the equilibrium constant for  $A \rightleftharpoons B + C$  is  $K_{eq}^{(1)}$  and that of  $B + C \rightleftharpoons P$  is  $K_{eq}^{(2)}$ , the equilibrium constant for  $A \rightleftharpoons P$  is: [Sep. 04, 2020 (II)]

(a)  $K_{eq}^{(1)} / K_{eq}^{(2)}$  (b)  $K_{eq}^{(2)} - K_{eq}^{(1)}$   
 (c)  $K_{eq}^{(1)} + K_{eq}^{(2)}$  (d)  $K_{eq}^{(1)} K_{eq}^{(2)}$

6. In the figure shown below reactant A (represented by square) is in equilibrium with product B (represented by circle). The equilibrium constant is: [Jan. 09, 2020 (II)]



(a) 4 (b) 8 (c) 1 (d) 2

7. In which one of the following equilibria,  $K_p \neq K_c$ ?

[April 12, 2019 (II)]

(a)  $2\text{C}(s) + \text{O}_2(g) \rightleftharpoons 2\text{CO}(g)$   
 (b)  $2\text{HI}(g) \rightleftharpoons \text{H}_2(g) + \text{I}_2(g)$   
 (c)  $\text{NO}_2(g) + \text{SO}_2(g) \rightleftharpoons \text{NO}(g) + \text{SO}_3(g)$   
 (d)  $2\text{NO}(g) \rightleftharpoons \text{N}_2(g) + \text{O}_2(g)$



8. For the following reactions, equilibrium constants are given:  
 $S(s) + O_2(g) \rightleftharpoons SO_2(g); K_1 = 10^{52}$   
 $2S(s) + 3O_2(g) \rightleftharpoons 2SO_3(g); K_2 = 10^{259}$   
 The equilibrium constant for the reaction,  
 $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$  is: [April 8, 2019 (II)]  
 (a)  $10^{154}$  (b)  $10^{181}$  (c)  $10^{25}$  (d)  $10^{77}$
9. Two solids dissociate as follows  
 $A(s) \rightarrow B(g) + C(g); K_p = x \text{ atm}^2$   
 $D(s) \rightarrow E(g) + F(g); K_p = y \text{ atm}^2$   
 The total pressure when both the solids dissociate simultaneously is: [Jan. 12, 2019 (I)]  
 (a)  $\sqrt{x+y} \text{ atm}$  (b)  $2\sqrt{x+y} \text{ atm}$   
 (c)  $(x+y) \text{ atm}$  (d)  $x^2 + y^2 \text{ atm}$
10. In a chemical reaction,  $A + 2B \rightleftharpoons 2C + D$ , the initial concentration of B was 1.5 times of the concentration of A, but the equilibrium concentrations of A and B were found to be equal. The equilibrium constant (K) for the aforesaid chemical reaction is: [Jan. 12, 2019 (I)]  
 (a) 4 (b) 16 (c)  $\frac{1}{4}$  (d) 1
11. Consider the reaction  
 $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$   
 The equilibrium constant of the above reaction is  $K_p$ . If pure ammonia is left to dissociate, the partial pressure of ammonia at equilibrium is given by (Assume that  $P_{NH_3} \ll P_{\text{Total}}$  at equilibrium) [Jan. 11, 2019 (I)]  
 (a)  $\frac{3/2 K_p^{1/2} p^2}{16}$  (b)  $\frac{K_p^{1/2} p^2}{16}$   
 (c)  $\frac{K_p^{1/2} p^2}{4}$  (d)  $\frac{3/2 K_p^{1/2} p^2}{4}$
12. The values of  $K_p/K_c$  for the following reactions at 300 K are, respectively: (At 300 K,  $RT = 24.62 \text{ dm}^3 \text{ atm mol}^{-1}$ )  
 $N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$  [Jan. 10, 2019 (I)]  
 $N_2O_4(g) \rightleftharpoons 2NO_2(g)$   
 $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$   
 (a)  $1, 24.62 \text{ dm}^3 \text{ atm mol}^{-1}, 606.0 \text{ dm}^6 \text{ atm}^2 \text{ mol}^{-2}$   
 (b)  $1, 24.62 \text{ dm}^3 \text{ atm mol}^{-1}, 1.65 \times 10^{-3} \text{ dm}^{-6} \text{ atm}^{-2} \text{ mol}^2$   
 (c)  $1, 4.1 \times 10^{-2} \text{ dm}^{-3} \text{ atm}^{-1} \text{ mol}, 606 \text{ dm}^6 \text{ atm}^2 \text{ mol}^{-2}$   
 (d)  $24.62 \text{ dm}^3 \text{ atm mol}^{-1}, 606.0 \text{ dm}^6 \text{ atm}^2 \text{ mol}^{-2}, 1.65 \times 10^{-3} \text{ dm}^{-6} \text{ atm}^{-2} \text{ mol}^2$
13.  $5.1 \text{ g NH}_4\text{SH}$  is introduced in  $3.0 \text{ L}$  evacuated flask at  $327^\circ\text{C}$ , 30% of the solid  $\text{NH}_4\text{SH}$  decomposed to  $\text{NH}_3$  and  $\text{H}_2\text{S}$  as gases. The  $K_p$  of the reaction at  $327^\circ\text{C}$  is ( $R = 0.082 \text{ L atm mol}^{-1} \text{ K}^{-1}$ , molar mass of S =  $32 \text{ g mol}^{-1}$ , molar mass of N =  $14 \text{ g mol}^{-1}$ ) [Jan. 10, 2019 (II)]  
 (a)  $0.242 \times 10^{-4} \text{ atm}^2$  (b)  $1 \times 10^{-4} \text{ atm}^2$   
 (c)  $4.9 \times 10^{-3} \text{ atm}^2$  (d)  $0.242 \text{ atm}^2$
14. Consider the following reversible chemical reactions:  
 $A_2(g) + B_2(g) \xrightleftharpoons{K_1} 2AB(g) \dots (1)$   
 $6AB(g) \xrightleftharpoons{K_2} 3A_2(g) + 3B_2(g) \dots (2)$   
 The relation between  $K_1$  and  $K_2$  is: [Jan. 9, 2019 (II)]  
 (a)  $K_1 K_2 = \frac{1}{3}$  (b)  $K_2 = K_1^3$   
 (c)  $K_2 = K_1^{-3}$  (d)  $K_1 K_2 = 3$
15. At a certain temperature in a  $5 \text{ L}$  vessel, 2 moles of carbon monoxide and 3 moles of chlorine were allowed to react according to the reaction,  $\text{CO} + \text{Cl}_2 \rightleftharpoons \text{COCl}_2$ . At equilibrium, if one mole of CO is present then equilibrium constant ( $K_c$ ) for the reaction is: [Online April 15, 2018 (II)]  
 (a) 2.5 (b) 4 (c) 2 (d) 3
16. The equilibrium constant at  $298 \text{ K}$  for a reaction  $A + B \rightleftharpoons C + D$  is 100. If the initial concentration of all the four species were  $1 \text{ M}$  each, then equilibrium concentration of D (in  $\text{mol L}^{-1}$ ) will be: [2016]  
 (a) 1.818 (b) 1.182 (c) 0.182 (d) 0.818
17. A solid XY kept in an evacuated sealed container undergoes decomposition to form a mixture of gases X and Y at temperature T. The equilibrium pressure is  $10 \text{ bar}$  in the vessel.  $K_p$  for this reaction is: [Online April 10, 2016]  
 (a) 25 (b) 100 (c) 10 (d) 5
18. Gaseous  $\text{N}_2\text{O}_4$  dissociates into gaseous  $\text{NO}_2$  according to the reaction  
 $[\text{N}_2\text{O}_4(g) \rightleftharpoons 2\text{NO}_2(g)]$   
 At  $300 \text{ K}$  and  $1 \text{ atm}$  pressure, the degree of dissociation of  $\text{N}_2\text{O}_4$  is 0.2. If one mole of  $\text{N}_2\text{O}_4$  gas is contained in a vessel, then the density of the equilibrium mixture is: [Online April 10, 2015]  
 (a)  $1.56 \text{ g/L}$  (b)  $6.22 \text{ g/L}$   
 (c)  $3.11 \text{ g/L}$  (d)  $4.56 \text{ g/L}$
19. For the reaction  $\text{SO}_2(g) + \frac{1}{2} \text{O}_2(g) \rightleftharpoons \text{SO}_3(g)$ , if  $K_p = K_c (RT)^x$  where the symbols have usual meaning then the value of x is (assuming ideality): [2014]  
 (a) -1 (b)  $-\frac{1}{2}$  (c)  $\frac{1}{2}$  (d) 1
20. At a certain temperature, only 50% HI is dissociated into  $\text{H}_2$  and  $\text{I}_2$  at equilibrium. The equilibrium constant is: [Online April 9, 2014]  
 (a) 1.0 (b) 3.0 (c) 0.5 (d) 0.25

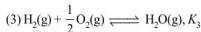
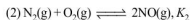


21. For the decomposition of the compound, represented as  $\text{NH}_4\text{COONH}_4(\text{s}) \rightleftharpoons 2\text{NH}_3(\text{g}) + \text{CO}_2(\text{g})$  the  $K_p = 2.9 \times 10^{-5} \text{ atm}^3$ . If the reaction is started with 1 mol of the compound, the total pressure at equilibrium would be :

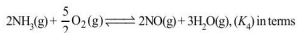
- [Online April 19, 2014]  
 (a)  $1.94 \times 10^{-2} \text{ atm}$  (b)  $5.82 \times 10^{-2} \text{ atm}$   
 (c)  $7.66 \times 10^{-2} \text{ atm}$  (d)  $38.8 \times 10^{-2} \text{ atm}$

22. In reaction  $\text{A} + 2\text{B} \rightleftharpoons 2\text{C} + \text{D}$ , initial concentration of B was 1.5 times of [A], but at equilibrium the concentrations of A and B became equal. The equilibrium constant for the reaction is :  
 [Online April 9, 2013]  
 (a) 8 (b) 4 (c) 12 (d) 6

23. (1)  $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g}), K_1$



The equation for the equilibrium constant of the reaction

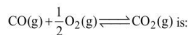


of  $K_1, K_2$  and  $K_3$  is : [Online April 23, 2013]

(a)  $\frac{K_1 \cdot K_2}{K_3}$  (b)  $\frac{K_1 \cdot K_2^2}{K_3}$

(c)  $K_1 K_2 K_3$  (d)  $\frac{K_2 \cdot K_3^3}{K_1}$

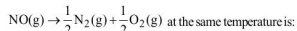
24. The ratio  $\frac{K_p}{K_c}$  for the reaction



[Online April 25, 2013]

(a)  $\frac{1}{\sqrt{RT}}$  (b)  $(RT)^{1/2}$   
 (c)  $RT$  (d) 1

25. The equilibrium constant ( $K_c$ ) for the reaction  $\text{N}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{NO}(\text{g})$  at temperature T is  $4 \times 10^{-4}$ . The value of  $K_c$  for the reaction

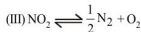
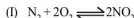


[2004, 2012]

- (a) 0.02 (b)  $2.5 \times 10^2$  (c)  $4 \times 10^{-4}$  (d) 50.0

26.  $K_1, K_2$  and  $K_3$  are the equilibrium constants of the following reactions (I), (II) and (III) respectively:

[Online May 7, 2012]

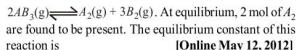


The correct relation from the following is

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

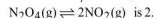
(c)  $K_1 = \sqrt{K_2} = K_3$  (d)  $K_1 = \frac{1}{K_2} = K_3$

27. 8 mol of  $\text{AB}_3(\text{g})$  are introduced into a 1.0  $\text{dm}^3$  vessel. If it dissociates as



- (a) 2 (b) 3 (c) 27 (d) 36

28. The value of  $K_p$  for the equilibrium reaction



The percentage dissociation of  $\text{N}_2\text{O}_4(\text{g})$  at a pressure of 0.5 atm is [Online May 19, 2012]

- (a) 25 (b) 88 (c) 50 (d) 71

29. One mole of  $\text{O}_2(\text{g})$  and two moles of  $\text{SO}_2(\text{g})$  were heated in a closed vessel of one-litre capacity at 1098 K. At equilibrium 1.6 moles of  $\text{SO}_3(\text{g})$  were found. The equilibrium constant  $K_c$  of the reaction would be [Online May 26, 2012]

- (a) 30 (b) 40 (c) 80 (d) 60

30. In aqueous solution the ionization constants for carbonic acid are

$K_1 = 4.2 \times 10^{-7}$  and  $K_2 = 4.8 \times 10^{-11}$ .

Select the correct statement for a saturated 0.034 M solution of the carbonic acid. [2010]

- (a) The concentration of  $\text{CO}_3^{2-}$  is 0.034 M.

- (b) The concentration of  $\text{CO}_3^{2-}$  is greater than that of  $\text{HCO}_3^-$ .

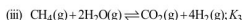
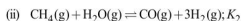
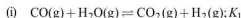
- (c) The concentrations of  $\text{H}^+$  and  $\text{HCO}_3^-$  are approximately equal.

- (d) The concentration of  $\text{H}^+$  is double that of  $\text{CO}_3^{2-}$ .

31. The equilibrium constants  $K_{p1}$  and  $K_{p2}$  for the reactions  $\text{X} = 2\text{Y}$  and  $\text{Z} = \text{P} + \text{Q}$ , respectively are in the ratio of 1 : 9. If the degree of dissociation of X and Z be equal, then the ratio of total pressures at these equilibria is [2008]

- (a) 1:36 (b) 1:1 (c) 1:3 (d) 1:9

32. For the following three reactions (i), (ii) and (iii), equilibrium constants are given: [2008]



Which of the following is correct?

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

(c)  $K_3 = K_1K_2$  (d)  $K_3K_2^3 = K_1^2$



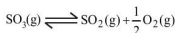
33. Phosphorus pentachloride dissociates as follows, in a closed reaction vessel [2006]



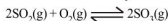
If total pressure at equilibrium of the reaction mixture is P and degree of dissociation of  $\text{PCl}_5$  is  $x$ , the partial pressure of  $\text{PCl}_3$  will be

- (a)  $\left(\frac{x}{x-1}\right)P$  (b)  $\left(\frac{x}{1-x}\right)P$   
 (c)  $\left(\frac{x}{x+1}\right)P$  (d)  $\left(\frac{2x}{1-x}\right)P$

34. The equilibrium constant for the reaction



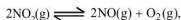
is  $K_c = 4.9 \times 10^{-2}$ . The value of  $K_c$  for the reaction



will be [2006]

- (a)  $9.8 \times 10^{-2}$  (b)  $4.9 \times 10^{-2}$   
 (c) 416 (d)  $2.40 \times 10^{-3}$

35. For the reaction : [2005]



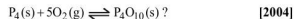
( $K_c = 1.8 \times 10^{-6}$  at  $184^\circ\text{C}$ ) ( $R = 0.0831 \text{ kJ}/(\text{mol}\cdot\text{K})$ )

When  $K_p$  and  $K_c$  are compared at  $184^\circ\text{C}$ , it is found that

- (a) Whether  $K_p$  is greater than, less than or equal to  $K_c$  depends upon the total gas pressure  
 (b)  $K_p = K_c$   
 (c)  $K_p$  is less than  $K_c$   
 (d)  $K_p$  is greater than  $K_c$
36. An amount of solid  $\text{NH}_4\text{HS}$  is placed in a flask already containing ammonia gas at a certain temperature and 0.50 atm pressure. Ammonium hydrogen sulphide decomposes to yield  $\text{NH}_3$  and  $\text{H}_2\text{S}$  gases in the flask. When the decomposition reaction reaches equilibrium, the total pressure in the flask rises to 0.84 atm? The equilibrium constant for  $\text{NH}_4\text{HS}$  decomposition at this temperature is [2005]

- (a) 0.11 (b) 0.17 (c) 0.18 (d) 0.30

37. What is the equilibrium expression for the reaction



- (a)  $K_c = [\text{O}_2]^5$   
 (b)  $K_c = [\text{P}_4\text{O}_{10}]/5[\text{P}_4][\text{O}_2]$   
 (c)  $K_c = [\text{P}_4\text{O}_{10}]/[\text{P}_4][\text{O}_2]^5$   
 (d)  $K_c = 1/[\text{O}_2]^5$

38. For the reaction,  $\text{CO}(\text{g}) + \text{Cl}_2(\text{g}) \rightleftharpoons \text{COCl}_2(\text{g})$  the  $K_p/K_c$  is equal to [2004]

- (a)  $\sqrt{RT}$  (b)  $RT$  (c)  $1/RT$  (d) 1.0

39. For the reaction equilibrium [2003]



the concentrations of  $\text{N}_2\text{O}_4$  and  $\text{NO}_2$  at equilibrium are  $4.8 \times 10^{-2}$  and  $1.2 \times 10^{-2} \text{ mol L}^{-1}$  respectively. The value of  $K_c$  for the reaction is

- (a)  $3 \times 10^{-1} \text{ mol L}^{-1}$  (b)  $3 \times 10^{-3} \text{ mol L}^{-1}$   
 (c)  $3 \times 10^3 \text{ mol L}^{-1}$  (d)  $3.3 \times 10^2 \text{ mol L}^{-1}$

40. For the reaction  $\text{CO}(\text{g}) + (1/2)\text{O}_2(\text{g}) \rightleftharpoons \text{CO}_2(\text{g})$ ,  $K_p/K_c$  is [2002]

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

## TOPIC 2 Relation between $K_p$ , $K_c$ and $Q$ and Factors Effecting Equilibrium



41. The variation of equilibrium constant with temperature is given below: [Sep. 06, 2020 (I)]

Temperature Equilibrium Constant

$T_1 = 25^\circ\text{C}$   $K_1 = 10$

$T_2 = 100^\circ\text{C}$   $K_2 = 100$

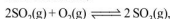
The values of  $\Delta H^\circ$ ,  $\Delta G^\circ$  at  $T_1$  and  $\Delta G^\circ$  at  $T_2$  (in  $\text{kJ mol}^{-1}$ ) respectively, are close to

[use  $R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$ ]

- (a) 28.4, -7.14 and -5.71  
 (b) 0.64, -7.14 and -5.71  
 (c) 28.4, -5.71 and -14.29  
 (d) 0.64, -5.71 and -14.29
42. Consider the following reaction : [Sep. 05, 2020 (I)]  
 $\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2\text{NO}_2(\text{g}); \Delta H^\circ = +58 \text{ kJ}$   
 For each of the following cases ((i), (ii)), the direction in which the equilibrium shifts is :  
 (i) Temperature is decreases  
 (ii) Pressure is increased by adding  $\text{N}_2$  at constant T.  
 (a) (i) towards product, (ii) towards product  
 (b) (i) towards reactant, (ii) towards product  
 (c) (i) towards reactant, (ii) no change  
 (d) (i) towards product, (ii) no change
43. The INCORRECT match in the following is : [April 12, 2019 (II)]

- (a)  $\Delta G^\circ < 0, K > 1$  (b)  $\Delta G^\circ = 0, K = 1$   
 (c)  $\Delta G^\circ > 0, K < 1$  (d)  $\Delta G^\circ < 0, K < 1$

44. For the reaction,



$\Delta H = -57.2 \text{ kJ mol}^{-1}$  and  $K_c = 1.7 \times 10^{16}$

Which of the following statement is INCORRECT ?

[April 10, 2019 (II)]

- The equilibrium constant is large suggestive of reaction going to completion and so no catalyst is required.
- The equilibrium will shift in forward direction as the pressure increases.
- The equilibrium constant decreases as the temperature increases.
- The addition of inert gas at constant volume will not affect the equilibrium constant.

45. For the equilibrium

$2\text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{OH}^-$ ; the value of  $\Delta G^\circ$  at 298 K is approximately.

[Jan. 11, 2019 (II)]

- 100 kJ mol<sup>-1</sup>
- 80 kJ mol<sup>-1</sup>
- 80 kJ mol<sup>-1</sup>
- 100 kJ mol<sup>-1</sup>

46. In which of the following reactions, an increase in the volume of the container will favour the formation of products? [Online April 15, 2018 (I)]

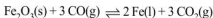
- $4\text{NH}_3(\text{g}) + 5\text{O}_2(\text{g}) \rightleftharpoons 4\text{NO}(\text{g}) + 6\text{H}_2\text{O}(\text{l})$
- $2\text{NO}_2(\text{g}) \rightleftharpoons 2\text{NO}(\text{g}) + \text{O}_2(\text{g})$
- $3\text{O}_2 \rightleftharpoons 2\text{O}_3(\text{g})$
- $\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightleftharpoons 2\text{HI}(\text{g})$

47. The gas phase reaction  $2\text{NO}_2(\text{g}) \longrightarrow \text{N}_2\text{O}_4(\text{g})$  is an exothermic reaction. The decomposition of  $\text{N}_2\text{O}_4$ , in equilibrium mixture of  $\text{NO}_2(\text{g})$  and  $\text{N}_2\text{O}_4(\text{g})$ , can be increased by :

[Online April 16, 2018]

- addition of an inert gas at constant pressure
- lowering the temperature
- increasing the pressure
- addition of an inert gas at constant volume

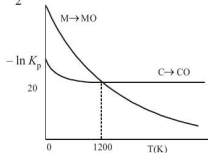
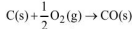
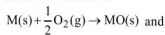
48. The following reaction occurs in the Blast Furnace where iron ore is reduced to iron metal : [Online April 9, 2017]



Using the Le Chatelier's principle, predict which one of the following will not disturb the equilibrium ?

- Removal of CO
- Removal of  $\text{CO}_2$
- Addition of  $\text{CO}_2$
- Addition of  $\text{Fe}_2\text{O}_3$

49. The plot shows the variation of  $-\ln K_p$  versus temperature for the two reactions. [Online April 9, 2016]



Identify the correct statement:

- At  $T < 1200\text{ K}$ , oxidation of carbon is unfavourable.
- Oxidation of carbon is favourable at all temperatures.
- At  $T < 1200\text{ K}$ , the reaction  $\text{MO}(\text{s}) + \text{C}(\text{s}) \rightarrow \text{M}(\text{s}) + \text{CO}(\text{g})$  is spontaneous.
- At  $T > 1200\text{ K}$ , carbon will reduce  $\text{MO}(\text{s})$  to  $\text{M}(\text{s})$ .

50. For the reaction, [Online April 9, 2016]

$\text{A}(\text{g}) + \text{B}(\text{g}) \rightarrow \text{C}(\text{g}) + \text{D}(\text{g})$ ,  $\Delta F^\circ$  and  $\Delta S^\circ$  are, respectively,  $-29.8\text{ kJ mol}^{-1}$  and  $-0.100\text{ kJ K}^{-1}\text{ mol}^{-1}$  at 298 K. The equilibrium constant for the reaction at 298 K is :

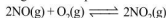
- $1.0 \times 10^{-10}$
- 10
- 1
- $1.0 \times 10^{10}$

51. The standard Gibbs energy change at 300 K for the reaction  $2\text{A} \rightleftharpoons \text{B} + \text{C}$  is 2494.2 J. At a given time, the composition

of the reaction mixture is  $[\text{A}] = \frac{1}{2}$ ,  $[\text{B}] = 2$  and  $[\text{C}] = \frac{1}{2}$ . The reaction proceeds in the :  $[R = 8.314\text{ J/K/mol}$ ,  $e = 2.718]$

- forward direction because  $Q < K_c$
- reverse direction because  $Q < K_c$
- forward direction because  $Q > K_c$
- reverse direction because  $Q > K_c$

52. The following reaction is performed at 298 K. [2015]



The standard free energy of formation of  $\text{NO}(\text{g})$  is 86.6 KJ/mol at 298 K. What is the standard free energy of formation of  $\text{NO}_2(\text{g})$  at 298 K? ( $K_p = 1.6 \times 10^{12}$ )

- $86600 - \frac{\ln(1.6 \times 10^{12})}{R(298)}$
- $0.5[2 \times 86.600 - R(298) \ln(1.6 \times 10^{12})]$
- $R(298) \ln(1.6 \times 10^{12}) - 86600$
- $86600 + R(298) \ln(1.6 \times 10^{12})$

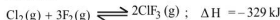
53. The increase of pressure on ice  $\rightleftharpoons$  water system at constant temperature will lead to [Online April 11, 2015]

- a decrease in the entropy of the system
- an increase in the Gibb's energy of the system
- no effect on the equilibrium
- a shift of the equilibrium in the forward direction

54. What happens when an inert gas is added to an equilibrium keeping volume unchanged? [Online April 12, 2014]

- More product will form
- Less product will form
- More reactant will form
- Equilibrium will remain unchanged

55. The exothermic formation of  $\text{ClF}_3$  is represented by the equation :



Which of the following will increase the quantity of  $\text{ClF}_3$  in an equilibrium mixture of  $\text{Cl}_2$ ,  $\text{F}_2$  and  $\text{ClF}_3$ ? [2005]

- Adding  $\text{F}_2$
- Increasing the volume of the container
- Removing  $\text{Cl}_2$
- Increasing the temperature

56. Consider the reaction equilibrium [2003]



On the basis of Le Chatelier's principle, the condition favourable for the forward reaction is

- (a) increasing temperature as well as pressure  
 (b) lowering the temperature and increasing the pressure  
 (c) any value of temperature and pressure  
 (d) lowering of temperature as well as pressure
57. Change in volume of the system does not alter which of the following equilibria? [2002]

- (a)  $\text{N}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{NO}(\text{g})$   
 (b)  $\text{PCl}_5(\text{g}) \rightleftharpoons \text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g})$   
 (c)  $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$   
 (d)  $\text{SO}_2\text{Cl}_2(\text{g}) \rightleftharpoons \text{SO}_2(\text{g}) + \text{Cl}_2(\text{g})$

TOPIC 3

Theories of Acids and Bases,  
 Ionic Product of Water and pH  
 Scale



58. Arrange the following solutions in the decreasing order of pH: [Sep. 06, 2020 (I)]

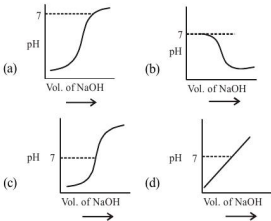
- (A) 0.01 M HCl (B) 0.01 M NaOH  
 (C) 0.01 M  $\text{CH}_3\text{COONa}$  (D) 0.01 M NaCl  
 (a) (A) > (C) > (D) > (B) (b) (A) > (D) > (C) > (B)  
 (c) (B) > (C) > (D) > (A) (d) (B) > (D) > (C) > (A)

59. A soft drink was bottled with a partial pressure of  $\text{CO}_2$  of 3 bar over the liquid at room temperature. The partial pressure of  $\text{CO}_2$  over the solution approaches a value of 30 bar when 44 g of  $\text{CO}_2$  is dissolved in 1 kg of water at room temperature. The approximate pH of the soft drink is  $\times 10^{-1}$ .

(First dissociation constant of  $\text{H}_2\text{CO}_3 = 4.0 \times 10^{-7}$ ;  $\log 2 = 0.3$ ; density of the soft drink =  $1 \text{ g mL}^{-1}$ )

[NV, Sep. 05, 2020 (I)]

60. 100 mL of 0.1 M HCl is taken in a beaker and to it 100 mL of 0.1 M NaOH is added in steps of 2 mL and the pH is continuously measured. Which of the following graphs correctly depicts the change in pH? [Sep. 03, 2020 (II)]



61. For the following Assertion and Reason, the correct option is: [Jan. 08, 2020 (II)]

**Assertion:** The pH of water increases with increase in temperature.

**Reason:** The dissociation of water into  $\text{H}^+$  and  $\text{OH}^-$  is an exothermic reaction.

- (a) Both assertion and reason are true, and the reason is the correct explanation for the assertion.  
 (b) Both assertion and reason are false.  
 (c) Both assertion and reason are true, but the reason is not the correct explanation for the assertion.  
 (d) Assertion is not true, but reason is true.
62. Two solutions, A and B, each of 100 L was made by dissolving 4g of NaOH and 9.8 g of  $\text{H}_2\text{SO}_4$  in water, respectively. The pH of the resultant solution obtained from mixing 40 L of solution A and 10 L of solution B is [NV, Jan. 07, 2020 (I)]

63. 3 g of acetic acid is added to 250 mL of 0.1 M HCl and the solution made up to 500 mL. To 20 mL of this solution  $\frac{1}{2}$  mL of 5 M NaOH is added. The pH of the solution is [NV, Jan. 07, 2020 (II)]  
 [Given:  $\text{pK}_a$  of acetic acid = 4.75, molar mass of acetic acid =  $60 \text{ g/mol}$ ,  $\log 3 = 0.4771$ ]  
 Neglect any changes in volume.

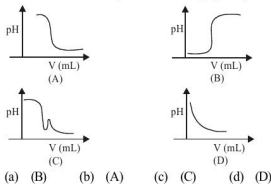
64. Consider the following statements [April 10, 2019 (I)]

- (a) The pH of a mixture containing 400 mL of 0.1 M  $\text{H}_2\text{SO}_4$  and 400 mL of 0.1 M NaOH will be approximately 1.3.  
 (b) Ionic product of water is temperature dependent.  
 (c) A monobasic acid with  $\text{K}_a = 10^{-5}$  has a  $\text{pH} = 5$ . The degree of dissociation of this acid is 50%.  
 (d) The Le Chatelier's principle is not applicable to common-ion effect.

The correct statements are:

[April 10, 2019 (I)]

- (a) (a), (b), and (d) (b) (a), (b) and (c)  
 (c) (b) and (c) (d) (a) and (b)
65. In an acid base titration, 0.1 M HCl solution was added to the NaOH solution of unknown strength. Which of the following correctly shows the change of pH of the titration mixture in this experiment? [April 9, 2019 (II)]



- (a) (B) (b) (A) (c) (C) (d) (D)

66. Which amongst the following is the strongest acid? [Jan. 9, 2019 (I)]
- (a)  $\text{CHBr}_3$  (b)  $\text{CHI}_3$   
(c)  $\text{CH}(\text{CN})_3$  (d)  $\text{CHCl}_3$
67. Following four solutions are prepared by mixing different volumes of NaOH and HCl of different concentrations, pH of which one of them will be equal to 1? [Online April 15, 2018 (II)]
- (a)  $55 \text{ mL } \frac{M}{10} \text{ HCl} + 45 \text{ mL } \frac{M}{10} \text{ NaOH}$   
(b)  $75 \text{ mL } \frac{M}{5} \text{ HCl} + 25 \text{ mL } \frac{M}{5} \text{ NaOH}$   
(c)  $100 \text{ mL } \frac{M}{10} \text{ HCl} + 100 \text{ mL } \frac{M}{10} \text{ NaOH}$   
(d)  $60 \text{ mL } \frac{M}{10} \text{ HCl} + 40 \text{ mL } \frac{M}{10} \text{ NaOH}$
68. Which of the following is a Lewis acid? [Online April 15, 2018 (I)]
- (a)  $\text{PH}_3$  (b)  $\text{NF}_3$   
(c)  $\text{NaH}$  (d)  $\text{B}(\text{CH}_3)_3$
69. 50 mL of 0.2 M ammonia solution is treated with 25 mL of 0.2 M HCl. If  $pK_b$  of ammonia solution is 4.75, the pH of the mixture will be: [Online April 9, 2017]
- (a) 3.75 (b) 4.75 (c) 8.25 (d) 9.25
70. The conjugate base of hydrazoic acid is: [Online April 12, 2014]
- (a)  $\text{N}^{3-}$  (b)  $\text{N}_3^-$  (c)  $\text{N}_2^-$  (d)  $\text{HN}_3^-$
71. 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? [2013]
- (a) 0.1L (b) 0.9L (c) 2.0L (d) 9.0L
72. NaOH is a strong base. What will be pH of  $5.0 \times 10^{-2} \text{ M NaOH}$  solution? ( $\log 2 = 0.3$ ) [Online April 22, 2013]
- (a) 14.00 (b) 13.70 (c) 13.00 (d) 12.70
73. Equimolar solutions of the following compounds are prepared separately in water. Which will have the lowest pH value? [Online April 23, 2013]
- (a)  $\text{BeCl}_2$  (b)  $\text{SrCl}_2$   
(c)  $\text{CaCl}_2$  (d)  $\text{MgCl}_2$
74. What is the pH of a  $10^{-4} \text{ M OH}^-$  solution at 330K, if  $K_w$  at 330K is  $10^{-13.6}$ ? [Online April 23, 2013]
- (a) 4 (b) 9.0 (c) 10 (d) 9.6
75. Which one of the following arrangements represents the correct order of the proton affinity of the given species : [Online April 25, 2013]
- (a)  $\text{I}^- < \text{F}^- < \text{HS}^- < \text{NH}_2^-$   
(b)  $\text{HS}^- < \text{NH}_2^- < \text{F}^- < \text{I}^-$   
(c)  $\text{F}^- < \text{I}^- < \text{NH}_2^- < \text{HS}^-$   
(d)  $\text{NH}_2^- < \text{HS}^- < \text{I}^- < \text{F}^-$
76. Four species are listed below: [2008]
- i.  $\text{HCO}_3^-$  ii.  $\text{H}_3\text{O}^+$   
iii.  $\text{HSO}_4^-$  iv.  $\text{HSO}_3\text{F}$
- Which one of the following is the correct sequence of their acid strength?
- (a)  $\text{iv} < \text{ii} < \text{iii} < \text{i}$  (b)  $\text{ii} < \text{iii} < \text{i} < \text{iv}$   
(c)  $\text{i} < \text{iii} < \text{ii} < \text{iv}$  (d)  $\text{iii} < \text{i} < \text{iv} < \text{ii}$
77. Hydrogen ion concentration in mol/L in a solution of  $\text{pH} = 5.4$  will be: [2005]
- (a)  $3.98 \times 10^{-6}$  (b)  $3.68 \times 10^{-6}$   
(c)  $3.88 \times 10^6$  (d)  $3.98 \times 10^8$
78. What is the conjugate base of  $\text{OH}^-$ ? [2005]
- (a)  $\text{O}^{2-}$  (b)  $\text{O}^-$  (c)  $\text{H}_2\text{O}$  (d)  $\text{O}_2$
79. The conjugate base of  $\text{H}_2\text{PO}_4^-$  is [2004]
- (a)  $\text{H}_3\text{PO}_4$  (b)  $\text{P}_2\text{O}_5$   
(c)  $\text{PO}_4^{3-}$  (d)  $\text{HPO}_4^{2-}$
80. Which one of the following statements is not true? [2003]
- (a)  $\text{pH} + \text{pOH} = 14$  for all aqueous solutions  
(b) The pH of  $1 \times 10^{-8} \text{ M HCl}$  is 8  
(c) 96,500 coulombs of electricity when passed through a  $\text{CuSO}_4$  solution deposits 1 gram equivalent of copper at the cathode  
(d) The conjugate base of  $\text{H}_2\text{PO}_4^-$  is  $\text{HPO}_4^{2-}$
81. When rain is accompanied by a thunderstorm, the collected rain water will have a pH value [2003]
- (a) slightly higher than that when the thunderstorm is not there  
(b) uninfluenced by occurrence of thunderstorm  
(c) that depends on the amount of dust in air  
(d) slightly lower than that of rain water without thunderstorm.
82. Species acting as both Bronsted acid and base is [2002]
- (a)  $\text{HSO}_4^-$  (b)  $\text{Na}_2\text{CO}_3$   
(c)  $\text{NH}_3$  (d)  $\text{OH}^-$

**TOPIC 4 Ionisation of Weak Acids and Bases and Relation between  $K_a$  and  $K_b$**



83.  $pK_a$  of a weak acid (HA) and  $pK_b$  of a weak base (BOH) are 3.2 and 3.4, respectively. The pH of their salt (AB) solution is [2017]
- (a) 7.2 (b) 6.9 (c) 7.0 (d) 1.0
84. Assuming that the degree of hydrolysis is small, the pH of 0.1 M solution of sodium acetate ( $K_a = 1.0 \times 10^{-5}$ ) will be: [Online April 11, 2014]
- (a) 5.0 (b) 6.0 (c) 8.0 (d) 9.0

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

Acid	$K_a$
HClN	$6.2 \times 10^{-10}$
HF	$7.2 \times 10^{-4}$
$\text{HNO}_2$	$4.0 \times 10^{-4}$

Correct order of increasing base strength of the base  $\text{CN}^-$ ,  $\text{F}^-$  and  $\text{NO}_2^-$  will be : **[Online April 22, 2013]**

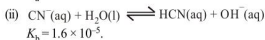
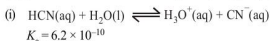
- (a)  $\text{F}^- < \text{CN}^- < \text{NO}_2^-$  (b)  $\text{NO}_2^- < \text{CN}^- < \text{F}^-$   
 (c)  $\text{F}^- < \text{NO}_2^- < \text{CN}^-$  (d)  $\text{NO}_2^- < \text{F}^- < \text{CN}^-$

86. What would be the pH of a solution obtained by mixing 5g of acetic acid and 7.5g of sodium acetate and making the volume equal to 500 mL?

( $K_a = 1.75 \times 10^{-5}$ ,  $pK_a = 4.76$ ) **[Online April 25, 2013]**

- (a) pH=4.70  
 (b) pH<4.70  
 (c) pH of solution will be equal to pH of acetic acid  
 (d)  $4.76 < \text{pH} < 5.0$
87. The pH of a 0.1 molar solution of the acid HQ is 3. The value of the ionization constant,  $K_a$  of the acid is : **[2012]**
- (a)  $3 \times 10^{-1}$  (b)  $1 \times 10^{-3}$   
 (c)  $1 \times 10^{-5}$  (d)  $1 \times 10^{-7}$

88. Given **[Online May 12, 2012]**

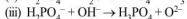
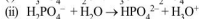
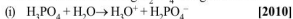


These equilibria show the following order of the relative base strength,

- (a)  $\text{OH}^- > \text{H}_2\text{O} > \text{CN}^-$  (b)  $\text{OH}^- > \text{CN}^- > \text{H}_2\text{O}$   
 (c)  $\text{H}_2\text{O} > \text{CN}^- > \text{OH}^-$  (d)  $\text{CN}^- > \text{H}_2\text{O} > \text{OH}^-$
89. An acid HA ionises as  
 $\text{HA} \rightleftharpoons \text{H}^+ + \text{A}^-$

The pH of 1.0 M solution is 5. Its dissociation constant would be : **[2011RS]**

- (a) 5 (b)  $5 \times 10^{-8}$   
 (c)  $1 \times 10^{-5}$  (d)  $1 \times 10^{-10}$
90. Three reactions involving  $\text{H}_2\text{PO}_4^-$  are given below :



In which of the above does  $\text{H}_2\text{PO}_4^-$  act as an acid ?

- (a) (ii) only (b) (i) and (ii)  
 (c) (iii) only (d) (i) only
91. 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 corresponding salt, BA, will be **[2008]**
- (a) 9.58 (b) 4.79 (c) 7.01 (d) 9.22

92. The first and second dissociation constants of an acid  $\text{H}_2\text{A}$  are  $1.0 \times 10^{-5}$  and  $5.0 \times 10^{-10}$  respectively. The overall dissociation constant of the acid will be **[2007]**
- (a)  $0.2 \times 10^5$  (b)  $5.0 \times 10^{-5}$   
 (c)  $5.0 \times 10^{15}$  (d)  $5.0 \times 10^{15}$
93. The  $pK_a$  of a weak acid (HA) is 4.5. The pH of an aqueous buffer solution of HA in which 50% of the acid is ionized is **[2007]**
- (a) 7.0 (b) 4.5 (c) 2.5 (d) 9.5

**TOPIC 5 Common Ion Effect, Salt Hydrolysis, Buffer Solutions and Solubility Product**



94. If the solubility product of  $\text{AB}_3$  is  $3.20 \times 10^{-11} \text{M}^3$ , then the solubility of  $\text{AB}_3$  in pure water is  $\times 10^{-4} \text{mol L}^{-1}$ . **[Assuming that neither kind of ion reacts with water]**

**[NV, Sep. 06, 2020 (II)]**

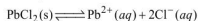
95. An acidic buffer is obtained on mixing : **[Sep. 03, 2020 (I)]**
- (a) 100 mL of 0.1 M  $\text{CH}_3\text{COOH}$  and 100 mL of 0.1 M NaOH  
 (b) 100 mL of 0.1 M HCl and 200 mL of 0.1 M NaCl  
 (c) 100 mL of 0.1 M  $\text{CH}_3\text{COOH}$  and 200 mL of 0.1 M NaOH  
 (d) 100 mL of 0.1 M HCl and 200 mL of 0.1 M  $\text{CH}_3\text{COONa}$
96. For the following Assertion and Reason, the correct option is **[Sep. 02, 2020 (I)]**

**Assertion (A) :** When Cu (II) and sulphide ions are mixed, they react together extremely quickly to give a solid.

**Reason (R) :** The equilibrium constant of  $\text{Cu}^{2+}(\text{aq}) + \text{S}^{2-}(\text{aq}) \rightleftharpoons \text{CuS}(\text{s})$  is high because the solubility product is low.

- (a) (A) is false and (R) is true  
 (b) Both (A) and (R) are false  
 (c) Both (A) and (R) are true but (R) is not the explanation for (A)  
 (d) Both (A) and (R) are true and (R) is the explanation for (A)

97. The  $K_{sp}$  for the following dissociation is  $1.6 \times 10^{-5}$



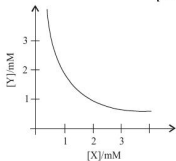
Which of the following choices is correct for a mixture of 300 mL 0.134 M  $\text{Pb}(\text{NO}_3)_2$  and 100 mL 0.4 M NaCl? **[Jan. 09, 2020 (I)]**

- (a) Not enough data provided  
 (b)  $Q < K_{sp}$   
 (c)  $Q > K_{sp}$   
 (d)  $Q = K_{sp}$
98. The solubility product of  $\text{Cr}(\text{OH})_3$  at 298 K is  $6.0 \times 10^{-31}$ . The concentration of hydroxide ions in a saturated solution of  $\text{Cr}(\text{OH})_3$  will be: **[Jan. 09, 2020 (II)]**
- (a)  $(2.22 \times 10^{-31})^{1/4}$  (b)  $(18 \times 10^{-31})^{1/4}$   
 (c)  $(18 \times 10^{-31})^{1/2}$  (d)  $(4.86 \times 10^{-29})^{1/4}$



99. The stoichiometry and solubility product of a salt with the solubility curve given below is, respectively:

[Jan. 08, 2020 (I)]



- (a)  $X_2Y_3, 2 \times 10^{-9} M^3$  (b)  $XY_2, 4 \times 10^{-9} M^3$   
 (c)  $XY_2, 1 \times 10^{-9} M^3$  (d)  $XY_2, 2 \times 10^{-6} M^3$
100. What is the molar solubility of  $Al(OH)_3$  in 0.2 M NaOH solution? Given that, solubility product of  $Al(OH)_3 = 2.4 \times 10^{-24}$ . [April 12, 2019 (I)]  
 (a)  $3 \times 10^{-19}$  (b)  $12 \times 10^{-21}$   
 (c)  $3 \times 10^{-22}$  (d)  $12 \times 10^{-23}$
101. The molar solubility of  $Cd(OH)_2$  is  $1.84 \times 10^{-5} M$  in water. The expected solubility of  $Cd(OH)_2$  in a buffer solution of pH = 12 is: [April 12, 2019 (II)]  
 (a)  $1.84 \times 10^{-9} M$  (b)  $\frac{2.49}{1.84} \times 10^{-9} M$   
 (c)  $6.23 \times 10^{-11} M$  (d)  $2.49 \times 10^{-10} M$
102. The pH of a 0.02 M  $NH_4Cl$  solution will be [given  $K_b(NH_4OH) = 10^{-5}$  and  $\log 2 = 0.301$ ] [April 10, 2019 (II)]  
 (a) 2.65 (b) 4.35 (c) 4.65 (d) 5.35
103. If solubility product of  $Zr_3(PO_4)_4$  is denoted by  $K_{sp}$  and its molar solubility is denoted by S, then which of the following relation between S and  $K_{sp}$  is correct? [April 8, 2019 (I)]  
 (a)  $S = \left(\frac{K_{sp}}{144}\right)^{1/6}$  (b)  $S = \left(\frac{K_{sp}}{6912}\right)^{1/7}$   
 (c)  $S = \left(\frac{K_{sp}}{929}\right)^{1/9}$  (d)  $S = \left(\frac{K_{sp}}{216}\right)^{1/7}$
104. If  $K_{sp}$  of  $Ag_2CO_3$  is  $8 \times 10^{-12}$ , the molar solubility of  $Ag_2CO_3$  in 0.1 M  $AgNO_3$  is: [Jan. 12, 2019 (II)]  
 (a)  $8 \times 10^{-12} M$  (b)  $8 \times 10^{-11} M$   
 (c)  $8 \times 10^{-10} M$  (d)  $8 \times 10^{-13} M$
105. 20 mL of 0.1 M  $H_2SO_4$  solution is added to 30 mL of 0.2 M  $NH_4OH$  solution. The pH of the resultant mixture is: [ $pK_b$  of  $NH_4OH = 4.7$ ]. [Jan. 9, 2019 (I)]  
 (a) 5.2 (b) 9.0 (c) 5.0 (d) 9.4
106. A mixture of 100 m mol of  $Ca(OH)_2$  and 2 g of sodium sulphate was dissolved in water and the volume was made up to 100 mL. The mass of calcium sulphate formed and

the concentration of  $OH^-$  in resulting solution, respectively, are: (Molar mass of  $Ca(OH)_2$ ,  $Na_2SO_4$  and  $CaSO_4$  are 74, 143 and  $136 g mol^{-1}$ , respectively;  $K_{sp}$  of  $Ca(OH)_2$  is  $5.5 \times 10^{-6}$ ) [Jan. 10, 2019 (I)]

- (a) 1.9 g,  $0.28 mol L^{-1}$  (b) 13.6 g,  $0.28 mol L^{-1}$   
 (c) 1.9 g,  $0.14 mol L^{-1}$  (d) 13.6 g,  $0.14 mol L^{-1}$

107. Which of the following salts is the most basic in aqueous solution? [2018]  
 (a)  $Al(CN)_3$  (b)  $CH_3COOK$   
 (c)  $FeCl_3$  (d)  $Pb(CH_3COO)_2$
108. An aqueous solution contains 0.10 M  $H_2S$  and 0.20 M HCl. If the equilibrium constants for the formation of  $HS^-$  from  $H_2S$  is  $1.0 \times 10^{-7}$  and that of  $S^{2-}$  from  $HS^-$  ions is  $1.2 \times 10^{-15}$  then the concentration of  $S^{2-}$  ions in aqueous solution is: [2018]  
 (a)  $5 \times 10^{-8}$  (b)  $3 \times 10^{-20}$   
 (c)  $6 \times 10^{-21}$  (d)  $5 \times 10^{-19}$
109. An aqueous solution contains an unknown concentration of  $Ba^{2+}$ . When 50 mL of a 1 M solution of  $Na_2SO_4$  is added,  $BaSO_4$  just begins to precipitate. The final volume is 500 mL. The solubility product of  $BaSO_4$  is  $1 \times 10^{-10}$ . What is the original concentration of  $Ba^{2+}$ ? [2018]  
 (a)  $5 \times 10^{-9} M$  (b)  $2 \times 10^{-9} M$   
 (c)  $1.1 \times 10^{-9} M$  (d)  $1.0 \times 10^{-10} M$
110. The minimum volume of water required to dissolve 0.1 g lead (II) chloride to get a saturated solution ( $K_{sp}$  of  $PbCl_2 = 3.2 \times 10^{-8}$ ; atomic mass of Pb = 207 u) is: [Online April 15, 2018 (I)]  
 (a) 1.798 L (b) 0.36 L  
 (c) 17.95 L (d) 0.18 L
111. Addition of sodium hydroxide solution to a weak acid (HA) results in a buffer of pH 6. If ionisation constant of HA is  $10^{-5}$ , the ratio of salt to acid concentration in the buffer solution will be: [Online April 8, 2017]  
 (a) 4:5 (b) 1:10 (c) 10:1 (d) 5:4
112. In some solutions, the concentration of  $H_3O^+$  remains constant even when small amounts of strong acid or strong base are added to them. These solutions are known as: [Online April 11, 2014]  
 (a) Ideal solutions (b) Colloidal solutions  
 (c) True solutions (d) Buffer solutions
113. Consider the following equilibrium  
 $AgCl \downarrow + 2NH_3 \rightleftharpoons [Ag(NH_3)_2]^+ + Cl^-$   
 White precipitate of  $AgCl$  appears on adding which of the following? [Online April 11, 2014]  
 (a)  $NH_3$  (b) aqueous NaCl  
 (c) aqueous  $HNO_3$  (d) aqueous  $NH_4Cl$
114. Zirconium phosphate [ $Zr_3(PO_4)_4$ ] dissociates into three zirconium cations of charge +4 and four phosphate anions of charge -3. If molar solubility of zirconium phosphate is denoted by S and its solubility product by  $K_{sp}$ , then which of the following relationship between S and  $K_{sp}$  is correct? [Online April 19, 2014]  
 (a)  $S = \{K_{sp} / (6912)\}^{1/7}$  (b)  $S = \{K_{sp} / 144\}^{1/7}$   
 (c)  $S = \{K_{sp} / 6912\}^{1/7}$  (d)  $S = \{K_{sp} / 6912\}^{1/7}$

115. Solid  $\text{Ba}(\text{NO}_3)_2$  is gradually dissolved in a  $1.0 \times 10^{-4} \text{ M Na}_2\text{CO}_3$  solution. At which concentration of  $\text{Ba}^{2+}$ , precipitate of  $\text{BaCO}_3$  begins to form? ( $K_{\text{sp}}$  for  $\text{BaCO}_3 = 5.1 \times 10^{-9}$ ) [Online April 9, 2013]
- (a)  $5.1 \times 10^{-5} \text{ M}$  (b)  $7.1 \times 10^{-8} \text{ M}$   
(c)  $4.1 \times 10^{-5} \text{ M}$  (d)  $8.1 \times 10^{-7} \text{ M}$
116. Which one of the following arrangements represents the correct order of solubilities of sparingly soluble salts  $\text{Hg}_2\text{Cl}_2$ ,  $\text{Cr}_2(\text{SO}_4)_3$ ,  $\text{BaSO}_4$  and  $\text{CrCl}_3$  respectively? [Online April 22, 2013]
- (a)  $\text{BaSO}_4 > \text{Hg}_2\text{Cl}_2 > \text{Cr}_2(\text{SO}_4)_3 > \text{CrCl}_3$   
(b)  $\text{BaSO}_4 > \text{Hg}_2\text{Cl}_2 > \text{CrCl}_3 > \text{Cr}_2(\text{SO}_4)_3$   
(c)  $\text{BaSO}_4 > \text{CrCl}_3 > \text{Hg}_2\text{Cl}_2 > \text{Cr}_2(\text{SO}_4)_3$   
(d)  $\text{Hg}_2\text{Cl}_2 > \text{BaSO}_4 > \text{CrCl}_3 > \text{Cr}_2(\text{SO}_4)_3$
117. The solubility (in  $\text{mol L}^{-1}$ ) of  $\text{AgCl}$  ( $K_{\text{sp}} = 1.0 \times 10^{-10}$ ) in a  $0.1 \text{ M KCl}$  solution will be [Online May 7, 2012]
- (a)  $1.0 \times 10^{-9}$  (b)  $1.0 \times 10^{-10}$   
(c)  $1.0 \times 10^{-5}$  (d)  $1.0 \times 10^{-11}$
118. If  $K_{\text{sp}}$  of  $\text{CaF}_2$  at  $25^\circ \text{C}$  is  $1.7 \times 10^{-10}$ , the combination amongst the following which gives a precipitate of  $\text{CaF}_2$  is [Online May 19, 2012]
- (a)  $1 \times 10^{-2} \text{ M Ca}^{2+}$  and  $1 \times 10^{-3} \text{ M F}^-$   
(b)  $1 \times 10^{-4} \text{ M Ca}^{2+}$  and  $1 \times 10^{-4} \text{ M F}^-$   
(c)  $1 \times 10^{-2} \text{ M Ca}^{2+}$  and  $1 \times 10^{-5} \text{ M F}^-$   
(d)  $1 \times 10^{-3} \text{ M Ca}^{2+}$  and  $1 \times 10^{-5} \text{ M F}^-$
119. The solubility of  $\text{PbI}_2$  at  $25^\circ \text{C}$  is  $0.7 \text{ g L}^{-1}$ . The solubility product of  $\text{PbI}_2$  at this temperature is (molar mass of  $\text{PbI}_2 = 461.2 \text{ g mol}^{-1}$ ) [Online May 26, 2012]
- (a)  $1.40 \times 10^{-9}$  (b)  $0.14 \times 10^{-9}$   
(c)  $140 \times 10^{-9}$  (d)  $14.0 \times 10^{-9}$
120. The  $K_{\text{sp}}$  for  $\text{Cr}(\text{OH})_3$  is  $1.6 \times 10^{-30}$ . The solubility of this compound in water is: [2011IRS]
- (a)  $4\sqrt{1.6 \times 10^{-30}}$  (b)  $4\sqrt{1.6 \times 10^{-30}}/27$   
(c)  $1.6 \times 10^{-30/27}$  (d)  $2\sqrt{1.6 \times 10^{-30}}$
121. Solubility product of silver bromide is  $5.0 \times 10^{-13}$ . The quantity of potassium bromide (molar mass taken as  $120 \text{ g mol}^{-1}$ ) to be added to 1 litre of  $0.05 \text{ M}$  solution of silver nitrate to start the precipitation of  $\text{AgBr}$  is [2010]
- (a)  $1.2 \times 10^{-10} \text{ g}$  (b)  $1.2 \times 10^{-9} \text{ g}$   
(c)  $6.2 \times 10^{-5} \text{ g}$  (d)  $5.0 \times 10^{-8} \text{ g}$
122. At  $25^\circ \text{C}$ , the solubility product of  $\text{Mg}(\text{OH})_2$  is  $1.0 \times 10^{-11}$ . At which pH, will  $\text{Mg}^{2+}$  ions start precipitating in the form of  $\text{Mg}(\text{OH})_2$  from a solution of  $0.001 \text{ M Mg}^{2+}$  ions? [2010]
- (a) 9 (b) 10  
(c) 11 (d) 8
123. Solid  $\text{Ba}(\text{NO}_3)_2$  is gradually dissolved in a  $1.0 \times 10^{-4} \text{ M Na}_2\text{CO}_3$  solution. At what concentration of  $\text{Ba}^{2+}$  will a precipitate begin to form? ( $K_{\text{sp}}$  for  $\text{BaCO}_3 = 5.1 \times 10^{-9}$ ) [2009]
- (a)  $5.1 \times 10^{-5} \text{ M}$  (b)  $8.1 \times 10^{-8} \text{ M}$   
(c)  $8.1 \times 10^{-7} \text{ M}$  (d)  $4.1 \times 10^{-5} \text{ M}$
124. In a saturated solution of the sparingly soluble strong electrolyte  $\text{AgIO}_3$  (molecular mass = 283) the equilibrium which sets in is  $\text{AgIO}_3(\text{s}) \rightleftharpoons \text{Ag}^+(\text{aq}) + \text{IO}_3^-(\text{aq})$ . If the solubility product constant  $K_{\text{sp}}$  of  $\text{AgIO}_3$  at a given temperature is  $1.0 \times 10^{-8}$ , what is the mass of  $\text{AgIO}_3$  contained in  $100 \text{ mL}$  of its saturated solution? [2007]
- (a)  $1.0 \times 10^{-4} \text{ g}$  (b)  $28.3 \times 10^{-2} \text{ g}$   
(c)  $2.83 \times 10^{-3} \text{ g}$  (d)  $1.0 \times 10^{-7} \text{ g}$
125. The solubility product of a salt having general formula  $\text{MX}_2$ , in water, is:  $4 \times 10^{-12}$ . The concentration of  $\text{M}^{2+}$  ions in the aqueous solution of the salt is [2005]
- (a)  $4.0 \times 10^{-10} \text{ M}$  (b)  $1.6 \times 10^{-4} \text{ M}$   
(c)  $1.0 \times 10^{-4} \text{ M}$  (d)  $2.0 \times 10^{-6} \text{ M}$
126. The molar solubility (in  $\text{mol L}^{-1}$ ) of a sparingly soluble salt  $\text{MX}_4$  is 's'. The corresponding solubility product is  $K_{\text{sp}}$ , 's' is given in term of  $K_{\text{sp}}$  by the relation: [2004]
- (a)  $s = (256 K_{\text{sp}})^{1/5}$  (b)  $s = (128 K_{\text{sp}})^{1/4}$   
(c)  $s = (K_{\text{sp}}/128)^{1/4}$  (d)  $s = (K_{\text{sp}}/256)^{1/5}$
127. The solubility in water of a sparingly soluble salt  $\text{AB}_2$  is  $1.0 \times 10^{-5} \text{ mol L}^{-1}$ . Its solubility product will be [2003]
- (a)  $4 \times 10^{-10}$  (b)  $1 \times 10^{-15}$   
(c)  $1 \times 10^{-10}$  (d)  $4 \times 10^{-15}$
128.  $1 \text{ M NaCl}$  and  $1 \text{ M HCl}$  are present in an aqueous solution. The solution is [2002]
- (a) not a buffer solution with  $\text{pH} < 7$   
(b) not a buffer solution with  $\text{pH} > 7$   
(c) a buffer solution with  $\text{pH} < 7$   
(d) a buffer solution with  $\text{pH} > 7$
129. Let the solubility of an aqueous solution of  $\text{Mg}(\text{OH})_2$  be  $x$ , then its  $K_{\text{sp}}$  is [2002]
- (a)  $4x^3$  (b)  $108x^5$   
(c)  $27x^4$  (d)  $9x$

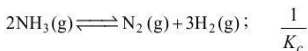




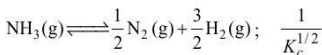
# Hints & Solutions

1. (c)  $K_p = K_c(RT)^{\Delta n_g} = K_c(RT)^{1-3/2} = K_c(RT)^{-1/2}$   
 $\Rightarrow K_c = K_p(RT)^{1/2}$

2. (d)  $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g); K_c$

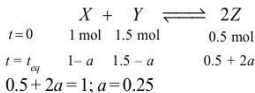


For



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

3. (16)

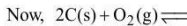


	$X$	$+$	$Y$	$\rightleftharpoons$	$2Z$
	0.75		1.25		1

$$K_{eq} = \frac{[Z]^2}{[X][Y]} = \frac{1}{0.75 \times [1.25]} = \frac{x}{15}$$

$$\Rightarrow x = \frac{15}{(0.75 \times 1.25)} = 16$$

4. (b) At equilibrium, rate of forward reaction = Rate of backward reaction.

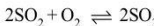
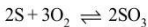


$$\Delta n_g = +1$$

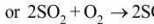
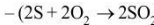
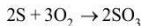
$$\Rightarrow K_p = K_c(RT)^1$$

Hence,  $K_p \neq K_c$

8. (c) Given,  $S + O_2 \rightleftharpoons S$

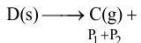


To get equation (iii)



9. (b)  $A(s) \longrightarrow B(g) + C(g)$

$$K_{P_1} = \frac{P_1(P_1)}{P_1}$$



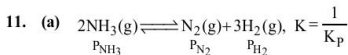
$$K_{P_2} = \frac{P_1 + P_2}{P_1 + P_2}$$

$$(P_1 + P_2)$$

Adding (i) and (ii)

$$\therefore \frac{P_1(P_1)}{P_1 + P_2}$$





$$\therefore K = \frac{1}{K_p} = \frac{P_{\text{N}_2} (P_{\text{H}_2})^3}{(P_{\text{NH}_3})^2} \quad \dots (i)$$

$$\Rightarrow P_{\text{Total}}(P) = P_{\text{N}_2} + P_{\text{H}_2} + P_{\text{NH}_3}$$

$$\approx P_{\text{N}_2} + P_{\text{H}_2} \quad (\because P_{\text{NH}_3} \ll P_T)$$

Now,

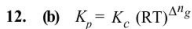
$$\text{Partial pressure of } \text{N}_2 = \frac{1}{4}P; \text{ Partial pressure of } \text{H}_2 = \frac{3}{4}P$$

$$\text{From eq (i), } \frac{1}{K_p} = \frac{\left(\frac{1}{4}P\right) \left(\frac{3}{4}P\right)^3}{(P_{\text{NH}_3})^2}$$

$$\frac{(P_{\text{NH}_3})^2}{K_p} = \frac{P}{4} \cdot \frac{P^3}{4^3} \cdot 3^3; \frac{(P_{\text{NH}_3})^2}{K_p} = \frac{P^4}{4^4} \cdot 3^3$$

$$(P_{\text{NH}_3})^2 = K_p \cdot \frac{P^4}{4^4} \cdot 3^3; P_{\text{NH}_3} = \left[ K_p \cdot \frac{P^4}{4^4} \cdot 3^3 \right]^{1/2}$$

$$P_{\text{NH}_3} = \frac{3^{3/2} \cdot P^2 \cdot K_p^{1/2}}{16}$$

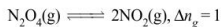


$\Delta n_g =$  No. of gaseous moles of products – No. of gaseous moles of reactants

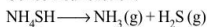
$$\frac{K_p}{K_c} = (RT)^{\Delta n_g}$$



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

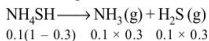


13. (d) Concerned reaction:



$$\text{Initial moles} = \frac{5.1}{51} = 0.1 \text{ mol}$$

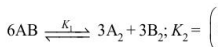
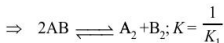
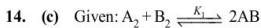
Moles at equilibrium



$$\therefore K_c = [\text{NH}_3][\text{H}_2\text{S}] = \left(\frac{0.03}{3}\right)^2 =$$

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

$$= 10^{-4} \times (0.082 \times 600)^2 =$$



The relation between  $K_1$  and  $K_2$  is  $K_2 = K_1^3$

15. (a) Initially 2 moles of CO are present

At equilibrium, 1 mole of CO is present

Hence,  $2 - 1 = 1$  moles of CO has reacted

1 mole of CO will react with 1 mole of  $\text{Cl}_2$

$\text{COCl}_2$

$3 - 1 = 2$  moles of  $\text{Cl}_2$  remains at equilibrium

The equilibrium constant

$$K_c = \frac{[\text{COCl}_2]}{[\text{CO}][\text{Cl}_2]} = \frac{\frac{1 \text{ mol}}{5\text{L}}}{\frac{1 \text{ mol}}{5\text{L}} \times \frac{2 \text{ mol}}{5\text{L}}} = \frac{1}{2}$$



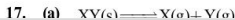
No. of moles initially 1 1 1

At eqm. 1-x 1-x 1+x

$$K_c = \left(\frac{1+x}{1-x}\right)^2 = 100; \frac{1+x}{1-x} = 10$$

On solving;  $x = 0.81$

$$[\text{D}]_{\text{At eq}} = 1 + x = 1 + 0.81 = 1.81$$



## Equilibrium

$$= \frac{(1-\alpha) \times M_{\text{N}_2\text{O}_4} + 2\alpha \times M_{\text{NO}_2}}{(1-\alpha + 2\alpha)}$$

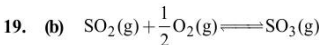
$$= \frac{(1-0.2)92 + 2 \times 0.2 \times 46}{(1+0.2)} = 76.66$$

Now, as per ideal gas equation,

$$PV = nRT$$

$$PM_{\text{mix}} = dRT$$

$$\therefore d = \frac{PM_{\text{mix}}}{RT} = \frac{1 \times 76.66}{0.0821 \times 300} = 3.11 \text{ g/L}$$



$$K_p = K_c(\text{RT})^x$$

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

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



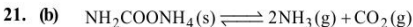
At  $t = 0$             c            0            0

At eqm.            c - c\alpha             $\frac{c\alpha}{2}$              $\frac{c\alpha}{2}$

$$\text{Now, } K_c = \frac{\left(\frac{c\alpha}{2}\right)\left(\frac{c\alpha}{2}\right)}{(c - c\alpha)^2}$$

$$K_c = \frac{\alpha}{4(1-\alpha)^2}; K_c = \frac{0.5}{4(1-0.5)^2}$$

$$K_c = 0.25$$



$$\left(p_{\dots}\right)^2 \times \left(p_{\dots}\right)$$

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

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



At  $t = 0$     a    1.5a

At eqns. (a-x) (1.5-2x)

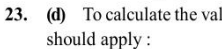
$$\text{Hence, } K_c = \frac{(2x)^2}{(a-x)(1.5-2x)}$$

Given, at equilibrium

$$\therefore (a-x) = (1.5a-2x)$$

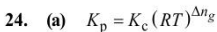
$$\therefore a = 2x$$

On solving  $K_c = 4$

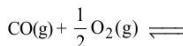


eqn. (2) + eqn. (3)  $\times 3 - \text{eqn. (1)}$

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

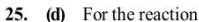


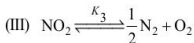
For the reaction



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

$$\therefore K_p = \frac{K_c}{\sqrt{RT}}; \frac{K_p}{K_c}$$



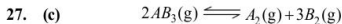


$$K_3 = \frac{[\text{N}_2]^{1/2} [\text{O}_2]}{[\text{NO}_2]}$$

$$\therefore (K_3)^2 = \frac{[\text{N}_2][\text{O}_2]^2}{[\text{NO}_2]^2} \quad \dots(ii)$$

\(\therefore\) From equation (i), (ii) and (iii)

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



	8	0	0
at $t = 0$			
at eqm.	(8 - 2 \times 2)	2	3 \times 2
	= 4	2	6
molar concs.	4/V	2/V	6/V

$$\text{now } K_c = \frac{[A_2][B_2]^3}{[AB_3]^2} = \frac{2/1 \times [6/1]^3}{[4/1]^2} = 27$$



Initial moles	1	0	
Moles at eqm.	(1 - \alpha)	2\alpha	
	(\alpha = \text{degree of dissociation})		

Total number of moles at eqm.

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

$$= (1 + \alpha)$$

$$P_{\text{N}_2\text{O}_4} = \frac{(1 - \alpha)}{1 + \alpha} \times P$$

$$P_{\text{NO}_2} = \frac{2\alpha}{1 + \alpha} \times P$$

$$K_p = \frac{(P_{\text{NO}_2})^2}{P_{\text{N}_2\text{O}_4}} = \frac{\left(\frac{2\alpha}{1 + \alpha} \times P\right)^2}{\left(\frac{1 - \alpha}{1 + \alpha}\right) \times P}$$

$$K_p = \frac{4\alpha^2 P}{(1 + \alpha)^2 (1 - \alpha)}; \quad K_p = \frac{4\alpha^2 P}{(1 + \alpha)(1 - \alpha)}; \quad = \frac{4\alpha^2 P}{1 - \alpha^2}$$

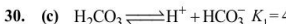


At $t = 0$	1	2	
At eqm.	(1 - \alpha)	2(1 - \alpha)	

Given at equilibrium,  $2\alpha =$   
 $\alpha =$

$$K_c = \frac{(2\alpha)^2}{(1 - \alpha)(2 - 2\alpha)^2} = \frac{(0.8)^2}{(1 - 0.8)(1 - 0.8)^2}$$

$$K_c = 80$$



$\text{HCO}_3^- \rightleftharpoons \text{H}^+ + \text{CO}_3^{2-} \quad K_2 = 4.8 \times 10^{-11}$   
Second dissociation constant ( $K_2$ ) is the first one ( $K_1$ ). Just a small fraction formed will undergo second stage of ionisation in a saturated solution

$$[\text{H}^+] \gg \gg [\text{CO}_3^{2-}]; \quad [\text{CO}_3^{2-}] \neq 0.034 \text{ M}$$

$$[\text{HCO}_3^{2-}] \gg [\text{CO}_3^{2-}] \text{ and}$$

31. (a) Let the initial moles of X be 'a'; then for the given reactions,

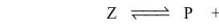


Initial	a moles		
At eqm.	a(1 - \alpha)	2a\alpha	
(moles)			

Total no. of moles = a(1 - \alpha) + 2a\alpha  
= a - a\alpha + 2a\alpha  
= a(1 + \alpha)

$$\text{Now, } K_{p1} = \frac{(n_y)^2}{n_x} \times \left(\frac{P_{T1}}{\sum n}\right)^{\Delta n}$$

$$\text{or, } K_{p1} = \frac{(2a\alpha)^2 \cdot P_{T1}}{[a(1 - \alpha)][a(1 + \alpha)]}$$



Initial	b moles	0	
At eqm.	b(1 - \alpha)	b\alpha	
(moles)			

Total no. of moles = b(1 - \alpha) + b\alpha



## Equilibrium

$$\text{or } \frac{K_{p_1}}{K_{p_2}} = \frac{4\alpha^2 \cdot P_{T_1}}{(1-\alpha^2)} \times \frac{(1-\alpha)^2}{P_{T_2} \cdot \alpha^2} = \frac{4P_{T_1}}{P_{T_2}}$$

$$\text{or } \frac{4P_{T_1}}{P_{T_2}} = \frac{1}{9} \quad \left[ \because \frac{K_{p_1}}{K_{p_2}} = \frac{1}{9} \text{ given} \right]$$

$$\text{or } \frac{P_{T_1}}{P_{T_2}} = \frac{1}{36} \quad \text{or } 1 : 36$$

32. (c) Reaction (iii) can be obtained by adding reactions (i) and (ii) therefore  $K_3 = K_1 \cdot K_2$

Hence (c) is the correct answer.

33. (c)  $\text{PCl}_5(\text{g}) \rightleftharpoons \text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g})$   
 $\begin{matrix} 1-x & & x & & x \end{matrix}$

Total moles after dissociation

$$1-x+x+x=1+x$$

$P_{\text{PCl}_3}$  = Mole fraction of  $\text{PCl}_3 \times$  Total pressure

$$= \left( \frac{x}{1+x} \right) P$$

34. (c)  $\text{SO}_3(\text{g}) \rightleftharpoons \text{SO}_2(\text{g}) + \frac{1}{2} \text{O}_2(\text{g})$

$$K_c = \frac{[\text{SO}_2][\text{O}_2]^{1/2}}{[\text{SO}_3]} = 4.9 \times 10^{-2};$$

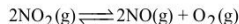
On taking the square of the above reaction

$$\frac{[\text{SO}_2]^2[\text{O}_2]}{[\text{SO}_3]^2} = 24.01 \times 10^{-4}$$

Now for  $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3$

$$K'_c = \frac{[\text{SO}_3]^2}{[\text{SO}_2]^2[\text{O}_2]} = \frac{1}{24.01 \times 10^{-4}} = 416$$

35. (d) For the reaction:-



$$P_{\text{H}_2\text{S}} = 0.17 \text{ atm}$$

$$K = P_{\text{NH}_3} \times P_{\text{H}_2\text{S}} = 0.67 \times 0.17 = 0.1139$$

37. (d) For  $\text{P}_4(\text{s}) + 5\text{O}_2(\text{g}) \rightleftharpoons \text{P}_4\text{O}_{10}(\text{s})$

$$K_c = \frac{1}{(\text{O}_2)^5}$$

Solids have concentration 1

38. (c)  $K_p = K_c(\text{RT})^{\Delta n}$ ;  
 Here  $\Delta n = 1 - 2 = -1$

$$\therefore \frac{K_p}{K_c} = \frac{1}{\text{RT}}$$

39. (b)  $K_c = \frac{[\text{NO}_2]^2}{[\text{N}_2\text{O}_4]}$   
 $\frac{[\text{NO}_2]^2}{[\text{N}_2\text{O}_4]} = \frac{1}{3}$

40. (c)  $K_p = K_c(\text{RT})^{\Delta n}$ ;

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

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

41. (c)  $\Delta G^\circ = -RT \ln K$ ,

$$\Delta G^\circ \text{ at } T_1 = -8.314 \times 298 \ln K$$

$$\Delta G^\circ \text{ at } T_2 = -8.314 \times 373 \ln K$$

$$= -14.29 \text{ kJ/mol}$$

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$$

$$\Rightarrow -5.71 = \Delta H^\circ - 298\Delta S^\circ$$

$$\Rightarrow -14.29 = \Delta H^\circ - 373\Delta S^\circ$$

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

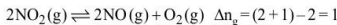
42. (c) (i) As reaction is c

45. (c)  $\Delta G = \Delta G^\circ + RT \ln Q$

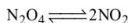
At equilibrium;  $\Delta G = 0$  and  $Q = K_{\text{eq}}$

$$\begin{aligned} \Rightarrow \Delta G^\circ &= -2.303 RT \log K_w \\ &= -2.303 \times 8.314 \times 298 \times \log 10^{-14} \\ &= 79.9 \text{ kJ/mol} = 80 \text{ kJ/mol} \end{aligned}$$

46. (b) Volume  $\uparrow$  P  $\downarrow$ , reaction proceeds in which direction where the number of moles of gases increases.



47. (c) Reaction at equilibrium

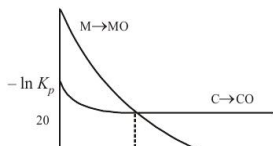


According to Le chatelier's principle-

- (a) addition of an inert gas at constant pressure will increase volume and equilibrium shifts towards more number of molecules.
- (b) Decomposition of  $\text{N}_2\text{O}_4$  will be endothermic, so reaction will move in forward reaction when temperature is increased. So, It is incorrect. It will not effect reaction (volume is constant)
- (c) Increasing the pressure on a gas reaction shifts the position of equilibrium towards the side with fewer molecules. So, it will move in backward direction which leads to formation of  $\text{N}_2\text{O}_4$  from  $\text{NO}_2$ .
48. (d) Perturbation                      Shifts reaction towards
- |                                     |           |
|-------------------------------------|-----------|
| Removal of CO                       | Left      |
| Removal of $\text{CO}_2$            | Right     |
| Addition of $\text{CO}_2$           | Left      |
| Addition of $\text{Fe}_2\text{O}_3$ | No change |

(This is a solid compound. Its concentration has no effect on the equilibrium.)

49. (c)



From the equation

$$\begin{aligned} \Delta G^\circ &= \Delta H^\circ - T\Delta S^\circ = -29.8 - (298 \times -0.1) \\ &= -29.8 + 29.8 = 0 \end{aligned}$$

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

$$0 = -2.303 RT \log K_{\text{eq}}$$

$$\therefore K_{\text{eq}} = 1.$$

51. (d)  $\Delta G^\circ = 2494.2\text{J}$



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

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

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

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

$$\Rightarrow \log K_c = -\frac{2494.2\text{J}}{2.303 \times 8.314 \text{ J/K/mol}}$$

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

52. (b)  $\Delta G_{\text{rex}}^\circ = 2\Delta G_f^\circ(\text{NO}_2) - 2\Delta G_f^\circ(\text{NO})$

$$2\Delta G_f^\circ(\text{NO}_2) = \Delta G_{\text{rex}}^\circ + 2\Delta G_f^\circ(\text{NO})$$

$$\therefore \Delta G = \Delta G^\circ + RT \ln K_p$$

At equilibrium,

$$\Delta G = 0, Q = K_p; \Delta G^\circ = -RT \ln K_p$$

$$\Delta G_f^\circ(\text{O}_2) = 0$$

$$\therefore \Delta G_f^\circ(\text{NO}_2) = \frac{1}{2} [2 \times 86600 - R(298)]$$

53. (d) Volume of ice is greater than that of water. The direction in which the reaction will proceed is predicted by applying Le-Chatelier's principle.

$$\text{Pressure} \propto \frac{1}{\text{Volume}}$$

So equilibrium, will shift forward.

54. (d) On adding inert gas at constant pressure of the system is increased.



## Equilibrium

57. (a) In reaction (a) the ratio of number of moles of reactants to products is same i.e. 2 : 2, hence change in volume will not alter the number of moles.

58. (b)

(A) 0.01 M HCl

$$[H^+] = 10^{-2}, \text{pH} = -\log 10^{-2} = 2$$

$$\text{pOH} = 14 - 2 = 12$$

(B) 0.01 M NaOH

$$[OH^-] = 10^{-2}, \text{pOH} = -\log[OH^-] = 2$$

(C) 0.01 M  $\text{CH}_3\text{COONa}$

$$\text{pH} = 7 + \frac{1}{2}[\text{p}K_a + \log 0.01]$$

$$\text{pH} > 7 \Rightarrow \text{pOH} < 7$$

(D) 0.01 M NaCl,  $\text{pH} = 7$ ,  $\text{pOH} = 7$

Decreasing order of pOH value is,

$$(A) > (D) > (C) > (B).$$

59. (7)  $\text{CO}_2 + \text{H}_2\text{O} \longrightarrow \text{H}_2\text{CO}_3$

$$\begin{array}{ccc} 30 \text{ bar} & \dots\dots\dots & 1 \text{ mol/L} \\ 3 \text{ bar} & \dots\dots\dots & 0.1 \text{ mol/L} \end{array}$$

$$\text{H}_2\text{CO}_3 \rightleftharpoons \text{H}^+ + \text{HCO}_3^-$$

$$\begin{array}{cccc} t=0 & & & \\ \text{at Equib.} & 0.1(1-\alpha) & 0.1\alpha & 0.1\alpha \end{array}$$

$$4.0 \times 10^{-7} = \frac{0.1\alpha^2}{1-\alpha}$$

$$\Rightarrow (1-\alpha) = 1$$

$$\alpha^2 = 4 \times 10^{-6} \Rightarrow \alpha = 2 \times 10^{-3}$$

$$[H^+] = 2 \times 10^{-4} \text{ M}$$

$$\text{pH} = 4 \times \log 2 = 3.7 \approx 37 \times 10^{-1}$$

60. (c) At equivalence point pH is 7 and pH increases with addition of NaOH so correct graph is (c).

61. (b) Temperature plays a significant role on pH

$$[OH^-] = \frac{(40 \times \dots)}{\dots}$$

$$= \frac{20}{50} \times \dots$$

$$[OH^-] = \frac{2}{5} \times 1 \dots$$

$$\text{pOH} = 3.397$$

$$\text{pH} = 14 - \text{pOH}$$

$$= 14 - 3.3$$

63. (5.22)

$$\text{No. of moles} = \frac{\text{Mass}}{\text{Molar mass}}$$

$$3 \text{ g } \text{CH}_3\text{COOH} = \frac{3}{60} \times 0.5$$

$$\text{No. of millimoles} = \text{Molar mass} \times \dots$$

$$250 \text{ mL of } 0.1 \text{ M HCl} = 25 \dots$$

$$500 \text{ mL solution} = 50 \text{ m} \dots$$

$$20 \text{ mL solution} = \frac{50}{500} \times 2 \dots$$

$$500 \text{ mL solution contains} \dots$$

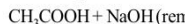
$$20 \text{ mL solution contains} \dots$$

$$\frac{1}{2} \text{ mL of } 5 \text{ M NaOH} = \frac{1}{2} \dots$$



$$1 \quad 2.5 \quad 1$$

$$\text{Remaining NaOH} = 2.5 - \dots$$



$$2 \quad 1 \dots$$

$$0.5 \quad 0 \dots$$

Given  $\text{pH} = 5 \Rightarrow -\log(\text{H}^+) = 5$

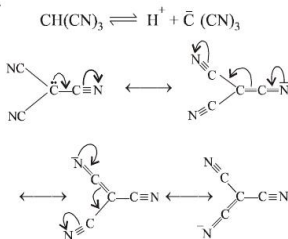
$$\therefore [\text{H}^+] = 10^{-5}$$

As we know,

$$K_a = \frac{C\alpha^2}{1-\alpha}; 10^{-5} = \frac{C\alpha^2}{1-\alpha} = \frac{C\alpha\alpha}{(1-\alpha)}$$

$$10^{-5} = 10^{-5} \frac{\alpha}{1-\alpha}; \alpha = \frac{1}{2} \text{ i.e., } 50\%$$

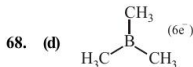
65. (b) Graph A and B, both represents the titration curve between strong acid and strong base, i.e., HCl and NaOH but, the pH of NaOH is more than 7 and during the titration it decreases, so graph (A) is correct.
66. (c) Due to the resonance stabilisation of the conjugate base,  $\text{CH}(\text{CN})_3$  is the strongest acid amongst the given compounds.



The conjugate bases of  $\text{CHBr}_3$  and  $\text{CHI}_3$  are stabilised by inductive effect of halogens. This is why, they are less stable. Also, the conjugate base of  $\text{CHCl}_3$  involves back-bonding between  $2p$  and  $3p$  orbitals.

67. (b)  $75 \text{ mL} \frac{M}{5} \text{HCl} + 25 \text{ mL} \frac{M}{5} \text{NaOH}$

$$25 \text{ mL} \frac{M}{5} \text{NaOH will neutralise } 25 \text{ mL} \frac{M}{5} \text{HCl}$$



69. (d)  $\text{NH}_3 + \text{HCl} \longrightarrow \text{NH}_4\text{Cl}$   
 moles of HCl =  $0.2 \text{ M} \times 25 \times 10^{-3} \text{ L} = 0.005$  (consumed)  
 moles of  $\text{NH}_3 = 0.2 \text{ M} \times 50 \times 10^{-3} \text{ L} = 0.01$   
 excess  $\text{NH}_3 = 0.01 - 0.005 = 0.005$  mole  
 1 mole ammonia = 1 mole  $\text{NH}_4\text{Cl}$   
 $0.005 \text{ NH}_3 = 0.005 \text{ NH}_4\text{Cl}$   
 Total volume =  $V_{\text{HCl}} + V_{\text{NH}_3} = 25 + 50$

$$[\text{NH}_3] = [\text{NH}_4\text{Cl}] = \frac{0.005 \text{ mole}}{75 \times 10^{-3} \text{ L}} = 0.0066$$

$$\text{pOH} = \text{p}K_b + \log \frac{[\text{NH}_4\text{Cl}]}{[\text{NH}_3]}$$

$$\text{pOH} = 4.75 + \log \frac{[0.066]}{[0.066]}$$

$$\text{pOH} = 4.75$$

$$\text{pH} = 14 - \text{pOH} \Rightarrow \text{pH} = 9.25$$

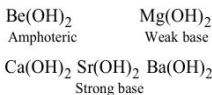
70. (b)  $\text{N}_3\text{H} \rightleftharpoons \text{N}_3^- + \text{H}^+$   
 Hydrazoic acid  
 i.e., conjugate base of hydrazoic acid

71. (d)  $\therefore \text{pH} = 1; \text{H}^+ = 10^{-1} = 0.1 \text{ M}$   
 $\text{pH} = 2; \text{H}^+ = 10^{-2} = 0.01 \text{ M}$   
 $\therefore M_1 = 0.1, V_1 = 1$   
 $M_2 = 0.01, V_2 = ?$   
 From  
 $M_1V_1 = M_2V_2$   
 $0.1 \times 1 = 0.01 \times V_2$   
 $V_2 = 10 \text{ L}$   
 $\therefore$  Volume of water added =  $10 - 1 = 9$

72. (d) Given  $[\text{OH}^-] = 5 \times 10^{-2}$

## Equilibrium

which results in decrease of ionization energy which weakens the strength of M – O bonds in MOH and thus increases the basic strength.



Hence, Be(OH)<sub>2</sub> will have lowest pH.

74. (d) Given at 330 K

$$K_w = 10^{-13.6}$$

i.e.  $pK_w = \text{pH} + \text{pOH}$

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

$$13.6 = \text{pH} + \text{pOH}$$

$$\text{pOH} = -\log 10^{-4}$$

$$\text{pOH} = 4$$

$$\therefore \text{pH} = 13.6 - 4 = 9.6$$

75. (a) The species with the greatest proton affinity will be the strongest base, and its conjugate acid will be the weakest acid. The weakest acid will have the smallest value of  $K_a$ . Since HI is a stronger acid than HF which is a stronger acid than H<sub>2</sub>S, a partial order of proton affinity is



Since NH<sub>3</sub> is a very weak acid, NH<sub>2</sub><sup>-</sup> must be a very strong base. Therefore the correct order of proton affinity is



76. (c) The correct order of acidic strength of the given species is  $\text{HSO}_3\text{F} > \text{H}_3\text{O}^+ > \text{HSO}_4^- > \text{HCO}_3^-$



or (i) < (iii) < (ii) < (iv)

77. (a)  $\text{pH} = -\log [\text{H}^+] = \log \frac{1}{[\text{H}^+]}$

$$5.4 = \log \frac{1}{[\text{H}^+]}$$

$$\begin{aligned} \therefore \text{Total } [\text{H}^+] &= 10^{-8} + 10^{-8} \\ &= 10^{-8} (1 + 1) \\ \therefore \text{pH} &= -\log [\text{H}^+] = -\log (2 \times 10^{-8}) \\ &= -[\log 2 + \log 10^{-8}] \\ &= -[0.3010 - 8] = 7.6989 \end{aligned}$$

81. (d) The rain water after thunderstorm.

82. (a) (HSO<sub>4</sub>)<sup>-</sup> can accept H<sup>+</sup> to form H<sub>2</sub>SO<sub>4</sub>.  
(HSO<sub>4</sub>)<sup>-</sup> + H<sup>+</sup> → H<sub>2</sub>SO<sub>4</sub>  
(HSO<sub>4</sub>)<sup>-</sup> - H<sup>+</sup> → SO<sub>4</sub><sup>2-</sup>.

83. (b) The salt (AB) gives a basic solution. Hence the pH can be

$$\begin{aligned} \therefore \text{pH} &= 7 + \frac{1}{2} \text{p}K_a \\ &= 7 + \frac{1}{2}(3.2) \end{aligned}$$

84. (d) Sodium acetate is a weak base.

$$\begin{aligned} \therefore \text{pH} &= 7 + \frac{1}{2} \text{p}K_a + \frac{1}{2} \text{p}K_b \\ &= 7 + \frac{5}{2} - \frac{1}{2} \end{aligned} \quad \left\{ \begin{array}{l} \therefore \text{p}K_b = 14 - \text{p}K_a \\ \text{p}K_a = 5 \end{array} \right.$$

$$= 9.0$$

85. (c) Higher the value of  $K_a$ , i.e. higher will be the acidic strength. CN<sup>-</sup>, F<sup>-</sup> and NO<sub>2</sub><sup>-</sup> are conjugate bases of HCN and HNO<sub>2</sub> respectively. Hence the acidic strength will be



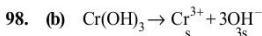
(∴ stronger the acid, weaker the conjugate base)

86. (d) Concentration of CH<sub>3</sub>COOH conc. = 5g in 500 mL = 10 g/L

$$[\text{CH}_3\text{COOH}] = \frac{10}{60} \text{ M}; \quad \frac{1}{60}$$



## Equilibrium



$$K_{sp} = s.(3s)^3$$

$$\Rightarrow 6 \times 10^{-31} = 27.s^4; s = \left(\frac{6}{27} \times 10^{-31}\right)^{1/4}$$

$$[\text{OH}^-] = 3s = 3 \times \left(\frac{6}{27} \times 10^{-31}\right)^{1/4} \\ = (18 \times 10^{-31})^{1/4} \text{ M}$$

99. (b) From the given curve,  
if  $[\text{X}] = 1 \text{ mM}$  then  $[\text{Y}] = 2 \text{ mM}$

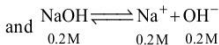
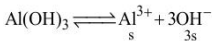
$\therefore$  Salt is  $\text{XY}_2$

$$K_{sp} = [\text{X}][\text{Y}]^2 = (10^{-3})(2 \times 10^{-3})^2 = 4 \times 10^{-9} \text{ M}^3$$

100. (c) Let the solubility of  $\text{Al}(\text{OH})_3$  in  $0.2 \text{ M NaOH}$  solution

be  $s$ .

Then,

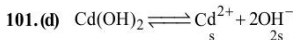


$$[\text{Al}^{3+}] = s \text{ and } [\text{OH}^-] = 3s + 0.2 \approx 0.2$$

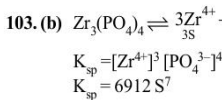
$$K_{sp} = 2.4 \times 10^{-24} = [\text{Al}^{3+}][\text{OH}^-]^3$$

$$2.4 \times 10^{-24} = s(0.2)^3$$

$$s = \frac{2.4 \times 10^{-24}}{8 \times 10^{-3}} = 3 \times 10^{-22} \text{ mol/L}$$

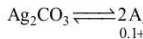
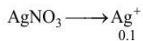


102. (d)  $\text{pH} = 7 - \frac{1}{2} \text{p}K_b - \frac{1}{2} \log C$   
 $= 7 - \frac{5}{2} - \frac{1}{2}(\log 2 \times 10^{-2})$   
 $\text{pH} = 5.35$



$$S = \left(\frac{K_{sp}}{6912}\right)^{1/7}$$

104. (c) As  $\text{AgNO}_3$  dissociates completely, therefore in  $0.1 \text{ M}$  solution



$$K_{sp} = [\text{Ag}^+]^2 [\text{CO}_3^{2-}]$$

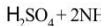
$$8 \times 10^{-12} = (0.1 + 2s)^2 (s)$$

$$0.01 s = 8 \times 10^{-12}; (s \ll 0.1)$$

$$s = 8 \times 10^{-10} \text{ M}$$

105. (b) m. mol of  $\text{H}_2\text{SO}_4$

m. mol of  $\text{NH}_4\text{OH} = 3$



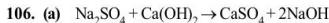
Initial 2 m mol 6 m mol

Final (2-2) (6-2)



$$\text{pH} = 14 - \text{pOH}$$

$$\text{pH} = 14 - 5 = 9$$

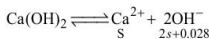


$$\text{m mol of Na}_2\text{SO}_4 = \frac{2 \times 1000}{143} = 13.98 \text{ m mol}$$

$$\text{m mol of CaSO}_4 \text{ formed} = 13.98 \text{ m mol}$$

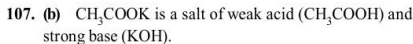
$$\text{Mass of CaSO}_4 \text{ formed} = 13.98 \times 10^{-3} \times 136 = 1.90 \text{ g}$$

$$\text{m mol of NaOH} = 28 \text{ m mol} \approx 0.028 \text{ mol}$$



Value of 'S' will be negligible so

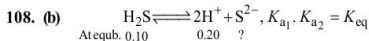
$$[\text{OH}^-] = \frac{0.028 \text{ mol}}{0.1 \text{ L}} = 0.28 \text{ mol L}^{-1}$$



$\text{FeCl}_3$  is a salt of weak base [ $\text{Fe}(\text{OH})_3$ ] and strong acid (HCl).

$\text{Pb}(\text{CH}_3\text{COO})_2$  is a salt of weak base  $\text{Pb}(\text{OH})_2$  and weak acid ( $\text{CH}_3\text{COOH}$ )

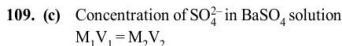
$\text{Al}(\text{CN})_3$  is a salt of weak base [ $\text{Al}(\text{OH})_3$ ] and weak acid (HCN).



$$\therefore \frac{[\text{H}^+]^2 [\text{S}^{2-}]}{[\text{H}_2\text{S}]} = 1 \times 10^{-7} \times 1.2 \times 10^{-13}$$

$$\frac{[0.2]^2 [\text{S}^{2-}]}{[0.1]} = 1.2 \times 10^{-20}$$

$$[\text{S}^{2-}] = 3 \times 10^{-20}$$



$$[\text{Ba}^{2+}] = 10^{-9} \text{ M in 500 mL solution}$$

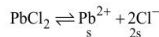
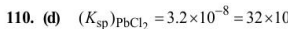
Thus  $[\text{Ba}^{2+}]$  in original solution

$$(500 - 50) = 450 \text{ mL}$$

$$\Rightarrow M_1 \times 450 = 10^{-9} \times 500$$

[where  $M_1$  = Molarity of

$$M_1 = \frac{500}{450} \times 10^{-9} = 1.11 \times 10^{-9} \text{ M}$$



$$K_{sp} = [\text{Pb}^{2+}][\text{Cl}^-]^2$$

$$K_{sp} = 4s^3 = 32 \times 10^{-9}$$

$$s^3 = 8 \times 10^{-9}$$

$$s = 2 \times 10^{-3} \text{ M}$$

$$\frac{w}{\text{M.W.}} \times \frac{1}{V_L} = 2 \times 10^{-3}$$

$$\frac{0.1}{278} \times \frac{1}{V_L} = 2 \times 10^{-3}$$

$$V_L = \frac{0.1 \times 1000}{278 \times 2} = 0.18 \text{ L}$$



(Unionized, weak acid and common ion)



$$K_a = \frac{[\text{H}^+][\text{A}^-]}{[\text{HA}]}$$

$$\text{Given, pH} = 6, [\text{H}^+] = 1 \times 10^{-6}$$

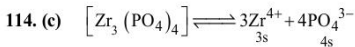
$$[\text{H}^+] = \frac{K_a [\text{Acid}]}{[\text{Salt}]}$$

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



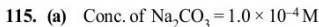
## Equilibrium

When nitric acid is added to amine solution, solution is made acidic and the complex ion dissociates and liberate silver ion to recombine with chloride ion. This is the conformatory test for silver in group 1.



$$\begin{aligned} K_{sp} &= (3s)^3 (4s)^4 \\ &= 27s^3 \times 256s^4 \\ &= 6912s^7. \end{aligned}$$

$$\therefore s = \left( \frac{K_{sp}}{6912} \right)^{1/7}$$



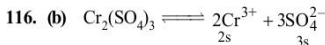
$$\therefore [\text{CO}_3^{2-}] = 1.0 \times 10^{-4} \text{ M}$$

$$\text{i.e. } s = 1.0 \times 10^{-4} \text{ M}$$

At equilibrium

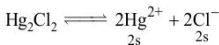
$$[\text{Ba}^{2+}][\text{CO}_3^{2-}] = K_{sp} \text{ of } \text{BaCO}_3$$

$$\begin{aligned} [\text{Ba}^{2+}] &= \frac{K_{sp}}{[\text{CO}_3^{2-}]} = \frac{5.1 \times 10^{-9}}{1.0 \times 10^{-4}} \\ &= 5.1 \times 10^{-5} \text{ M} \end{aligned}$$



$$K_{sp} = (2s)^2 (3s)^3 = 4s^2 \times 27s^3 = 108s^5$$

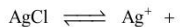
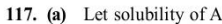
$$s = \left( \frac{K_{sp}}{108} \right)^{1/5}$$



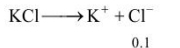
$$K_{sp} = (2s)^2 \times (2s)^2 = 16s^4$$

$$s = \left( \frac{K_{sp}}{16} \right)^{1/4}$$

$$\sqrt{K_{sp}} > \left( \frac{K_{sp}}{16} \right)^{1/4} > \left( \frac{K_{sp}}{2} \right)^{1/4}$$



$$\text{i.e., } K_{sp(\text{AgCl})} = s \times s$$



0.1

[Cl<sup>-</sup>] from KCl = 0.1 M

Total [Cl<sup>-</sup>] in solution

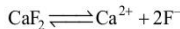
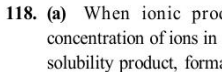
$$K_{sp}(\text{AgCl}) = [\text{Ag}^+][\text{Cl}^-]$$

$$1.0 \times 10^{-10} = s(s + 0.1)$$

$$1.0 \times 10^{-10} = s^2 + 0.1s$$

$$1.0 \times 10^{-10} = 0.1s$$

$$s = 1.0 \times 10^{-9} \text{ mol/L}$$



$$\text{Ionic product} = [\text{Ca}^{2+}][\text{F}^-]^2$$

$$\text{when, } [\text{Ca}^{2+}] = 1 \times 10^{-2} \text{ M}$$

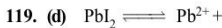
$$[\text{F}^-]^2 = (1 \times 10^{-3})^2 \text{ M}^2$$

$$= 1 \times 10^{-6} \text{ M}^2$$

$$\therefore [\text{Ca}^{2+}][\text{F}^-]^2 = 1 \times 10^{-6} \text{ M}^2$$

In this case,

$$\text{Ionic product } (1 \times 10^{-8}) < K_{sp}$$



$$K_{sp} = s \times (2s)^2 = 4s^3$$

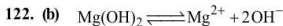
$$= 4 \times \left( \frac{0.7}{4} \right)^3$$



i.e., precipitation just starts when  $10^{-11}$  moles of KBr is added to 1L  $\text{AgNO}_3$  solution

$\therefore$  Number of moles of  $\text{Br}^-$  needed from KBr =  $10^{-11}$

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



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

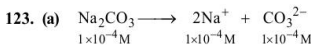
$$1.0 \times 10^{-11} = 10^{-3} \times [\text{OH}^-]^2$$

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

$$\therefore \text{pOH} = 4$$

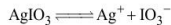
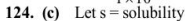
$$\therefore \text{pH} + \text{pOH} = 14$$

$$\therefore \text{pH} = 10$$



$$K_{\text{sp}}(\text{BaCO}_3) = [\text{Ba}^{2+}][\text{CO}_3^{2-}]$$

$$[\text{Ba}^{2+}] = \frac{5.1 \times 10^{-9}}{1 \times 10^{-4}} = 5.1 \times 10^{-5} \text{M}$$



$$K_{\text{sp}} = [\text{Ag}^+][\text{IO}_3^-] = s \times s = s^2$$

$$\text{Given } K_{\text{sp}} = 1 \times 10^{-8}$$

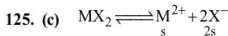
$$\therefore s = \sqrt{K_{\text{sp}}} = \sqrt{1 \times 10^{-8}}$$

$$= 1.0 \times 10^{-4} \text{ mol/L} = 1.0 \times 10^{-4} \times 283 \text{ g/L}$$

( $\therefore$  Molecular mass of  $\text{AgIO}_3 = 283$ )

$$= \frac{1.0 \times 10^{-4} \times 283 \times 100}{1000} \text{ g/100 mL}$$

$$= 2.83 \times 10^{-3} \text{ g/100 mL}$$

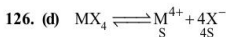


Where  $s$  is the solubility of  $\text{MX}_2$

$$\text{then } K_{\text{sp}} = 4s^3$$

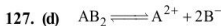
$$4 \times 10^{-12} = 4s^3$$

$$\text{or } s = 1 \times 10^{-4}$$



$$K_{\text{sp}} = [s][4s]^4 = 256s^5$$

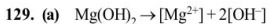
$$\therefore s = \left( \frac{K_{\text{sp}}}{256} \right)^{1/5}$$



$$[\text{A}] = 1.0 \times 10^{-5}, [\text{B}] = [2.0 \times 10^{-5}]$$

$$K_{\text{sp}} = [\text{B}]^2[\text{A}] = [2 \times 10^{-5}]^2 [1.0 \times 10^{-5}] = 4 \times 10^{-15}$$

128. (a) A buffer is a solution of weak acid and strong base and vice versa. HCl is strong acid and its salt with strong base. pH is less than 7.



$$K_{\text{sp}} = [\text{Mg}][\text{OH}]^2 = [x][2x]^2 = 4x^3 = 4 \times 10^{-12}$$

