



EXERCISE # (O-I)

Dissociation of Water & pH of Water

1. Ionic product of water will increase, if:

(A) Pressure is decreased	(B) H^+ is added
(C) OH^- is increased	(D) Temperature is increased

2. At 60°C , pure water has $[\text{H}_3\text{O}^+] = 10^{-6.7}$ mol/lit. what is the value of K_W at 60°C :

(A) 10^{-6}	(B) 10^{-12}	(C) 10^{-67}	(D) $10^{-13.4}$
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3. The pH of solution is increased from 3 to 6. Its H^+ ion conc. will be:

(A) Reduced to half	(B) Doubled
(C) Reduced by 1000 times	(D) Increased by 1000 times

4. A solution with pH 2.0 is more acidic than the one with pH 6.0 by a factor of:

(A) 3	(B) 4	(C) 3000	(D) 10000
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pH of Strong Electrolyte

5. What is the quantity of NaOH present in 250 cc of the solution, so that it gives a pH= 13:

(A) 10^{-13} g	(B) 10^{-1} g	(C) 1.0 g	(D) 4.0 g
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6. An aqueous solution of HCl is 10^{-9} M HCl. The pH of the solution should be:

(A) 9	(B) Between 6 and 7
(C) 7	(D) Unpredictable

7. How many moles of HCl must be removed from 1 litre of aqueous HCl solution to change its pH from 2 to 3:

(A) 1	(B) 0.02	(C) 0.009	(D) 0.01
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8. 10 ml of $\frac{\text{M}}{200}$ H_2SO_4 is mixed with 40 ml of $\frac{\text{M}}{200}$ H_2SO_4 . The pH of the resulting solution is

(A) 1	(B) 2	(C) 2.3	(D) none of these
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pH of Weak Electrolyte

9. For two monobasic acids A and B, $pK_{a1} = 1.2$, $pK_{a2} = 2.8$ respectively in value, then which is true:
- (A) A & B both have equal acidic strength
 - (B) A is stronger than B
 - (C) B is stronger than A
 - (D) Depends on concentration
10. When ammonia is added to water it decreases the concentration of which of the following ion
- (A) OH^-
 - (B) H_3O^+
 - (C) NH_4^+
 - (D) $\text{NH}_4^+ & \text{OH}^-$
11. Which one of the following has highest pH:
- (A) Distilled water
 - (B) 1 M NH_3
 - (C) 1 M NaOH
 - (D) 1M HCl
12. Degree of dissociation of 0.1 N CH_3COOH is: (Dissociation constant = 1×10^{-5})
- (A) 10^{-5}
 - (B) 10^{-4}
 - (C) 10^{-3}
 - (D) 10^{-2}
13. The pH of a 0.02 M ammonia solution which is 5% ionised will be:
- (A) 2
 - (B) 11
 - (C) 5
 - (D) 7

pH of Mixture of More Than One Acid/Base

14. Consider an aqueous solution, 0.1 M each in HOCl , HCOOH , $(\text{COOH})_2$ and H_3PO_4 . For HOCl , we can write: $K_a(\text{HOCl}) = \frac{[\text{H}^+][\text{OCN}^-]}{[\text{HOCl}]}$. $[\text{H}^+]$ in this equation is:
- (A) H^+ ions released by HOCl
 - (B) Sum of H^+ ions released by all monoprotic acids
 - (C) Sum of H^+ ions released only the first dissociation of all the acids.
 - (D) Overall H^+ ion concentration in the solution.



Polyprotic Acid Base



21. In a solution containing 0.1 M HCl & 0.1 M H_3PO_4 (having dissociation constants K_{a_1} , K_{a_2} & K_{a_3}), assuming $\alpha \ll 1$ for H_3PO_4 :

- (A) $[\text{PO}_4^{3-}] = 100 K_{a_1} K_{a_2} K_{a_3}$ (B) $[\text{PO}_4^{3-}] = 10 K_{a_1} K_{a_2} K_{a_3}$
 (C) $[\text{PO}_4^{3-}] = 1000 K_{a_1} K_{a_2} K_{a_3}$ (D) $[\text{PO}_4^{3-}] = K_{a_1} K_{a_2} K_{a_3}$

Conjugate Acid Base, Bronsted Theory

22. The conjugate acid of NH_2^- is
 (A) NH_3 (B) NH_2OH (C) NH_4^+ (D) N_2H_4

23. Which of the following is not a Bronsted acid:
 (A) CH_3NH_4^+ (B) CH_3COO^- (C) H_2O (D) HSO_4^-

24. In the reaction, $\text{HNO}_3 + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{NO}_3^-$, the conjugate base of HNO_3 is:
 (A) H_2O (B) H_3O^+
 (C) NO_3^- (D) H_3O^+ and NO_3^-

25. If equilibrium constant of

$$\text{CH}_3\text{COOH} + \text{H}_2\text{O} \rightleftharpoons \text{CH}_3\text{COO}^- + \text{H}_3\text{O}^+$$

Is 1.8×10^{-5} , equilibrium constant for

$\text{CH}_3\text{COOH} + \text{OH}^- \rightleftharpoons \text{CH}_3\text{COO}^- + \text{H}_2\text{O}$ is

- (A) 1.8×10^{-9} (B) 1.8×10^9
 (C) 5.55×10^{-9} (D) 5.55×10^{10}

26. If pK_b for fluoride ion at 25°C is 10.83, the ionisation constant of hydrofluoric acid in water at this temperature is:
 (A) 1.74×10^{-5} (B) 3.52×10^{-3} (C) 6.75×10^{-4} (D) 5.38×10^{-2}



27. A certain weak acid has $K_a = 1 \times 10^{-4}$. Calculate the equilibrium constant for its reaction with strong base -
- (A) 10^6 (B) 10^8 (C) 10^{10} (D) 10^{-10}

Salt Hydrolysis

28. pH of an aqueous solution of NaCl at 85°C should be
- (A) 7 (B) > 7 (C) < 7 (D) 0
29. 1 cc of 0.1 N HCl is added to 99 cc solution of NaCl. The pH of the resulting solution will be
- (A) 7 (B) 3 (C) 4 (D) 1
30. The highest pH value is of:
- (A) 0.1 M NaCl (B) 0.1 M NH_4Cl
 (C) 0.1 M CH_3COONa (D) 0.1 M HCl

31. What is the percentage hydrolysis of NaCN in N/80 solution when the dissociation constant for HCN is 1.3×10^{-9} and $K_w = 1.0 \times 10^{-14}$
- (A) 2.48 (B) 5.26 (C) 8.2 (D) 9.6
32. Degree of Hydrolysis of $\frac{N}{100}$ solution of KCN is (Given $K_a = 1.4 \times 10^{-9}$)
- (A) 2.7×10^{-3} (B) 2.7×10^{-2} (C) 2.7×10^{-4} (D) 2.7×10^{-5}

Salt Hydrolysis of Multivalent Cation or Anion

33. A solution of FeCl_3 in water acts as acidic due to:
- (A) Acidic impurities (B) Ionisation
 (C) Hydrolysis of Fe^{3+} (D) Dissociation
34. pH of K_2S solution is:
- (A) 7 (B) Less than 7 (C) More than 7 (D) 0



35. For a c M K_3A (potassium salt of a tribasic acid H_3A) solution:

(Dissociation constants of acid are K_{a_1} , K_{a_2} & K_{a_3} ; $h \ll 1$)

$$(A) \text{ pH} = \frac{1}{2} (\text{pK}_W + \text{pK}_{a_3} + \log c)$$

$$(B) \text{ pH} = \frac{1}{2} (\text{p}K_{\text{W}} + \text{p}K_{\text{a}_2} + \log c)$$

$$(C) \text{ pH} = \frac{1}{2} (\text{pK}_W + \text{pK}_{a_1} + \log c)$$

$$(D) \text{ pH} = \frac{1}{2} (\text{pK}_W - \text{pK}_{a_3} - \log c)$$

Amphiprotic Salt and Salt of WA + WB

36. The degree of hydrolysis of a salt of weak acid and weak base in its 0.1 M solution is found to be 50%. If the molarity of the solution is 0.2 M, the percentage hydrolysis of the salt should be
(A) 100% (B) 50% (C) 25% (D) none of these

37. 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:
(A) 8.58 (B) 4.79 (C) 7.01 (D) 9.22

38. Out of the following, amphiprotic species in aqueous medium are

Buffer Solution and pH of Buffer Solution

- 41.** 1 M NaCl and 1M HCl are present in an aqueous solution. The solution is
(A) not a buffer solution and with pH < 7 (B) not a buffer solution with pH > 7
(C) a buffer solution with pH < 7 (D) a buffer solution with pH > 7

42. pK_b for NH_4OH at certain temperature is 4.74. The pH of basic buffer containing equimolar concentration of NH_4OH and NH_4Cl will be:
(A) 7.74 (B) 4.74 (C) 2.37 (D) 9.26

43. If equal volume of 0.05 M ammonium hydroxide solution and 0.001 M ammonium chloride solution are mixed. What will be the OH^- ion concentration of this solution $K_b(\text{NH}_4\text{OH}) = 1.8 \times 10^{-5}$
(A) 3.0×10^{-3} (B) 9.0×10^{-4} (C) 9.0×10^{-3} (D) 3.0×10^{-4}

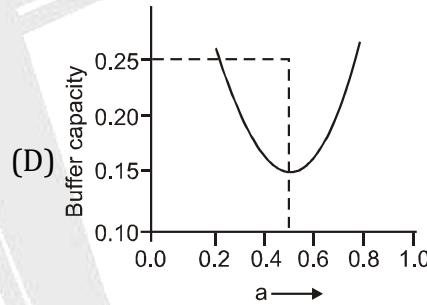
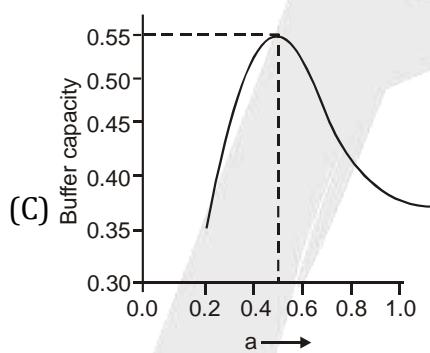
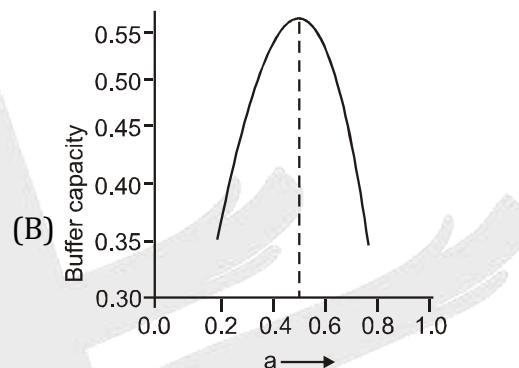
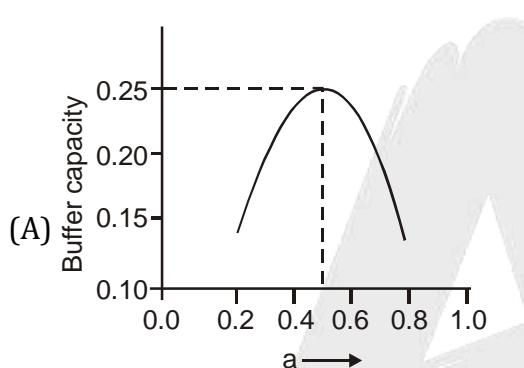
44. Calculate the pH of a buffer prepared by mixing 300 cc of 0.3 M NH_3 and 500 cc of 0.5 M NH_4Cl .
 K_b for $\text{NH}_3 = 1.8 \times 10^{-5}$, $\left(\log\left(\frac{25}{16.2}\right) = 0.188 \right)$
(A) 8.1187 (B) 9.8117 (C) 8.812 (D) 7.812

45. 500 ml of 0.2 M acetic acid are added to 500 ml of 0.30 M sodium acetate solution. If the dissociation constant of acetic acid is 1.5×10^{-5} then pH of the resulting solution is:
(A) 5.0 (B) 9.0 (C) 3.0 (D) 4.0

46. 50 ml. of 2N acetic acid mixed with 10 ml. of 1N sodium acetate solution will have an approximate pH of ($K_a = 10^{-5}$):
(A) 4 (B) 5 (C) 6 (D) 7

47. K_a for HCN is 5×10^{-10} at 25°C . For maintaining a constant pH of 9, the volume of 5M KCN solution required to be added to 10ml. of 2M HCN solution is-
(A) 4 ml (B) 7.95 ml (C) 2 ml (D) 9.3 ml

Change on pH of Buffer Solution & Buffer Capacity



Problems related with mixing ... Titration type



58. Which of the following solution will have pH close to 1.0?
- 100 ml of M/100 HCl + 100 ml of M/10 NaOH
 - 55 ml of M/10 HCl + 45 ml of M/10 NaOH
 - 10 ml of M/10 HCl + 90 ml of M/10 NaOH
 - 75 ml of M/5 HCl + 25 ml of M/5 NaOH
59. Which can act as buffer:
- $\text{NH}_4\text{OH} + \text{NaOH}$
 - $\text{HCOOH} + \text{HCl}$
 - 40 ml. of 0.1 M NaCN + 20 ml. of 0.1 M HCl
 - All of them
60. Which of the following solutions does not act as buffer:
- $\text{H}_3\text{PO}_4 + \text{NaH}_2\text{PO}_4$
 - $\text{NaHCO}_3 + \text{H}_2\text{CO}_3$
 - $\text{NH}_4\text{Cl} + \text{HCl}$
 - $\text{CH}_3\text{COOH} + \text{CH}_3\text{COONa}$
61. If 40 ml of 0.2 M KOH is added to 160 ml of 0.1 M HCOOH [$K_a = 2 \times 10^{-4}$], the pOH of the resulting solution is
- 3.4
 - 3.7
 - 7
 - 10.3
62. On addition of NaOH to CH_3COOH solution, 60% of the acid is neutralised. If pK_a of CH_3COOH is 4.7 then the pH of the resulting solution is:
- More than 4.7 but less than 5.0
 - Less than 4.7 but more than 4.0
 - More than 5.0
 - Remains unchanged
63. Half of the formic acid solution is neutralised on addition of a KOH solution to it.
If $K_a (\text{HCOOH}) = 2 \times 10^{-4}$ then pH of the solution is: ($\log 2 = 0.3010$)
- 3.6990
 - 10.3010
 - 3.85
 - 4.3010
64. $\frac{N}{10}$ acetic acid was titrated with $\frac{N}{10}$ NaOH. When 25%, 50% and 75% of titration is over then the pH of the solution will be: [$K_a = 10^{-5}$]
- $5 + \log 1/3, 5, 5 + \log 3$
 - $5 + \log 3, 4, 5 + \log 1/3$
 - $5 - \log 1/3, 5, 5 - \log 3$
 - $5 - \log 1/3, 4, 5 + \log 1/3$

Indicators & Double Indicator

- 69** The rapid change of pH near the stoichiometric point of an acid–base titration is the basis of indicator detection. pH of the solution is related to ratio of the concentrations of the acid (HIn) and conjugate base (In^-) forms of the indicator by the expression:

(A) $\log \frac{[\text{HIn}]}{[\text{In}^-]} = \text{PK}_{\text{In}} - \text{pH}$

(B) $\log \frac{[\text{HIn}]}{[\text{In}^-]} = \text{pH} - \text{pK}_{\text{In}}$

(C) $\log \frac{[\text{In}^-]}{[\text{HIn}]} = \text{pH} + \text{pK}_{\text{In}}$

(D) $\log \frac{[\text{In}^-]}{[\text{HIn}]} = \text{pK}_{\text{In}} - \text{pH}$

70 Calculate the pH range in which an acid indicator with $K_{\text{acid}}(\text{indicator}) = 1.0 \times 10^{-5}$ changes colour when the concentration of the indicator is $1 \times 10^{-3}\text{M}$.

(A) 5 ± 1

(B) 11 ± 1

(C) 3 ± 1

(D) 8 ± 1

71 pH-range of Methyl red indicator is:

(A) $4.2\text{--}6.3$

(B) $8.5\text{--}10.3$

(C) $8.3\text{--}10$

(D) $3.1\text{--}4.4$

- 72** Indicator which is used in the titration of CH_3COOH & NaOH :
 (A) Methyl orange (B) Methyl red (C) Phenolphthalein (D) Litmus
- 73** In the volumetric estimation of HCl , if we make use of phenolphthalein as an indicator, which base is unsuitable for the titration:
 (A) NaOH (B) RbOH (C) KOH (D) NH_4OH
- 74** What is the suitable indicator for titration of NaOH and oxalic acid:
 (A) Methyl orange (B) Methyl red (C) Phenolphthalein (D) None
- 75** Phenolphthalein does not act as an indicator for the titration between:
 (A) KOH and H_2SO_4 (B) NaOH and CH_3COOH
 (C) Oxalic acid and KMnO_4 (D) $\text{Ba}(\text{OH})_2$ and HCl
- 76** For weak acid and strong base titration, the indicator used is:
 (A) Potassium di-chromate (B) Methyl orange
 (C) Litmus (D) Phenolphthalein
- 77.** 20 ml of 0.2M RNH_2 ($K_b = 10^{-5}$) is titrated against 0.2 M HCl . Which of the following graph is correct?
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- (A)
- (B)
- (C)
- (D)
- 78** An acid-base indicator has a $K_a = 1.0 \times 10^{-5}$. The acid form of the indicator is red and the basic form is blue. Calculate the pH change required to change the colour of the indicator from 80% red to 80% blue.
 (A) 1.20 (B) 0.80 (C) 0.20 (D) 1.40
- 79.** 10gm $\text{NaHCO}_3(s)$ sample is heated in open to constant weight, the residue is titrated against 0.1M HCl in presence of phenolphthalein as an indicator, 500 ml of acid was required to reach end point hence % purity of sample is-
 (A) 21% (B) 42 % (C) 63% (D) 84%

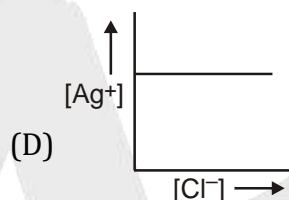
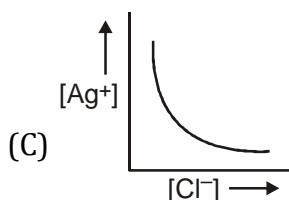
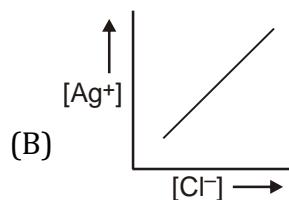
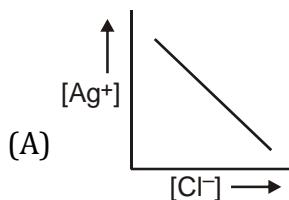


80. A mixture of NaOH & Na₂CO₃ when titrated against 0.1N H₂SO₄ solution, it requires 30 ml to decolorise the phenolphthalein. Now methyl orange is added to it and further 20 ml of same acid are added to observe methyl orange end point then millimoles of NaOH & Na₂CO₃ in mixture respectively
- (A) 2 & 2 (B) 2 & 4 (C) 1 & 2 (D) 2 & 1

Solubility and K_{sp}

81. The solubility of A₂X₃ is y mol dm⁻³. Its solubility product is
- (A) 6 y² (B) 64 y⁴ (C) 36 y⁵ (D) 108 y⁵
82. If K_{sp} for HgSO₄ is 6.4×10^{-5} M² then solubility of this substance in mole per m³ is
- (A) 8×10^{-3} (B) 6.4×10^{-5} (C) 8×10^{-6} (D) 8
83. If the solubility of AgCl (formula mass=143) in water at 25°C is 1.43×10^{-4} gm./100 ml. of solution then the value of K_{sp} will be:
- (A) 1×10^{-5} (B) 2×10^{-5} (C) 1×10^{-10} (D) 2×10^{-10}
84. One litre of saturated solution of CaCO₃ is evaporated to dryness, 7.0 g of residue is left. The solubility product for CaCO₃ is:
- (A) 4.9×10^{-3} (B) 4.9×10^{-5} (C) 4.9×10^{-9} (D) 4.9×10^{-7}
85. Which of the following is most soluble in water?
- (A) MnS ($K_{sp} = 8 \times 10^{-37}$) (B) ZnS ($K_{sp} = 7 \times 10^{-16}$)
 (C) Bi₂S₃ ($K_{sp} = 1 \times 10^{-72}$) (D) Ag₃(PO₄) ($K_{sp} = 1.8 \times 10^{-18}$)
86. K_{sp} of Ag₂CrO₄ at a certain temperature is 8.64×10^{-13} . How many times is its solubility in water greater than in 0.6 M Na₂CrO₄ solution?
- (A) 10 (B) 10 (C) 1000 (D) 129

94. The moles of Ag^+ which must be added to decrease the concentration of Cl^- from $4 \times 10^{-5}\text{M}$ to 10^{-5}M in 100 ml solution, if K_{sp} for AgCl is 10^{-10}M_2 at 25°C
- (A) 4×10^{-5} mole (B) 2×10^{-5} mole (C) 3×10^{-6} mole (D) 4×10^{-6} mole
95. In a saturated solution of AgCl , NaCl is added gradually. The concentration of Ag^+ is plotted against the concentration of Cl^- . The graph appears as:



Effect of Complex Formation and Hydrolysis on Solubility

96. What is the effect of pH on the solubility of $\text{M}(\text{CN})_2$?
(Neglect hydrolysis of M^{2+} ion)
- (A) As pH decreases, solubility decreases.
(B) As pH decreases below 7 or increases above 7, solubility increases in both cases.
(C) As pH decreases, solubility increases.
(D) No dependence on pH of solution.
97. At 300°C , In which of the one litre solution, the solubility of Ag_2CO_3 (solubility product= 8×10^{-12}) will be maximum:
- (A) 0.05 M Na_2CO_3 (B) Pure water (C) 0.05 M AgNO_3 (D) 0.05 M NH_3
98. 1 mole of AgNO_3 is added to 10 litre of 1 M NH_3 . What is the concentration of $\text{Ag}(\text{NH}_3)^+$ in solution ?
- [Given : For $\text{Ag}(\text{NH}_3)_2^+$, $K_{f_1} = 2.0 \times 10^3$; $K_{f_2} = 10^4$]
- (A) 8×10^{-5} (B) 1.25×10^{-5}
(C) 4×10^{-6} (D) 1.25×10^{-4}
99. pH of a saturated solution of silver salt of monobasic acid HA is found to be 9.
Find the K_{sp} of sparingly soluble salt Ag A(s) .
Given : $K_a(\text{HA}) = 10^{-10}$
- (A) 1.1×10^{-11} (B) 1.1×10^{-10} (C) 10^{-12} (D) None of these



EXERCISE # (S-I)

Dissociation of Water, pH of Water

pH of Strong Electrolyte

5. Calculate pH of following solutions :

 - (a) 0.1 M HCl
 - (b) 10^{-3} mole of KOH dissolved in 100 L of water.
 - (c) Decimolar solution of Baryta ($\text{Ba}(\text{OH})_2$), diluted 100 times.
 - (d) 10^{-8} M HCl [$\sqrt{401} = (20.02)$] [$\log 1.051 = 0.03$]
 - (e) 10^{-10} M NaOH

6. 0.1 mole HCl is dissolved in distilled water of volume V. Then, at $\lim_{V \rightarrow \infty}$, $(\text{pH})_{\text{solution}}$ is equal to

7. pH of a dilute solution of HCl is 6.95. Calculate molarity of HCl solution.

$$\left[\begin{array}{l} 10^{-9.95} = 11.22 \times 10^{-8} \\ 10^{-7.05} = 8.90 \times 10^{-8} \end{array} \right]$$

pH of Weak Electrolyte

- 8.** Calculate pH of following solutions :

(b) 0.1 M CH₃COOH ($K_a = 1.8 \times 10^{-5}$) ($\log \sqrt{1.8} = 0.13$)

(c) 0.1 M NH₄OH ($K_b = 1.8 \times 10^{-5}$)

(f) 10⁻⁷ M CH₃COOH ($K_a = 10^{-5}$)

(g) 10⁻⁸ M CH₃COOH ($K_a = 1.8 \times 10^{-5}$) [$\sqrt{401} = (20.02)$] [$\log 1.051 = 0.03$]



9. Calculate:
- K_a for a monobasic acid whose 0.10 M solution has pH of 4.50.
 - K_b for a monoacidic base whose 0.10 M solution has a pH of 10.50.
- $$K_b = \frac{10^{-3.5} \times 10^{-3.5}}{0.1 - 10^{-3.5}} = 10^{-6}$$
10. Calculate the ratio of degree of dissociation (α_2/α_1) when 1 M acetic acid solution is diluted 100 times. [Given $K_a=10^{-5}$ M]
11. Calculate the ratio of degree of dissociation of acetic acid and hydrocyanic acid (HCN) in 1 M their respective solution of acids.[Given $K_{a(CH_3COOH)} = 1.8 \times 10^{-5}$; $K_{a(HCN)} = 6.2 \times 10^{-10}$]
- $$\left[\sqrt{\frac{18}{6.2}} = 1.704 \right]$$
12. The pH of aqueous solution of ammonia is 10. Find molarity of solution. $K_b(NH_4OH) = 10^{-5}$.
13. The solution of weak monoprotic acid which is 0.01 M has pH = 3. Calculate K_a of weak acid.
14. Boric acid is a weak monobasic acid. It ionizes in water as
- $$B(OH)_3 + H_2O \rightleftharpoons + H^+; K_a = 5.9 \times 10^{-10}$$
- Calculate pH of 0.3 M boric acid. [$\log(\sqrt{1.77}) = 0.13$]
- pH of Mixture of More Than One Acid/Base**
15. Calculate pH if equal volume of HCl solution (PH = 4) + 0.0019 N HCl solution
16. Calculate pH of following solutions:
- 0.1 M H_2SO_4 (50 ml) + 0.4 M HCl 50 (ml) [$\log 0.3 = -0.522$]
 - 0.1 M HA + 0.1 M HB [$K_a(HA) = 2 \times 10^{-5}$; $K_a(HB) = 4 \times 10^{-5}$] [$\log = 0.39$]
17. Upon passing 0.01 mole HCl gas through 100 mL of 0.05 M Formic acid solution ($K_a = 1.8 \times 10^{-4}$), determine change in pH of solution and $[HCOO^-]$ in resulting solution.
18. Calculate $[H^+]$ and $[CHCl_2COO^-]$ in a solution that is 0.01 M in HCl and 0.01 M in $CHCl_2COOH$. Take ($K_a = 3 \times 10^{-2}$) ($\sqrt{30} = 5.5$)



19. Calculate $[H^+]$, $[CH_3COO^-]$ and $[C_7H_5O_2^-]$ in a solution that is 0.02 M in acetic acid and 0.01M in benzoic acid. $K_a(\text{acetic}) = 1.8 \times 10^{-5}$, $K_a(\text{benzoic}) = 6.4 \times 10^{-5}$.

Polyprotic Acid Base

20. What are the concentration of H^+ , $H_2C_2O_4$, $HC_2O_4^-$ and $C_2O_4^{2-}$ in a 0.1 M solution of oxalic acid ?

$[K_1 = 10^{-2} \text{ M}$ and $K_2 = 10^{-5} \text{ M}]$

21. Calculate $[H^+]$, $[H_2PO_4^-]$, $[HPO_4^{2-}]$ and $[PO_4^{3-}]$ in a 0.01M solution of H_3PO_4 .

Take $K_1 = 10^{-3}$, $K_2 = 10^{-8}$, $K_3 = 10^{-13}$.

22. What are the concentrations of H^+ , HSO_4^- , SO_4^{2-} and H_2SO_4 in a 0.20 M solution of sulphuric acid?

Given: $H_2SO_4 \rightarrow H^+ + HSO_4^-$; strong



23. Calculate the pH of a 0.1M solution of $H_2NCH_2CH_2NH_2$; ethylenediamine (en). Determine the en H_2^{2+} . Concentration in the solution. K_{b_1} and K_{b_2} values of ethylenediamine are 8.5×10^{-5} and 7.1×10^{-8} respectively.

Conjugate Acid Base, Bronsted Theory

24. Which of the following ions or compounds in a solution tend to produce an acidic, a basic or a neutral solution ?

- | | | | |
|-----------------|-----------------|-----------------|-------------|
| (a) $C_2H_5O^-$ | (b) Cu^{+2} | (c) SO_3^{2-} | (d) F^- |
| (e) NH_4^+ | (f) CH_3COONa | (g) KNO_3 | (h) $NaOCl$ |
| 5(i) Na_2CO_3 | (j) $ZnCl_2$ | | |

25. What is ionisation constant of HOCl, if K_b of $OCl^- = 4 \times 10^{-10}$? Also find its pK_a .

26. K_{a1} , K_{a2} and K_{a3} values for H_3PO_4 are 10^{-3} , 10^{-8} and 10^{-12} respectively. If $K_w(H_2O) = 10^{-14}$, then:

- (i) What is dissociation constant of HPO_4^{2-} ?
- (ii) What is K_b of HPO_4^{2-} ?
- (iii) What is K_b of $H_2PO_4^-$?
- (iv) What is order of K_b of PO_4^{3-} (K_{b_3}), HPO_4^{2-} (K_{b_2}) and $H_2PO_4^-$ (K_{b_1}) ?



Salt Hydrolysis

27. What is the OH^- concentration of a 0.08 M solution of CH_3COONa .

$$[\text{K}_a(\text{CH}_3\text{COOH}) = 1.8 \times 10^{-5}]$$

28. Calculate the pH of a 2.0 M solution of NH_4Cl . $[\text{K}_b(\text{NH}_3) = 1.8 \times 10^{-5}]$

29. 0.25 M solution of pyridinium chloride $\text{C}_5\text{H}_6\text{N}^+ \text{Cl}^-$ was found to have a pH of 2.699. What is K_b for pyridine, $\text{C}_5\text{H}_5\text{N}$? ($\log 2 = 0.3010$) antilog (0.796) = 6.25

30. Calculate the percent hydrolysis in a 0.06 M solution of KCN .

$$[\text{K}_a(\text{HCN}) = 6 \times 10^{-10}]$$

31. Calculate the pH of 1.0×10^{-3} M sodium phenolate, NaOC_6H_5 . K_a for HOOC_6H_5 is 1.05×10^{-10} .

$$\frac{\sqrt{43}-1}{21} = 0.26 \text{ & } \log 26 = 1.43$$

Salt Hydrolysis of Multivalent Cation Or Anion

32. Calculate the OH^- concentration and the H_3PO_4 concentration of a solution prepared by dissolving 0.1 mol of Na_3PO_4 in sufficient water to make 1L of solution.

$$\text{K}_1 = 7.1 \times 10^{-3}, \text{K}_2 = 6.3 \times 10^{-8}, \text{K}_3 = 4.5 \times 10^{-13}.$$

33. Calculate the extent of hydrolysis of 0.005 M K_2CrO_4 . $[\text{K}_2 = 3.1 \times 10^{-7}$ for H_2CrO_4]
(It is essentially strong for first ionization).

$$\frac{1}{\sqrt{5 \times 3.1}} = 0.26$$

34. A 0.010 M solution of $\text{PuO}_2(\text{NO}_3)_2$ was found to have a pH of 4.0. What is the hydrolysis constant, K_h , for PuO_2^{2+} and what is K_b for PuO_2OH^+ ?

35. The acid ionization (hydrolysis) constant of Zn^{2+} is 1.0×10^{-9}

(a) Calculate the pH of a 0.001 M solution of ZnCl_2

(b) What is the basic dissociation constant of $\text{Zn}(\text{OH})^+$?



Amphiprotic Salt and Salt of WA + WB

36. Calculate the extent of hydrolysis & the pH of 0.02 M $\text{CH}_3\text{COONH}_4$.

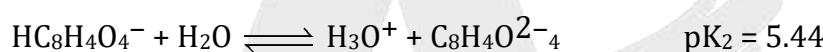
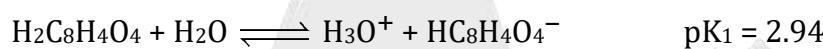
$$[\text{K}_b(\text{NH}_3) = 1.8 \times 10^{-5}, \text{K}_a(\text{CH}_3\text{COOH}) = 1.8 \times 10^{-5}]$$

37. What is the pH of 0.1M NaHCO_3 ?

$$\text{K}_1 = 4.5 \times 10^{-7}, \text{K}_2 = 4.5 \times 10^{-11} \text{ for carbonic acids.}$$

$$\log(4.5) = 0.66$$

38. Calculate pH of 0.05M potassium hydrogen phthalate, $\text{KHC}_8\text{H}_4\text{O}_4$.



pH of buffer solution and Change on pH of Buffer Solution

39. Determine $[\text{OH}^-]$ of a 0.050 M solution of ammonia to which sufficient NH_4Cl has been added to make the total $[\text{NH}_4^+]$ equal to 0.100. $[\text{K}_b(\text{NH}_3) = 1.8 \times 10^{-5}]$

40. A buffer of pH 9.26 is made by dissolving x moles of ammonium sulphate and 0.1 mole of ammonia into 100 mL solution. If pK_b of ammonia is 4.74, calculate value of x.

41. (a) Determine the pH of a 0.2 M solution of pyridine $\text{C}_5\text{H}_5\text{N}$. $\text{K}_b = 1.5 \times 10^{-9}$

(b) Predict the effect of addition of pyridinium ion $\text{C}_5\text{H}_5\text{NH}^+$ on the position of the equilibrium. Will the pH be raised or lowered ?

(c) Calculate the pH of 1.0 L of 0.10 M pyridine solution to which 0.3 mol of pyridinium chloride $\text{C}_5\text{H}_5\text{NH}^+\text{Cl}$, has been added, assuming no change in volume.

42. Calculate the pH of 0.5 L of a 0.2 M NH_4Cl – 0.2 M NH_3 buffer before and after addition of (a) 0.05 mole of NaOH and (b) 0.05 mole of HCl . Assume that the volume remains constant. [Given: pK_b of $\text{NH}_3 = 4.74$]



Problems Related with mixing... Titration type

- 43.** Calculate the pH of the resulting solution formed by mixing the following solutions:
- 20 mL of 0.2 M $\text{Ba}(\text{OH})_2$ + 30 mL of 0.1 M HCl
 - 2 mL of 0.1 M HCl + 10 mL of 0.01 M $\text{Sr}(\text{OH})_2$
 - 10 mL of 0.1 M H_2SO_4 + 10 mL of 0.1 M KOH.
- 44.** How many of the following statement(s) is/are correct for making a buffer solution ?
- It can be formed by mixing equal moles of HCl and CH_3COONa
 - It can be formed by mixing equal moles of HNO_3 and NH_3
 - It can be formed by mixing equal moles of HCN and Aniline.
 - It can be formed by mixing unequal moles of NH_4OH and HCl.
 - It can be formed by mixing unequal moles of HCN and KOH.
- 45.** Calculate the pH of a solution prepared by mixing 50.0 mL of 0.200 M $\text{HC}_2\text{H}_3\text{O}_2$ and 50.0 mL of 0.100 M NaOH. [$K_{\text{a}}(\text{CH}_3\text{COOH}) = 1.8 \times 10^{-5}$]
- 46.** 50 mL of 0.1 M NaOH is added to 75 mL of 0.1 M NH_4Cl to make a basic buffer. If pK_a of NH_4^+ is 9.26, calculate pH.
- 47.** Calculate the pH of a solution which results from the mixing of 50.0 ml of 0.3 M HCl with 50.0 ml of 0.4 M NH_3 . [$K_b(\text{NH}_3) = 1.8 \times 10^{-5}$]
- 48.** Calculate the pH of a solution made by mixing 50.0 ml of 0.2M NH_4Cl & 75.0 ml of 0.1 M NaOH. [$K_b(\text{NH}_3) = 1.8 \times 10^{-5}$]
- 49.** Calculate OH^- concentration at the equivalent point when a solution of 0.2 M acetic acid is titrated with a solution of 0.2 M NaOH. K_a for the acid = 10^{-5} .
- 50.** Calculate the hydronium ion concentration and pH at the equivalence point in the reaction of 22.0 mL of 0.10M acetic acid, CH_3COOH , with 22.0 mL of 0.10 M NaOH. [$K_a = 1.8 \times 10^{-5}$]
 $(10^{+0.29} = 1.95)$



51. Calculate the hydronium ion concentration and the pH at the equivalence point in a titration of 50.0 mL of 0.40 M NH_3 with 0.40M HCl. [$K_b = 1.8 \times 10^{-5}$]
 $10^{0.02} = 1.05$
52. CH_3COOH (50 ml, 0.1 M) is titrated against 0.1 M NaOH solution. Calculate the pH at the addition of 0 ml, 10 ml, 20 ml, 25 ml, 40 ml, 50 ml of NaOH. K_a of CH_3COOH is 2×10^{-5} .
 $[\log 2 = 0.3010, \log 3 = 0.4771]$

Indicators

53. For the acid indicator thymol blue, pH is 2.0 when half the indicator is in unionised form. Find the % of indicator in unionised form in the solution with $[\text{H}^+] = 4 \times 10^{-3}$ M.
54. An acid indicator has a K_a of 3×10^{-5} . The acid form of the indicator is red & the basic form is blue. By how much must the pH change in order to change the indicator form 75% red to 75 % blue? $[\log 3 = 0.4771]$
55. Bromophenol blue is an acid indicator with a K_a value of 6×10^{-5} . What % of this indicator is in its basic form at a pH of 5 ?
56. At what pH does an indicator change colour if the indicator is a weak acid with $K_{\text{ind}} = 4 \times 10^{-4}$. For which one(s) of the following neutralizations would the indicator be useful? Explain.
(a) $\text{NaOH} + \text{CH}_3\text{COOH}$ (b) $\text{HCl} + \text{NH}_3$ (c) $\text{HCl} + \text{NaOH}$

57. What indicator should be used for the titration of 0.10 M KH_2BO_3 with 0.10 M HCl ?

$$K_a (\text{H}_3\text{BO}_3) = 7.2 \times 10^{-10} . [\log \left(\frac{20}{7.2} \right) = 0.44]$$

Double Indicator, Solubility and K_{sp}

58. 100 ml solution containing Na_2CO_3 & NaHCO_3 is titrated with 0.1 M solution of triprotic strong acid then following results were obtained
(i) 25 ml solution required 10 ml of acid using phenolphthalein as indicator
(ii) 20 ml solution required 20 ml of acid using methyl orange indicator
What will be the value of sum of millimoles of Na_2CO_3 & NaHCO_3 in original solution.

- 59.** Calculate the solubility of A_2X_3 in pure water, assuming that neither kind of ion reacts with water. For A_2X_3 , $[K_{sp} = 1.08 \times 10^{-23}]$

60. The solubility of $PbSO_4$ water is 0.038 g/L. Calculate the solubility product constant of $PbSO_4$.
Molar mass $PbSO_4 = 304$ g/mole, $\frac{380}{304} = 1.25$ $(1.25)^2 = 1.56$

61. A solution of saturated CaF_2 is found to contain 4.1×10^{-4} M fluoride ion. Calculate the K_{sp} of CaF_2 . Use $4\left(\frac{4.1}{2}\right)^3 \approx 34$.

62. The solubility of ML_2 (formula weight, 60 g/mol) in water is 2.4×10^{-5} g/100 mL solution. Calculate the solubility product constant for ML_2 .

63. The values of K_{sp} for the slightly soluble salts MX and QX_2 are each equal to 4.0×10^{-18} . Which salt is more soluble? Explain your answer fully.

SOLUBILITY IN PRESENCE OF COMMON ION

- 64.** How many mol CuI ($K_{sp} = 5 \times 10^{-12}$) will dissolve in 1.0 L of 0.10 M NaI solution ?

65. Determine the solubility of AgCl in 0.1 M BaCl₂. [K_{sp} for AgCl = 1×10^{-10}]

66. Calculate the Simultaneous solubility of AgSCN and AgBr.
 $K_{sp}(\text{AgSCN}) = 1.1 \times 10^{-12}$, $K_{sp}(\text{AgBr}) = 5 \times 10^{-13}$. $\left(\frac{1.1}{1.26} \approx 0.9, \frac{5}{1.26} \approx 4 \right)$

67. Calculate F⁻ in a solution saturated with respect of both MgF₂ and SrF₂. $K_{sp}(\text{MgF}_2) = 9.5 \times 10^{-9}$,
 $K_{sp}(\text{SrF}_2) = 4 \times 10^{-9}$.

Precipitation

- 69.** 8×10^{-6} M AgNO₃ solution is gradually added in 1 L of 10^{-4} M KCl solution. Up to what volume AgNO₃ solution being added (in L), precipitation of AgCl will not take place? (K_{sp} of AgCl = 2×10^{-10})

70. Solubility of Ag₂CrO₄ in water at 25°C is 10^{-3} M. If 0.1 moles of K₂CrO₄ are added to 1 litre saturated solution of Ag₂CrO₄. Then find moles of Ag₂CrO₄ precipitated at 25°C. If your answer is $x \times 10^y$ then fill 'x' in OMR. Where 'x' is single digit number.

71. What mass of Pb²⁺ ion is left in solution when 50.0 mL of 0.20M Pb(NO₃)₂ is added to 50.0 mL of 1.5 M NaCl ? [Given K_{sp} for PbCl₂ = 1.7×10^{-4}]
[$5.6 \times 208 = 1.2 \times 10^3$] [Atomic mass of Pb = 208, $\frac{1.7}{(0.55)^2} = 5.6$]

72. The solubility of CaCO₃ is 7 mg/litre. Calculate the solubility of BaCO₃ (in mol/L) from this information and from the fact that when Na₂CO₃ is added slowly to a solution containing equimolar concentration of Ca²⁺ and Ba²⁺, no precipitate of CaCO₃ is formed until 90% of Ba²⁺ has been precipitated as BaCO₃. (Assume no hydrolysis of CO₃²⁻ ion).

Effect of Complex Formation And Hydrolysis on Solubility



EXERCISE # (O-II)

1. If K_1 & K_2 be first and second ionisation constant of H_3PO_4 and $K_1 \gg K_2$ which is correct.
 (A) $[H^+] = [H_2PO_4^-]$ (B) $[H^+] = \sqrt{K_1[H_3PO_4]}$ (C) $[HPO_4^{2-}] = K_2$ (D) $[H^+] = 3[PO_4^{3-}]$

2. Choose the correct statement(s)
 (A) K_a for an acid HA is 1×10^{-6} . K_b for A^- would be 10^{-8}
 (B) The value of K_w increases with increase in temperature
 (C) Larger the value of pK_a weaker is the acid.
 (D) Salts of strong acids and weak bases undergo cationic hydrolysis.

3. Choose the correct statement(s)
 (A) pH of 0.1M CH_3COOH solution decreases with increase in temperature
 (B) pOH of 0.1M NH_4OH solution decreases with increase in temperature
 (C) $10^{-4}M$ HCl solution is more acidic than 0.1M HCN ($K_{aHCN} = 10^{-5}$) solution.
 (D) On dilution degree of dissociation of weak electrolytes increases.

4. Choose the incorrect statement(s)
 (A) When a solution of a weak monoprotic acid is titrated against a strong base, at half-neutralization point, $pH = \frac{1}{2} pK_a$.
 (B) The pH of a solution which is 0.1 M in sodium acetate and 0.01 M in acetic acid ($pK_a = 4.74$) would be 5.74.
 (C) In a mixture of weak acid and its salt, the ratio of concentration of salt to acid is increased Ten times. The pH of the solution would Increase by one unit.
 (D) A buffer has maximum buffer capacity when the ratio of salt to acid is 10.

5. Select the correct statement(s):
 (A) If pOH of aq. solution at $70^\circ C$ is 7, then solution will be acidic
 (B) If $[H^+]$ concentration is decreases 100 times, pH of solution increases by 2 units
 (C) If solution of CH_3COONa (aq.) is diluted then pH increases.
 (D) Buffer capacity remains constant with dilution.



6. Which of the following is correct for 0.1 M BOH solution ($K_b = 10^{-5}$)
- pH of solution is 11
 - OH^- concentration is 10^{-3} mol/L
 - it's salt with HCl (i.e., BCl) form the acidic solution in water
 - Phenolphthalein indicator can be used during the titration of BOH with HCl
7. When equal volumes of the following solutions are mixed, precipitation of AgCl ($K_{\text{sp}} = 1.8 \times 10^{-10}$) will occur
- 10^{-4} M (Ag^+) and 10^{-4} M (Cl^-)
 - 10^{-5} M (Ag^+) and 10^{-5} M (Cl^-)
 - 10^{-6} M (Ag^+) and 10^{-6} M (Cl^-)
 - 10^{-10} M (Ag^+) and 10^{-10} M (Cl^-)
8. Choose the correct statement(s)
- From an equimolar solution of Cl^- and Br^- ions, the addition of Ag^+ will precipitates Br^- ion first (K_{sp} of AgCl & AgBr are 1×10^{-10} & 1×10^{-13} respectively). \
 - If the salts M_2X , QY_2 and PZ_3 have same solubilities ($<<<1$), their K_{sp} values are related as $\text{M}_2\text{X} = \text{QY}_2 > \text{PZ}_3$
 - If the solubility of the salt $\text{Li}_3\text{Na}_3(\text{AlF}_6)_2$ is x , then its solubility product would be 2916×8 .
 - K_{sp} of Fe(OH)_3 in aqueous solution is 3.8×10^{-38} at 298K. The concentration of Fe^{3+} will increase when $[\text{H}^+]$ ion concentration decreases
9. Choose the correct statement(s)
- AgCl is less soluble in aqueous sodium chloride solution than in pure water.
 - In the presence of a common ion (incapable of forming complex ion), the solubility of salt decreases.
 - The solubility of CH_3COOAg in water considering hydrolysis of CH_3COO^- ions would be Greater than that ignoring the hydrolysis.
 - The solubility of AgCl in NH_3 is greater than the solubility in pure water because of complex ion, $[\text{Ag}(\text{NH}_3)_2]^+$ formation.

Paragraph for Question 10 to 12

1 litre of 1M CH_3COOH (very weak acid) taken is a container initially. Now this solution is diluted upto volume V (litre) so that pH of the resulting solution becomes the twice of the original value. ($K_a(\text{CH}_3\text{COOH}) = 10^{-6}$). Now equal volume of $0.5 \times 10^{-6}\text{M}$ NaOH solution is added to this resulting solution. So that a buffer solution is obtained.

$$\text{pH (acidic buffer)} = \text{pK}_a + \log_{10} \left(\frac{[\text{Anion}]}{[\text{Acid}]} \right) \quad \& \quad \text{pOH (Basic buffer)} = \text{pK}_b + \log_{10} \left(\frac{[\text{Cation}]}{[\text{Base}]} \right)$$

Paragraph for Q.13 to Q.15

100ml of 1M Na_3PO_4 is titrated with 1M HCl the following observation were made

Stage of titration	pH
I half equivalence point	12
I equivalence point	10
II equivalence point	6



Paragraph for Question 16 to 17

A solution contains one mole each of HA & HB (both are weak acids) in one litre solution. Now one mole of NaOH is added to this solution so that both the acids are partially neutralised. Heat of neutralisation of HA & HB are -11.8 and -12.4 kcal per mole respectively and heat produced during partial neutralisation of HA & HB is -12.25 kcal.

Paragraph for question nos. 18 to 20

To find the K_{sp} of AgBrO_3 a student prepared one litre of a just saturated solution by adding AgBrO_3 at 27°C . He found that a copper wire left in the solution overnight became covered with silver and Cu^{+2} (aq) ions were also formed in solution. The wire was cleaned, dried, and found to weight 7.04 mg less than it did originally. ($R = 8 \text{ J/mol/K}$; $\ln x = 2.3 \log x$)

Given : $\text{Cu(s)} + 2\text{Ag}^+(\text{aq}) \rightleftharpoons \text{Cu}^{+2}(\text{aq}) + 2\text{Ag(s)}$ $\Delta G^\circ = 110.4 \text{ kJ}$

- 18.** The number of moles of Cu which reacted was
(A) 1.1×10^{-4} (B) 1.1 (C) 0.11 (D) 1.1×10^{-3}

19. The $[Ag^+]$ in the original saturated solution have been
(A) 1.1×10^{-2} (B) 1.1×10^{-4} (C) 2.2×10^{-4} (D) 5.5×10^{-5}

20. The K_{sp} for $AgBrO_3$ as calculated from the above data is about
(A) 1.21×10^{-8} (B) 3.025×10^{-9} (C) 1.7×10^{-4} (D) 4.84×10^{-8}

21. Match the effect of addition of 1 M NaOH to 100 mL 1 M CH_3COOH (in Column I) with pH (in Column II):

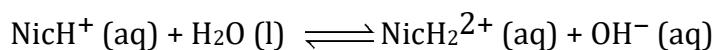
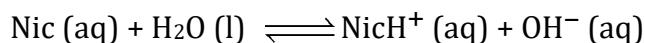
	Column-I		Column-II
(A)	25 mL of NaOH	(P)	pK_a
(B)	50 mL of NaOH	(Q)	$pK_a + \log 3$
(C)	75 mL of NaOH	(R)	$pK_a - \log 3$
(D)	100 mL of NaOH	(S)	$\frac{1}{2} [pK_w + pK_a - \log 2]$

22.	Column-I	Column-II
	PH	Solution
(A)	3	(P) When equal volumes of 0.2M NH_4OH ($K_b = 10^{-5}$) & 0.2M HCl are mixed
(B)	5	(Q) When equal volumes of 0.2M CH_3COONa & 0.2M HCl are mixed ($K_a(\text{CH}_3\text{COOH}) = 10^{-5}$)
(C)	8	(R) 0.1M Na_2HPO_4 (for H_3PO_4 ; $K_{a1} = 10^{-4}$; $K_{a2} = 10^{-6}$; $K_{a3} = 10^{-10}$)
(D)	9	(S) At 1 st half equivalence point of H_2CO_3 when titrated against 0.1M NaOH, $K_{a1} = 10^{-5}$, $K_{a2} = 10^{-9}$
		(T) $\text{Mg}(\text{OH})_2$; $K_{sp} = 5 \times 10^{-16}$



EXERCISE # (S-II)

- Determine the $[S^{2-}]$ in a saturated (0.1M) H_2S solution to which enough HCl has been added to produce a $[H^+]$ of 2×10^{-4} . $K_1 = 10^{-7}$, $K_2 = 10^{-14}$.
- Nicotine, $C_{10}H_{14}N_2$, has two basic nitrogen atoms and both can react with water to give a basic solution a



K_{b1} is 7×10^{-7} and K_{b2} is 10^{-10} . Calculate the approximate pH of a 0.020 M solution.

$$[(\log \sqrt{1.4} = 0.07)]$$

- Calculate the pH of 0.1 M solution of (i) $NaHCO_3$, (ii) Na_2HPO_4 and (iii) NaH_2PO_4 . Given that:



- Calculate the pH of the following solutions.

$$[K_1 = 7.5 \times 10^{-3} \text{ M} ; K_2 = 6.2 \times 10^{-8} \text{ M} ; K_3 = 1.0 \times 10^{-12} \text{ M}]$$

- 50 ml of 0.12 M H_3PO_4 + 20 ml of 0.15 M NaOH;
- 50 ml of 0.12 M H_3PO_4 + 40 ml of 0.15 M NaOH;
- 40 ml of 0.12 M H_3PO_4 + 40 ml of 0.18 M NaOH;
- 40 ml of 0.10 M H_3PO_4 + 40 ml of 0.25 M NaOH.

- A buffer solution was prepared by dissolving 0.02 mol propionic acid & 0.015 mol sodium propionate in enough water to make 1.00 L of solution .(K_a for propionic acid is 1.34×10^{-5})
 - What is the pH of the buffer?
 - What would be the pH if 1.0×10^{-5} mol HCl were added to 10 ml of the buffer ?
 - What would be the pH if 1.0×10^{-5} mol NaOH were added to 10 ml of the buffer.
 - Also report the percent change in pH of original buffer in cases (b) and (c).



6. A weak base (50.0mL) was titrated with 0.1 M HCl. The pH of the solution after the addition of 10.0 mL and 25.0 mL were found to be 9.84 and 9.24, respectively. Calculate K_b of the base and pH at the equivalence point. [$\log 2 = 0.3$]
7. The indicator phenol red is half in the ionic form when pH is 7.2. If the ratio of the undissociated form to the ionic form is 1: 5, find the pH of the solution. With the same pH for solution, if indicator is altered such that the ratio of undissociated form to dissociated form becomes 1: 4, find the pH when 50 % of the new indicator is in ionic form.
8. What $[H_3O^+]$ must be maintained in a saturated H_2S solution (0.1 M) to precipitate Pb^{2+} , but not Zn^{2+} from a solution in which each ion is present at a concentration of 0.01 M ? (K_1K_2 of $H_2S = 1.1 \times 10^{-21}$; K_{sp} of $ZnS = 1.0 \times 10^{-21}$; $\sqrt{11} = 3.3$)
9. What minimum pH must be maintained in a saturated H_2S solution (0.1 M) to cause precipitation of both Mn^{2+} & Fe^{2+} from a solution, in which each ion is present at a concentration of 0.01 M? (K_1K_2 of $H_2S = 9.6 \times 10^{-21}$; K_{sp} of $MnS = 2.5 \times 10^{-13}$; K_{sp} of $FeS = 6.4 \times 10^{-18}$)
10. 2M solution of Na_2CO_3 is boiled in a closed container with excess of CaF_2 . Very little amount of $CaCO_3$ and NaF are formed. If the solubility product (K_{sp}) of $CaCO_3$ is x and molar solubility of CaF_2 is y , find the molar concentration of F^- in resulting solution after equilibrium is attained.
11. Determine the concentration of NH_3 solution whose 1 L can dissolve 0.1 mole $CuCO_3$. Given: K_{sp} of $CuCO_3 = 1.4 \times 10^{-10}$ and K_f of $[Cu(NH_3)_4]^{2+} = 2 \times 10^{13}$.
Take $\sqrt[4]{\frac{1000}{2.8}} = 4.4$. Assume no other reaction to take place.
12. Calculate solubility of MnS in a buffer solution of given pH. Solubility constant of MnS is K_{sp} and dissociation constants of H_2S are K_1 & K_2 respectively.

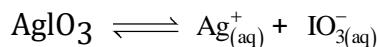


EXERCISE # JEE-MAINS

1. The solubility in water of a sparingly soluble salt AB_2 is 1.0×10^{-5} mol L $^{-1}$. Its solubility product will be [AIEEE-2003]
 (A) 1×10^{-15} (B) 1×10^{-10} (C) 4×10^{-15} (D) 4×10^{-10}
2. The solubility of $Mg(OH)_2$ is x mole/lit. then its solubility product is: [AIEEE-2002]
 (A) x^3 (B) $5x^3$ (C) $4x^3$ (D) $2x^2$
3. The molar solubility in mol L $^{-1}$ of a sparingly soluble salt MX_4 is ' s '. The corresponding solubility product is K_{SP} . ' s ' is given in terms of K_{SP} by relation: [AIEEE-2004]
 (A) $s = (K_{SP} / 128)^{1/4}$ (B) $s = (128K_{SP})^{1/4}$ (C) $s = (256K_{SP})^{1/5}$ (D) $s = (K_{SP}/256)^{1/5}$
4. The conjugate base of $H_2PO_4^{-}$ is [AIEEE-2004]
 (A) H_3PO_4 (B) P_2O_5 (C) PO_4^{3-} (D) HPO_4^{2-}
5. Hydrogen ion concentration in mol/L in a solution of pH = 5.4 will be: [AIEEE-2005]
 (A) 3.88×10^6 (B) 3.98×10^8 (C) 3.98×10^{-6} (D) 3.68×10^{-6}
6. The solubility product of a salt having general formula MX_2 , in water is: 4×10^{-12} . The concentration of M^{2+} ions in the aqueous solution of the salt is: [AIEEE-2005]
 (A) $1.0 \times 10^{-4}M$ (B) $2.0 \times 10^{-6}M$ (C) $4.0 \times 10^{-10}M$ (D) $1.6 \times 10^{-4}M$
7. What is the conjugate base of OH^- ? [AIEEE-2005]
 (A) O^{2-} (B) O^- (C) H_2O (D) O_2
8. The first and second dissociation constants of an acid H_2A are 1.0×10^{-5} and 5.0×10^{-10} respectively. the overall dissociation constant of the acid will be [AIEEE-2007]
 (A) 0.2×10^5 (B) 5.0×10^{-5} (C) 5.0×10^{15} (D) 5.0×10^{-15}
9. The pK_a of a weak acid (HA) is 4.5. The pOH of an aqueous buffer solution of HA in which 50% of the acid is ionised is [AIEEE-2007]
 (A) 7.0 (B) 4.5 (C) 2.5 (D) 9.5



- 10.** In a saturated solution of the sparingly soluble strong electrolyte AgIO_3 (molecular mass = 283) the equilibrium which sets in is: [AIEEE-2007]



If the solubility product constant K_{sp} of AgIO_3 at a given temperature is 1.0×10^{-8} , what is the mass of AgIO_3 contained in 100 ml of its saturated solution?

- (A) 28.3×10^{-2} g (B) 2.83×10^{-3} g (C) 1.0×10^{-7} g (D) 1.0×10^{-4} g

- 11.** 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: [AIEEE-2008]

- (A) 9.58 (B) 4.79 (C) 7.01 (D) 9.22

- 12.** Solid $\text{Ba}(\text{NO}_3)_2$ is gradually dissolved in a 1.0×10^{-4} M Na_2CO_3 solution. At what concentration of Ba^{2+} will a precipitate begin to form? (K_{sp} for $\text{Ba CO}_3 = 5.1 \times 10^{-9}$) [AIEEE-2009]

- (A) 8.1×10^{-8} M (B) 8.1×10^{-7} M (C) 4.1×10^{-5} M (D) 5.1×10^{-5} M

- 13.** Solubility product of silver bromide is 5.0×10^{-13} . The quantity of potassium bromide (molar mass taken as 120 g mol⁻¹) to be added to 1 litre of 0.05 M solution of silver nitrate to start the precipitation of AgBr is: [AIEEE-2010]

- (A) 5.0×10^{-8} g (B) 1.2×10^{-10} g (C) 1.2×10^{-9} g (D) 6.2×10^{-5} g

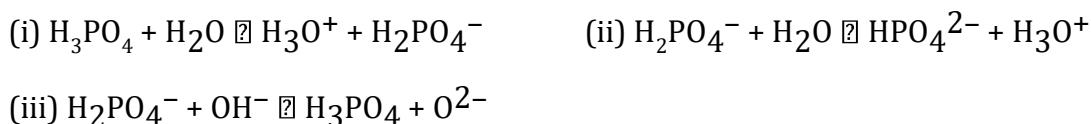
- 14.** In aqueous solution the ionization constants for carbonic acid are [AIEEE-2010]

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

Select the correct statement for a saturated 0.034 M solution of the carbonic acid:

- (A) The concentration of H^+ is double that of CO_3^{2-}
 (B) The concentration of CO_3^{2-} is 0.034 M
 (C) The concentration of CO_3^{2-} is greater than that of HCO_3^-
 (D) The concentrations of H^+ and HCO_3^- are approximately equal

16. Three reactions involving H_2PO_4^- are given below: [AIEEE-2010]



In which of the above does H_2PO_4^- act as an acid?

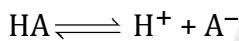
- (A) (ii) only (B) (i) and (ii) (C) (iii) only (D) (i) only

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

[AIEEE-2011]

- (A) $\sqrt[2]{1.6 \times 10^{-30}}$ (B) $\sqrt[4]{1.6 \times 10^{-30}}$ (C) $\sqrt[4]{1.6 \times 10^{-30} / 27}$ (D) $1.6 \times 10^{-30} / 27$

- 18.** An acid HA ionises as



The pH of 1.0 M solution is 5. Its dissociation constant would be:

[AIEEE-2011]

- (A) 1×10^{-10} (B) 5 (C) 5×10^{-8} (D) 1×10^{-5}

19. If K_{sp} of CaF_2 at 25°C is 1.7×10^{-10} , the combination amongst the following which gives a precipitate of CaF_2 is: [JEE-MAIN(online)-2012]

- (A) 1×10^{-2} M Ca²⁺ and 1×10^{-5} M F⁻ (B) 1×10^{-4} M Ca²⁺ and 1×10^{-4} M F⁻
 (C) 1×10^{-3} M Ca²⁺ and 1×10^{-5} M F⁻ (D) 1×10^{-2} M Ca²⁺ and 1×10^{-3} M F⁻

- 20.** The pH of a 0.1 molar solution of the acid HQ is 3. The value of the ionization constant, K_a of this acid is: [AIEEE-2012]

- (A) 1×10^{-7} (B) 3×10^{-7} (C) 1×10^{-3} (D) 1×10^{-5}

- 21.** Solid $\text{Ba}(\text{NO}_3)_2$ is gradually dissolved in a 1.0×10^{-4} M Na_2CO_3 solution. At which concentration of Ba^{2+} , precipitate of BaCO_3 begins to form?

(K_{sp} for $\text{BaCO}_3 = 5.1 \times 10^{-9}$)

[JEE-Main(Online)-2013]

- (A) $5.1 \times 10^{-5} \text{ M}$ (B) $8.1 \times 10^{-7} \text{ M}$ (C) $4.1 \times 10^{-5} \text{ M}$ (D) $7.1 \times 10^{-8} \text{ M}$



22. NaOH is a strong base. What will be pH of 5.0×10^{-2} M NaOH solution? ($\log 2 = 0.3$)

[JEE-MAIN(Online)-2013]

- (A) 13.70 (B) 13.00 (C) 14.00 (D) 12.70

23. Which one of the following arrangements represents the correct order of solubilities of sparingly soluble salts Hg_2Cl_2 , $Cr_2(SO_4)_3$, $BaSO_4$ and $CrCl_3$ respectively?

[JEE-MAIN(Online)-2013]

- (A) $\left(\frac{K_{sp}}{4}\right)^{\frac{1}{3}}, \left(\frac{K_{sp}}{108}\right)^{\frac{1}{8}}, \left(K_{sp}\right)^{\frac{1}{2}}, \left(\frac{K_{sp}}{27}\right)^{\frac{1}{4}}$
 (B) $\left(K_{sp}\right)^{\frac{1}{2}}, \left(\frac{K_{sp}}{4}\right)^{\frac{1}{3}}, \left(\frac{K_{sp}}{27}\right)^{\frac{1}{4}}, \left(\frac{K_{sp}}{108}\right)^{\frac{1}{3}}$
 (C) $\left(K_{sp}\right)^{\frac{1}{2}}, \left(\frac{K_{sp}}{108}\right)^{\frac{1}{3}}, \left(\frac{K_{sp}}{27}\right)^{\frac{1}{4}}, \left(\frac{K_{sp}}{4}\right)^{\frac{1}{3}}$
 (D) $\left(\frac{K_{sp}}{108}\right)^{\frac{1}{3}}, \left(\frac{K_{sp}}{27}\right)^{\frac{1}{4}}, \left(K_{sp}\right)^{\frac{1}{2}}, \left(\frac{K_{sp}}{4}\right)^{\frac{1}{3}}$

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

[JEE-MAIN(Online)-2013]

$$(K_a = 1.75 \times 10^{-5}, pK_a = 4.76)$$

- (A) $4.76 < pH < 5.0$
 (B) $pH < 4.70$
 (C) pH of solution will be equal to pH of acetic acid
 (D) $pH = 4.70$

25. How many litres of water must be added to 1 litre of an aqueous solution of HCl with a pH of 1 to create an aqueous solution with pH of 2?

[JEE-MAIN(Online)-2013]

- (A) 0.1 L (B) 0.9 L (C) 2.0 L (D) 9.0 L

26. 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:

[JEE-MAIN(Online)-2014]

- (A) Colloidal solutions (B) True solutions (C) Ideal solutions (D) Buffer solutions



27. 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?

[JEE-MAIN(Online)-2014]

(A) $S = \{K_{sp}/144\}^{1/7}$

(B) $S = \{K_{sp}/(6912)\}^{1/7}$

(C) $S = (K_{sp}/6912)^{1/7}$

(D) $S = \{K_{sp}/6912\}^7$

28. 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

[JEE-MAIN-2017]

(A) 7.2

(B) 6.9

(C) 7.0

(D) 1.0

29. An alkali is titrated against an acid with methyl orange as indicator, which of the following is a correct combination?

[JEE-MAIN-2018]

Base	Acid	End Point
------	------	-----------

(A) Strong Strong Pink to colourless

(B) Weak Strong Colourless to pink

(C) Strong Strong Pinkish red to yellow

(D) Weak Strong Yellow to Pinkish red

30. 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 500mL. The solubility product of $BaSO_4$ is 1×10^{-10} . What is the original concentration of Ba^{2+} ?

[JEE-MAIN-2018]

(A) 1.0×10^{-10} M

(B) 5×10^{-9} M

(C) 2×10^{-9} M

(D) 1.1×10^{-9} M

31. 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 1.0×10^{-7} and that S^{2-} from HS^- ions is 1.2×10^{-13} then the concentration of S^{2-} ions in aqueous solution is

[JEE-MAIN-2018]

(A) 5×10^{-19}

(B) 5×10^{-8}

(C) 3×10^{-20}

(D) 6×10^{-21}

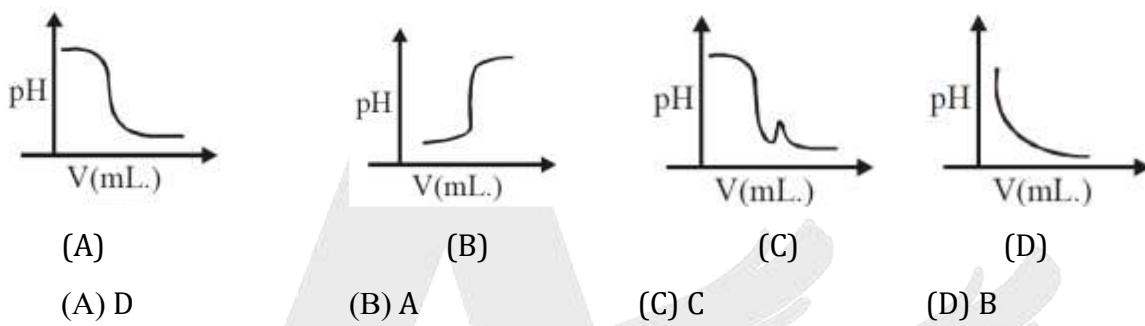


32. Which of the following salts is the most basic in aqueous solution? [JEE-MAIN-2018]
- (A) $\text{Pb}(\text{CH}_3\text{COO})_2$ (B) $\text{Al}(\text{CN})_3$ (C) CH_3COOK (D) FeCl_3
33. The minimum volume of water required to dissolve 0.1 g lead (II) chloride to get a saturated solution (K_{sp} of $\text{PbCl}_2 = 3.2 \times 10^{-8}$; atomic mass of Pb = 207 u) is: [JEE Main-2018 Online]
- (A) 0.36 L (B) 0.18 L (C) 17.98 L (D) 1.798 L
34. 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? [JEE Main-2018 Online]
- (A) 75mL $\frac{\text{M}}{5}$ HCl + 25mL $\frac{\text{M}}{5}$ NaOH (B) 100mL $\frac{\text{M}}{10}$ HCl + 100mL $\frac{\text{M}}{10}$ NaOH
 (C) 55 $\frac{\text{M}}{10}$ HCl + 40mL $\frac{\text{M}}{10}$ NaOH (D) 60mL $\frac{\text{M}}{10}$ HCl + 40mL $\frac{\text{M}}{10}$ NaOH
35. 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 $\text{NH}_4\text{OH} = 4.7$]. [JEE Main-2019 (Jan)]
- (A) 9.4 (B) 5.0 (C) 9.0 (D) 5.2
36. A mixture of 100m mol of $\text{Ca}(\text{OH})_2$ and 2g 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 $\text{Ca}(\text{OH})_2$, Na_2SO_4 and CaSO_4 are 74, 143 and 136 g mol^{-1} , respectively; K_{sp} of $\text{Ca}(\text{OH})_2$ is 5.5×10^{-6}) × [JEE Main-2019 (Jan)]
- (A) 13.6 g, 0.14 mol L^{-1} (B) 1.9 g, 0.14 mol L^{-1}
 (C) 1.9 g, 0.28 mol L^{-1} (D) 13.6 g, 0.28 mol L^{-1}
37. If K_{sp} of Ag_2CO_3 is 8×10^{-12} , the molar solubility of Ag_2CO_3 in 0.1M AgNO_3 is:
- [JEE Main-2019 (Jan)]
- (A) $8 \times 10^{-10} \text{ M}$ (B) $8 \times 10^{-13} \text{ M}$
 (C) $8 \times 10^{-12} \text{ M}$ (D) $8 \times 10^{-11} \text{ M}$

38. If solubility product of $\text{Zr}_3(\text{PO}_4)_4$ is denoted by K_{sp} and its molar solubility is denoted by S , then which of the following relation between A and K_{sp} is correct? [JEE Main-2019 (Apr)]

$$(A) S = \left(\frac{K_{\text{sp}}}{6912} \right)^{\frac{1}{7}} \quad (B) S = \left(\frac{K_{\text{sp}}}{144} \right)^{\frac{1}{6}} \quad (C) S = \left(\frac{K_{\text{sp}}}{929} \right)^{\frac{1}{9}} \quad (D) S = \left(\frac{K_{\text{sp}}}{216} \right)^{\frac{1}{7}}$$

39. 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? [JEE Main-2019 (Apr)]



40. Consider the following statements

[JEE Main-2019 (Apr)]

- (a) The pH of a mixture containing 400 mL of 0.1 M H_2SO_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 $K_a = 10^{-5}$ has a 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:

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

41. The pH of a 0.02 M NH_4Cl solution will be [given $K_b(\text{NH}_4\text{OH}) = 10^{-5}$ and $\log 2 = 0.301$]

[JEE Main-2019 (Apr)]

- (A) 5.35 (B) 4.65 (C) 4.35 (D) 2.65

42. What is the molar solubility of $\text{Al}(\text{OH})_3$ in 0.2 M NaOH solution? Given that, solubility product of $\text{Al}(\text{OH})_3 = 2.4 \times 10^{-24}$: [JEE Main-2019 (Apr)]

- (A) 12×10^{-23} (B) 3×10^{-22} (C) 12×10^{-21} (D) 3×10^{-19}



43. The molar solubility of $\text{Cd}(\text{OH})_2$ is 1.84×10^{-5} M in water. The expected solubility of $\text{Cd}(\text{OH})_2$ in a buffer solution of pH = 12 is: [JEE Main-2019 (Apr)]

(A) 6.23×10^{-11} M (B) 2.49×10^{-10} M (C) 1.84×10^{-9} M (D) 10^{-9} M

44. Arrange the following solutions in the decreasing order of pOH: [Jee Main, 2020]
- | | |
|--------------------------------------|---------------------------|
| (A) 0.01 M HCl | (B) 0.01 M NaOH |
| (C) 0.01 M CH_3COONa | (D) 0.01 M NaCl |
| (A) (B) > (C) > (D) > (A) | (B) (A) > (C) > (D) > (B) |
| (C) (B) > (D) > (C) > (A) | (D) (A) > (D) > (C) > (B) |

45. An acidic buffer is obtained on mixing : [Jee Main, 2020]
- | |
|---|
| (A) 100 mL of 0.1 M HCl and 200 mL of 0.1 M NaCl |
| (B) 100 mL of 0.1 M HCl and 200 mL of 0.1 M CH_3COONa |
| (C) 100 mL of 0.1 M CH_3COOH and 100 mL of 0.1 M NaOH |
| (D) 100 mL of 0.1 M CH_3COOH and 200 mL of 0.1 M NaOH |

46. Given below are two statements. [JEE Main, August 2021]

Statement I: In the titration between strong acid and weak base methyl orange is suitable as an indicator.

Statement II: For titration of acetic acid with NaOH phenolphthalein is not a suitable indicator.

In the light of the above statements, choose the most appropriate answer from the options given below:

- | |
|---|
| (A) Statement I is false but Statement II is true |
| (B) Statement I is true but Statement II is false |
| (C) Both Statement I and Statement II are true |
| (D) Both Statement I and Statement II are false |

47. The solubility of $\text{Ca}(\text{OH})_2$ in water is: [JEE Main, Feb 2021]

[Given : The solubility product of $\text{Ca}(\text{OH})_2$ in water = 5.5×10^{-6}]

- | | | | |
|---------------------------|---------------------------|---------------------------|---------------------------|
| (A) 1.77×10^{-6} | (B) 1.11×10^{-6} | (C) 1.11×10^{-2} | (D) 1.77×10^{-2} |
|---------------------------|---------------------------|---------------------------|---------------------------|

48. When 35 mL of 0.15 M lead nitrate solution is mixed with 20 mL of 0.12 M chromic sulphate solution, _____ $\times 10^{-5}$ moles of lead sulphate precipitate out. (Round off to the Nearest Integer) [JEE Main, March 2021]



49. The solubility of AgCN in a buffer solution of pH=3 is x. The value of x is: (Assume : No cyano complex is formed; $K_{sp}(\text{AgCN}) = 2.2 \times 10^{-16}$ and $K_a(\text{HCN}) = 6.2 \times 10^{-10}$)

[JEE Main, Feb 2021]

- (A) 0.625×10^{-6} (B) 1.9×10^{-5}
 (C) 2.2×10^{-16} (D) 1.6×10^{-6}

50. The number of moles of NH₃, that must be added to 2 L of 0.80 M AgNO₃ in order to reduce the concentration of Ag⁺ ions to 5.0×10^{-8} M ($K_{\text{formation}}$ for [Ag(NH₃)₂]⁺ = 1.0×10^8) is _____. (Nearest integer)

[Assume no volume change on adding NH₃]

[JEE Main, August 2021]

51. K_a for butyric acid (C₃H₇COOH) is 2×10^{-5} . The pH of 0.2 M solution of butyric acid is ____ × 10⁻¹. (Nearest integer) [Given log 2 = 0.30]

[JEE Main, July 2022]

52. 200 mL of 0.01 M HCl is mixed with 400 mL of 0.01M H₂SO₄. The pH of the mixture is _____. [JEE Main, July 2022]

- (A) 1.14 (B) 1.78 (C) 2.34 (D) 3.02

53. Class XII students were asked to prepare one litre of buffer solution of pH 8.26 by their chemistry teacher. The amount of ammonium chloride to be dissolved by the student in 0.2 M ammonia solution to make one litre of the buffer is [JEE Main, July 2022]

(Given pK_b(NH₃)=4.74; Molar mass of NH₃=17 g mol⁻¹; Molar mass of NH₄Cl= 53.5 g mol⁻¹)

- (A) 53.5 g (B) 72.3 g (C) 107.0 g (D) 126.0 g

54. In base vs. Acid titration, at the end point methyl orange is present as [JEE Main, July 2022]
 (A) quinonoid form (B) heterocyclic form (C) phenolic form (D) benzenoid form

55. The solubility of AgCl will be maximum in which of the following? [JEE Main, June 2022]
 (A) 0.01 M KCl (B) 0.01 M HC1
 (C) 0.01 M AgNO₃ (D) De-ionised water



EXERCISE # JEE-ADVANCED

1. What will be the resultant pH when 200 ml of an aqueous solution of HCl (pH = 2.0) is mixed with 300 ml of an aqueous solution of NaOH (pH = 12.0) ? [JEE 1998]
2. The solubility of $\text{Pb}(\text{OH})_2$ in water is 6.7×10^{-6} M. Calculate the solubility of $\text{Pb}(\text{OH})_2$ in a buffer solution of pH = 8. [JEE 1999]
3. A buffer solution can be prepared from a mixture of [JEE 1999]
 - (A) sodium acetate and acetic acid in water
 - (B) sodium acetate and hydrochloric acid in water
 - (C) ammonia and ammonium chloride in water
 - (D) ammonia and sodium hydroxide in water.
4. The pH of 0.1 M solution of the following salts increases in the order [JEE 1999]

(A) $\text{NaCl} < \text{NH}_4\text{Cl} < \text{NaCN} < \text{HCl}$	(B) $\text{HCl} < \text{NH}_4\text{Cl} < \text{NaCl} < \text{NaCN}$
(C) $\text{NaCN} < \text{NH}_4\text{Cl} < \text{NaCl} < \text{HCl}$	(D) $\text{HCl} < \text{NaCl} < \text{NaCN} < \text{NH}_4\text{Cl}$
5. The average concentration of SO_2 in the atmosphere over a city on a certain day is 10 ppm, when the average temperature is 298 K. Given that the solubility of SO_2 in water at 298 K is 1.3653 moles litre⁻¹ and the pK_a of H_2SO_3 is 1.92, estimate the pH of rain on that day. [JEE 2000]
6. An aqueous solution of 6.3 g oxalic acid dihydrate is made up to 250 mL. The volume of 0.1 N NaOH required to completely neutralise 10 mL of this solution is [JEE 2001]

(A) 40 mL	(B) 20 mL	(C) 10 mL	(D) 4 mL
-----------	-----------	-----------	----------
7. For sparingly soluble salt ApBq , the relationship of its solubility product (L_s) with its solubility (S) is: [JEE 2001]

(A) $L_s = S^{p+q}$, $p^p \cdot q^q$	(B) $L_s = S^{p+q}$, $p^p \cdot q^p$
(C) $L_s = S^{pq}$, $p^p \cdot q^q$	(D) $L_s = S^{pq}$, $(p \cdot q)^{p+q}$
8. 500 ml of 0.2 M aqueous solution of acetic acid is mixed with 500 mL of 0.2 M HCl at 25°C.
 - (a) Calculate the degree of dissociation of acetic acid in the resulting solution and pH of the solution.
 - (b) If 6 g of NaOH is added to the above solution, determine final pH. Assume there is no change in volume on mixing. K_a of acetic acid is 1.75×10^{-5} M. [JEE 2002]



9. Will the pH of water be same at 4°C and 25°C? Explain. [JEE 2003]
10. A solution which is 10^{-3} M each in Mn^{2+} , Fe^{2+} , Zn^{2+} and Hg^{2+} is treated with 10^{-16} M sulphide ion. If K_{sp} , MnS , FeS , ZnS and HgS are 10^{-15} , 10^{-23} , 10^{-20} and 10^{-54} respectively, which one will precipitate first? [JEE 2003]
- (A) FeS (B) MnS (C) HgS (D) ZnS
11. HX is a weak acid ($K_a = 10^{-5}$). It forms a salt NaX (0.1 M) on reacting with caustic soda. The degree of hydrolysis of NaX is [JEE 2004]
- (A) 0.01% (B) 0.0001% (C) 0.1% (D) 0.5%
12. 0.1 M of HA is titrated with 0.1 M $NaOH$, calculate the pH at end point.
Given $K_a(HA) = 5 \times 10^{-6}$ and $h \ll 1$. [JEE 2004]
13. CH_3NH_2 (0.1 mole, $K_b = 5 \times 10^{-4}$) is added to 0.08 moles of HCl and the solution is diluted to one litre, resulting hydrogen ion concentration is [JEE 2005]
- (A) 1.6×10^{-11} (B) 8×10^{-11} (C) 5×10^{-5} (D) 2×10^{-2}
14. The species present in solution when CO_2 is dissolved in water: [JEE 2006]
- (A) CO_2 , H_2CO_3 , HCO_3^{2-} (B) H_2CO_3 , CO_3^{2-}
 (C) CO_3^{2-} , HCO_3^- (D) CO_2 , H_2CO_3
15. Solubility product constants (K_{sp}) of salts of types MX , MX_2 and M_3X at temperature 'T' are 4.0×10^{-8} , 3.2×10^{-14} and 2.7×10^{-15} , respectively. Solubilities (mol dm^{-3}) of the salts at temperature 'T' are in the order: [JEE 2008]
- (A) $MX > MX_2 > M_3X$ (B) $M_3X > MX_2 > MX$
 (C) $MX_2 > M_3X > MX$ (D) $MX > M_3X > MX_2$
16. 2.5 mL of $\frac{2}{5}$ M weak monoacidic base ($K_b = 1 \times 10^{-12}$ at 25°C) is titrated with $\frac{2}{15}$ M HCl in water at 25°C. The concentration of H^+ at equivalence point is ($K_w = 1 \times 10^{-14}$ at 25°C) [JEE 2008]
- (A) 3.7×10^{-13} M (B) 3.2×10^{-7} M (C) 3.2×10^{-2} M (D) 2.7×10^{-2} M



Paragraph For Questions 22 and 23

When 100 mL of 1.0 M HCl was mixed with 100 mL of 1.0 M NaOH in an insulated beaker at constant pressure, a temperature increase of $5.7\text{ }^{\circ}\text{C}$ was measured for the beaker and its contents. (Expt-1). Because the enthalpy of neutralisation of a strong acid with a strong base is a constant (-57.0 kJmol^{-1}), this experiment could be used to measure the calorimeter constant. In a second experiment (Expt-2), 100 mL of 2.0 M acetic acid ($K_a = 2.0 \times 10^{-5}$) was mixed with 100 mL of 1.0M NaOH (under identical conditions to (Expt-1)) where a temperature rise of $5.6\text{ }^{\circ}\text{C}$ was measured.

(Consider heat capacity of all solutions as $4.2 \text{ J g}^{-1}\text{K}^{-1}$ and density of all solutions as 1.0 g mL^{-1})

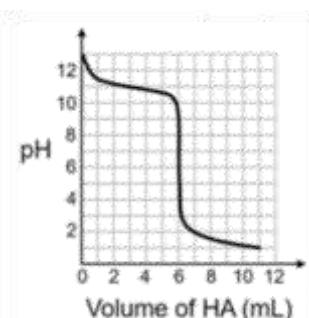


Match each process given in LIST-I with one or more effect(s) in LIST-II. The correct option is

- (A) P → 4; Q → 2; R → 3; S → 1 (B) P → 4; Q → 3; R → 2; S → 3
(C) P → 1; Q → 4; R → 5; S → 3 (D) P → 1; Q → 5; R → 4; S → 1

26. A solution of 0.1M weak base (B) is titrated with 0.1M of a strong acid (HA). The variation of pH of the solution with the volume of HA added is shown in the figure below. What is the pK_b of the base? The neutralization reaction is given by
 $B + HA \rightleftharpoons BH^+ + A^-$.

[JEE Advance 2020]



27. An acidified solution of 0.05M Zn²⁺ is saturated with 0.1MH₂S. What is the minimum molar concentration (M) of H⁺ required to prevent the precipitation of ZnS?

Use K_{sp}(ZnS) = 1.25×10^{-22} and overall dissociation constant of H₂S,

$$K_{NET} = K_1 K_2 = 1 \times 10^{-21}$$

[JEE Advance 2020]

28. A solution is prepared by mixing 0.01 mol each of H₂CO₃, NaHCO₃, Na₂CO₃, and NaOH in 100 mL of water. pH of the resulting solution is

[Given pK_{a1} and pK_{a2}of H₂CO₃ are 6.37 and 10.32, respectively; log 2 = 0.30]

[JEE Advance 2022]

29. Concentration of H₂SO₄ and Na₂SO₄ in a solution is 1M and 1.8×10^{-2} M, respectively. Molar solubility of PbSO₄ in the same solution is X × 10^{-Y}M (expressed in scientific notation). The value of Y is

[Given: Solubility product of PbSO₄ (K_{sp}) = 1.6×10^{-8} . For H₂SO₄, K_{a1} is very large and $K_{a2} = 1.2 \times 10^{-2}$]

30. On decreasing the pH from 7 to 2, the solubility of a sparingly soluble salt (MX) of a weak acid (HX) increased from 10^{-4} mol L⁻¹ to 10^{-3} mol L⁻¹. The pK_a of HX is

[JEE Advance 2023]

(A) 3

(B) 4

(C) 5

(D) 2



ANSWER KEY

EXERCISE # O-I

- | | | | | | | | | | | | | | |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1. | (D) | 2. | (D) | 3. | (C) | 4. | (D) | 5. | (C) | 6. | (B) | 7. | (C) |
| 8. | (B) | 9. | (A) | 10. | (B) | 11. | (C) | 12. | (D) | 13. | (B) | 14. | (D) |
| 15. | (A) | 16. | (D) | 17. | (A) | 18. | (D) | 19. | (A) | 20. | (D) | 21. | (A) |
| 22. | (A) | 23. | (B) | 24. | (C) | 25. | (B) | 26. | (C) | 27. | (C) | 28. | (C) |
| 29. | (B) | 30. | (C) | 31. | (A) | 32. | (B) | 33. | (C) | 34. | (C) | 35. | (A) |
| 36. | (B) | 37. | (C) | 38. | (C) | 39. | (C) | 40. | (B) | 41. | (A) | 42. | (D) |
| 43. | (B) | 44. | (C) | 45. | (A) | 46. | (A) | 47. | (D) | 48. | (D) | 49. | (C) |
| 50. | (B) | 51. | (B) | 52. | (A) | 53. | (A) | 54. | (A) | 55. | (B) | 56. | (B) |
| 57. | (D) | 58. | (D) | 59. | (C) | 60. | (C) | 61. | (D) | 62. | (A) | 63. | (A) |
| 64. | (A) | 65. | (A) | 66. | (C) | 67. | (A) | 68. | (A) | 69. | (A) | 70. | (A) |
| 71. | (A) | 72. | (C) | 73. | (D) | 74. | (C) | 75. | (C) | 76. | (D) | 77. | (D) |
| 78. | (A) | 79. | (D) | 80. | (C) | 81. | (D) | 82. | (D) | 83. | (C) | 84. | (A) |
| 85. | (D) | 86. | (A) | 87. | (B) | 88. | (C) | 89. | (B) | 90. | (A) | 91. | (B) |
| 92. | (C) | 93. | (D) | 94. | (D) | 95. | (C) | 96. | (C) | 97. | (D) | 98. | (B) |
| 99. | (A) | | | | | | | | | | | | |

EXERCISE # S-I

- | | | | | | |
|-----|---|-----|---|-----|--|
| 1. | 6.022×10^7 | 2. | (i) 6.53 ; (ii) (a) Basic , (b) Acidic | 3. | $K_w = 4 \times 10^{-14}$, pH = 6.7 |
| 4. | 600 ions /mm ³ | 5. | (a) + 1, (b) 9 (c) 11.30 (d) 6.97, (e) 7, | | |
| 6. | 7 | 7. | 2.32×10^{-8} M | 8. | (b) 2.87, (c) 11.13 (f) 6.78, (g) 6.97 |
| 9. | (a) $K_a = 10^{-8}$, (b) $K_b = 10^{-6}$ | 10. | 10 | 11. | 170.14 |
| 12. | 1.1×10^{-3} M | 13. | 1.11×10^{-4} | 14. | 4.87 |
| 15. | 3 | 16. | 2.61 | 17. | 9×10^{-5} M |
| 18. | $[H^+] = 1.75 \times 10^{-2}$ M, $[CHCl_2COO^-] = 0.75 \times 10^{-2}$ M | | | | |
| 19. | $[H^+] = 10^{-3}$ M, $[CH_3COO^-] = 3.6 \times 10^{-4}$ M, $[C_7H_5O_2^-] = 6.4 \times 10^{-4}$ M | | | | |
| 20. | 0.027M, 0.073M, 0.027M, 10^{-5} M | | | | |
| 21. | $[H^+] = [H_2PO_4^-] = 2.7 \times 10^{-3}$, $[HPO_4^{2-}] = 10^{-8}$, $[PO_4^{3-}] = 3.7 \times 10^{-19}$ | | | | |
| 22. | $[H^+] = 0.209$ M
$[SO_4^{2-}] = 0.009$ M
$[HSO_4^-] = 0.191$ M | | | | |



23. $\text{pH} = 11.46$, $[\text{enH}_2^{2+}] = 7.1 \times 10^{-8}\text{M}$
24. (a) Basic (b) acidic (c) basic (d) basic (e) acidic (f) basic
 (g) neutral (h) basic (i) basic (j) acidic
25. 2.5×10^{-5} ; 4.6
26. (i) 10^{-12} , (ii) 10^{-6} , (iii) 10^{-11} , (iv) $K_{\text{b}_1} < K_{\text{b}_2} < K_{\text{b}_3}$
27. $[\text{OH}^-] = 6.664 \times 10^{-6}$
28. $\text{pH} = 4.477$
29. $K_{\text{b}} = 6.25 \times 10^{-10}$
30. 1.66 %
31. $\text{pH} = 10.43$
32. $[\text{OH}^-] = 3.73 \times 10^{-2}\text{M}$, $[\text{H}_3\text{PO}_4] = 6 \times 10^{-18}\text{M}$
33. 4.19
34. $10^{-6}; 10^{-8}$
35. (a) 6, (b) 1×10^{-5}
36. 0.56%, $\text{pH} = 7$
37. 8.34
38. 4.19
39. $[\text{OH}^-] = 9.0 \times 10^{-6}$
40. 0.05 mol
41. (a) $\text{pH} = 9.239$ (b) lowered (c) $\text{pH} = 4.699$
42. $\text{pH} = 9.26$; (a) $\text{pH} = 9.74$;
43. (a) 13 ; (b) 7 ; (c) 1.3.
44. 3
45. 4.74
46. 9.56
47. 8.7782
48. 9.7324
49. 10^{-5} M
50. 8.71, $[\text{H}_3\text{O}^+] = 1.95 \times 10^{-9}\text{M}$
51. $4.98, 1.05 \times 10^{-5}\text{M}$
52. (i) 2.85, (ii) 4.0969, (iii) 4.5229, (iv) 4.699, (v) 5.301, (vi) 8.699
53. $[\text{HI}_n] = 28.57\%$
54. $\Delta\text{pH} = 0.954$
55. 85.71%



56. (b), (c)
 57. one with $pK_{In} = 5.22$, methyl orange
 58. (018)
 59. 1.0×10^{-5} mol/lit
 60. 1.56×10^{-8}
 61. 3.4×10^{-11}
 62. 2.6×10^{-16}
 63. QX_2 is more soluble
 64. $[Cu^+] = 5 \times 10^{-11}$ M
 65. 5×10^{-10} M
 66. 4×10^{-7} mol/L AgBr, 9×10^{-7} mol/L AgSCN
 67. $[F^-] = 3 \times 10^{-3}$ M
 68. (a) no precipitation will occur, (b) a precipitate will form
 69. 1
 70. (9×10^{-4}) ; OMR ANS (9)
 71. 12 mg
 72. 4.9×10^{-10}
 73. $69K_d = 1/K_f = 4.8 \times 10^{-4}$ Q. 700.444 M
 74. 2.82×10^{-3} mole
 75. (d) > (c) > (b) > (a)

EXERCISE # O - II

- | | | | | | |
|----------------------------------|-----------|--|----------|----------|------------|
| 1. (ABC) | 2. (ABCD) | 3. (A,B,D) | 4. (A,D) | 5. (A,B) | 6. (A,B,C) |
| 7. (A) | 8. (ABC) | 9. (ABCD) | 10. (B) | 11. (A) | 12. (C) |
| 13. (C) | 14. (B) | 15. (A) | 16. (C) | 17. (A) | 18. (A) |
| 19. (C) | 20. (D) | 21. (A) \rightarrow R; (B) \rightarrow P; (C) \rightarrow Q; (D) \rightarrow S | | | |
| 22. (A)-Q, (B)-P,S, (C)-R, (D)-T | | | | | |



EXERCISE: S-II

1. $[S^{2-}] = 2.5 \times 10^{-15}$
2. 10.07
3. 8.35, 9.60, 4.66
4. (a) 2.12 (b) 4.66 (c) 7.2 (d) 12
5. (a) 4.7525 (b) 4.697, (c) 4.798
(d) 1.134 % on acid addition 0.96 % on base addition.
6. $K_b = 1.8 \times 10^{-5}, 5.27$
7. $pH = 7.3; pH = 7.898, pH = 7.29$
8. 3.3×10^{-2}
9. (5.21)
10. $[F^-] = \sqrt{\frac{8y^3}{x}}$
11. 0.444 M
12. $s = \sqrt{K_{sp} \left(1 + \frac{[H^+]}{K_2} + \frac{[H^+]^2}{K_1 K_2} \right)}$

EXERCISE # JEE-MAINS

- | | | | | | | |
|---------|----------|---------|---------|---------|-----------|---------|
| 1. (C) | 2. (C) | 3. (D) | 4. (D) | 5. (C) | 6. (A) | 7. (A) |
| 8. (D) | 9. (D) | 10. (B) | 11. (C) | 12. (D) | 13. (C) | 14. (D) |
| 15. (C) | 16. (A) | 17. (C) | 18. (A) | 19. (D) | 20. (D) | 21. (A) |
| 22. (D) | 23. (A) | 24. (A) | 25. (D) | 26. (D) | 27. (C) | 28. (B) |
| 29. (D) | 30. (D) | 31. (C) | 32. (C) | 33. (B) | 34. (A) | 35. (C) |
| 36. (C) | 37. (A) | 38. (A) | 39. (B) | 40. (A) | 41. (A) | 42. (B) |
| 43. (B) | 44. (D) | 45. (B) | 46. (B) | 47. (C) | 48. (525) | 49. (B) |
| 50. (4) | 51. (27) | 52. (2) | 53. (C) | 54. (A) | 55. (D) | |

EXERCISE # JEE-ADVANCED

- | | | |
|---------------------------|--------------------------------------|------------------|
| 1. $pH = 11.3010$ | 2. $s = 1.203 \times 10^{-3}M$ | 3. (A, B, C) |
| 4. (B) | 5. $pH = 4.86$ | 6. (A) 7. (A) |
| 8. (a) 0.0175%, (b) 4.757 | 9. No it will be > 7 | 10. (C) 11. (A) |
| 12. $pH = 9$ | 13. (B) | 14. (A) 15. (D) |
| 16. (D) | 17. (8) | 18. (CD) 19. (7) |
| 20. (A) | 21. (A) | 22. (A) 23. (B) |
| 24. (4.47) | 25. (D) | 26. 3.3 |
| 27. $[H^+] \geq 0.2$ | 28. $\therefore pH = 10.0229. Y = 6$ | 30. (B) |