



IONIC EQUILIBRIUM-I

Exercise-1

Marked questions are recommended for Revision.

PART - I : SUBJECTIVE QUESTIONS

Section (A) : Acid-Base Concepts

Commit to memory :

Polyprotic Arrhenius acid : 2 or more replaceable H per acid molecule.

Polyprotic Arrhenius base : 2 or more replaceable OH per base molecule.

Acid – 1 H⁺ = its Conjugate Base

Base + 1 H⁺ = its Conjugate Acid

Amphiprotic species : H⁺ donor as well as acceptor.

Lewis acid : Lone pair acceptor

Lewis base : Lone pair donor

- A-1.** (a) Select Polyprotic Arrhenius acids from the following : H₃PO₂, H₃PO₃, H₃BO₃, HCOOH, (COOH)₂.
 (b) Write conjugate acids of SO₄²⁻, RNH₂, NH₂⁻, C₂H₅OC₂H₅, F⁻
 (c) Write conjugate base of HNO₂, OH⁻, H₂CO₃, HClO₄.
 (d) Write conjugate acid and conjugate base of following amphoteric species : HS⁻, NH₃, C₂H₅OH, H₂O
 (e) Classify the following into Lewis acid & Lewis base : H⁺, FeCl₃, (CH₃)₃N, F⁻, $\ddot{\text{C}}\text{H}_2$
- A-2.** Classify the following into acid, base and amphiprotic species on the basis of protonic concept :
 (i) H₂PO₂⁻ (ii) H₂PO₃⁻ (iii) H₂PO₄⁻ (iv) HPO₃²⁻
 (v) HPO₄²⁻ (vi) NH₄⁺ (vii) CH₃COOH₂⁺
- A-3.** Comment upon H₂O as an Arrhenius acid/base, Bronsted–Lowry acid/base and Lewis acid/base.

Section (B) : Properties of water, pH scale, Autoprotolysis

Commit to memory :

$K_w = [\text{H}^+][\text{OH}^-] = 10^{-14}$ at 25°C

$[\text{H}^+] = [\text{OH}^-]$ (in water / a neutral solution)

$\text{pH} = -\log [\text{H}^+]$; $\text{pOH} = -\log [\text{OH}^-]$

For H₂O, pH & pOH ↓ with ↑ in temperature

$\text{pH} + \text{pOH} = \text{p}K_w = 14$ (for an aqueous solution at 25°C)

$K_{\text{self ionisation of HA}} = [\text{A}^-][\text{H}_2\text{A}^+]$

- B-1.** At –50°C, liquid NH₃ has ionic product is 10⁻³⁰. How many amide (NH₂⁻) ions are present per mm³ in pure liquid NH₃ ? (Take N_A = 6 × 10²³)

Section (C) : Relation between K_a and K_b for conjugate acid - base pair

Commit to memory :

$K_a(\text{acid}) \times K_b(\text{conjugate base}) = K_w$

$\text{p}K_a(\text{acid}) + \text{p}K_b(\text{conjugate base}) = \text{p}K_w = 14$ (at 25°C)

- C-1.** What is ionisation constant of HOCl, if K_b of OCl⁻ = 4 × 10⁻¹⁰ ? Also find its pK_a.
- C-2.** K_{a1}, K_{a2} and K_{a3} values for H₃PO₄ are 10⁻³, 10⁻⁸ and 10⁻¹² respectively. If K_w (H₂O) = 10⁻¹⁴, then :
 (i) What is dissociation constant of HPO₄²⁻ ?
 (ii) What is K_b of HPO₄²⁻ ?
 (iii) What is K_b of H₂PO₄⁻ ?
 (iv) What is order of K_b of PO₄³⁻ (K_{b3}), HPO₄²⁻ (K_{b2}) and H₂PO₄⁻ (K_{b1}) ?



Section (D) : pH calculation : Strong acid solutions, Strong base solutions, Solutions containing mixture of two or more strong acids, Solutions containing mixture of two or more strong bases, Solutions containing mixture of strong acid and strong base

Commit to memory :

Strong acid solution: $[H^+] = \text{Molarity of strong acid solution} \times \text{number of } H^+ \text{ ions per acid molecule.}$

Strong base solution: $[OH^-] = \text{Molarity of strong base solution} \times \text{number of } OH^- \text{ ions per base molecule.}$

Mixture of two strong acids : $[H^+]_f = \frac{[H^+]_1 V_1 + [H^+]_2 V_2}{V_1 + V_2}$

Mixture of two strong bases : $[OH^-]_f = \frac{[OH^-]_1 V_1 + [OH^-]_2 V_2}{V_1 + V_2}$

Mixture of a strong acid and a strong base :

If $[H^+]V_1 > [OH^-]V_2$

$$[H^+] = \frac{[H^+]V_1 - [OH^-]V_2}{V_1 + V_2}$$

final solution will be acidic in nature

If $[OH^-]V_2 > [H^+]V_1$

$$[OH^-] = \frac{[OH^-]V_2 - [H^+]V_1}{V_1 + V_2}$$

final solution will be basic in nature

Further, $[H^+]_f = \frac{10^{-14}}{[OH^-]_f}$ (at 25°C)

D-1. Calculate pH of following solutions :

(i) 0.001 M HNO_3 ,

(ii) 0.005 M H_2SO_4 ,

(iii) 0.01 M KOH

(iv) 10^{-8} M NaOH,

(v) 0.0008 M $Ba(OH)_2$.

D-2. Calculate the pH of the following solutions :

(i) 2.21 g of T/OH dissolved in water to give 2 litre of solution. (Assume T/OH to be a strong base)

(ii) 0.49% w/v H_2SO_4 solution

(iii) $\frac{M}{1000}$ $Sr(OH)_2$ solution is diluted to quadruple volume.

(iv) 1 mL of 12 M HCl is diluted with water to obtain 1 litre of solution.

D-3. Calculate the pH of solution obtained by mixing 10 mL of 0.2 M HCl and 40 mL of 0.1 M H_2SO_4 .

D-4. Calculate the pH of the resulting solution formed by mixing the following solutions :

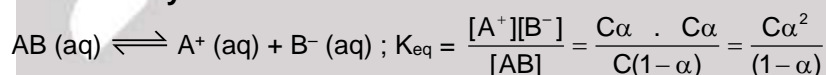
(a) 20 mL of 0.2 M $Ba(OH)_2$ + 30 mL of 0.1 M HCl

(b) 2 mL of 0.1 M HCl + 10 mL of 0.01 M $Sr(OH)_2$

(c) 10 mL of 0.1 M H_2SO_4 + 10 mL of 0.1 M KOH.

Section (E) : Ostwald dilution law, pH calculation : Solutions of weak monoprotic acid, Solutions of weak monoacidic base

Commit to memory :



$$\alpha = \sqrt{\frac{K_{eq}}{C}}; [A^+] = [B^-] = C\alpha = \sqrt{CK_{eq}} \quad (\text{both valid if } \alpha < 0.1 \text{ or } 10\%)$$

$$\text{Weak Acid (monoprotic) solution : } \alpha = \sqrt{\frac{K_a}{C}}; pH = \frac{1}{2} (pK_a - \log C) \quad (\text{both valid if } \alpha < 0.1 \text{ or } 10\%)$$

$$\text{Weak base (monoacidic) solution : } \alpha = \sqrt{\frac{K_b}{C}}; pOH = \frac{1}{2} (pK_b - \log C) \quad (\text{both valid if } \alpha < 0.1 \text{ or } 10\%)$$

$$\frac{\text{Acid strength of } HA_1}{\text{Acid strength of } HA_2} = \frac{\alpha_1}{\alpha_2} = \sqrt{\frac{K_{a1}}{K_{a2}}}; \frac{\text{Basic strength of } BOH_1}{\text{Basic strength of } BOH_2} = \frac{\alpha_1}{\alpha_2} = \sqrt{\frac{K_{b1}}{K_{b2}}}$$



- E-1.** Acetic acid gets 1.3% ionised in its decimolar solution. What is the ionisation constant of acetic acid?
- E-2.** Prove that degree of dissociation of a weak monoprotic acid is given by :
- $$\alpha = \frac{1}{1 + 10^{(pK_a - pH)}}$$
- where K_a is its dissociation constant.
- E-3.** Calculate the pH of a 500 mL solution of 1 M BOH. ($K_b = 2.5 \times 10^{-5}$)
- E-4.** Whose pH increases by greater value on dilution from initial pH = 2 ?
(a) CH_3COOH solution (b) HCl solution.

Section (F) : Salt hydrolysis, pH calculation : Solutions of salt of monoprotic acid and monoacidic base

Commit to memory :

Salt of strong acid and weak base : $K_h \times K_b = K_w$; $h = \sqrt{\frac{K_h}{c}}$; $\text{pH} = \frac{1}{2} [\text{p}K_w - \text{p}K_b - \log c]$ (valid if $h < 0.1$ or 10%)

Salt of strong base and weak acid : $K_h \times K_a = K_w$; $h = \sqrt{\frac{K_h}{c}}$; $\text{pH} = \frac{1}{2} [\text{p}K_w + \text{p}K_a + \log c]$ (valid if $h < 0.1$ or 10%)

Salt of weak acid and weak base : $K_h \times K_a \times K_b = K_w$; $\left(\frac{h}{1-h}\right) = \sqrt{K_h}$; $\text{pH} = \frac{1}{2} [\text{p}K_w + \text{p}K_a - \text{p}K_b]$

- F-1.** Which of the following ions or compounds in a solution tend to produce an acidic, a basic or a neutral solution ?
(a) $\text{C}_2\text{H}_5\text{O}^-$ (b) Cu^{+2} (c) SO_3^{2-} (d) F^- (e) NH_4^+ (f) CH_3COONa
(g) KNO_3 (h) NaOCl (i) Na_2CO_3 (j) ZnCl_2
- F-2.** Calculate pH of 0.2 M aqueous solution of sodium butyrate. Given : K_a of butyric acid = 2×10^{-5} .
- F-3.** A 0.25 M solution of pyridinium chloride $\text{C}_5\text{H}_5\text{NH}^+\text{Cl}^-$ was found to have a pH of 2.75. What is K_b for pyridine, $\text{C}_5\text{H}_5\text{N}$?
- F-4.** Calculate the percentage hydrolysis & the pH of 0.02 M $\text{CH}_3\text{COONH}_4$. $K_b(\text{NH}_3) = 1.6 \times 10^{-5}$, $K_a(\text{CH}_3\text{COOH}) = 1.6 \times 10^{-5}$.

PART - II : ONLY ONE OPTION CORRECT TYPE

Section (A) : Acid-Base Concepts

Commit to memory :

Polyprotic Arrhenius acid : 2 or more replaceable H per acid molecule.

Polyprotic Arrhenius base : 2 or more replaceable OH per base molecule.

Acid - 1 H^+ = its Conjugate Base

Base + 1 H^+ = its Conjugate Acid

Amphiprotic species : H^+ donor as well as acceptor.

Lewis acid : Lone pair acceptor

Lewis base : Lone pair donor

- A-1.** An acid with molecular formula $\text{C}_7\text{H}_6\text{O}_3$ forms three types of sodium salts. i.e. $\text{C}_7\text{H}_5\text{O}_3\text{Na}$, $\text{C}_7\text{H}_4\text{O}_3\text{Na}_2$ and $\text{C}_7\text{H}_3\text{O}_3\text{Na}_3$. The basicity of the acid is :
(A) One (B) Two (C) Three (D) Six
- A-2.** Select the incorrect option :
(A) H_3PO_4 is a tribasic acid. (B) H_3BO_3 is not an Arrhenius acid.
(C) $\text{Sr}(\text{OH})_2$ is a strong diacidic base. (D) $\text{NH}_3 \cdot \text{H}_2\text{O}$ is a strong monoacidic base.



- A-3.** In the reaction $\text{HC}_2\text{O}_4^- (\text{aq}) + \text{PO}_4^{3-} (\text{aq}) \rightleftharpoons \text{HPO}_4^{2-} (\text{aq}) + \text{C}_2\text{O}_4^{2-} (\text{aq})$, which are the two Bronsted bases ?
 (A) HC_2O_4^- and PO_4^{3-} (B) HPO_4^{2-} and $\text{C}_2\text{O}_4^{2-}$
 (C) HC_2O_4^- and HPO_4^{2-} (D) PO_4^{3-} and $\text{C}_2\text{O}_4^{2-}$
- A-4.** The following equilibrium is established when HClO_4 is dissolved in weak acid HF solvent :
 $\text{HF} + \text{HClO}_4 \rightleftharpoons \text{ClO}_4^- + \text{H}_2\text{F}^+$
 Which of the following is correct set of conjugate acid base pair ?
 (A) HF and HClO_4 (B) HF and ClO_4^- (C) HF and H_2F^+ (D) HClO_4 & H_2F^+
- A-5.** Which of the following correctly explains the nature of boric acid in aqueous medium ?
 (A) $\text{H}_3\text{BO}_3 \xrightarrow{\text{H}_2\text{O}} \text{H}_3\text{O}^+ + \text{H}_2\text{BO}_3^-$ (B) $\text{H}_3\text{BO}_3 \xrightarrow{2\text{H}_2\text{O}} 2\text{H}_3\text{O}^+ + \text{HBO}_3^{2-}$
 (C) $\text{H}_3\text{BO}_3 \xrightarrow{3\text{H}_2\text{O}} 3\text{H}_3\text{O}^+ + \text{BO}_3^{3-}$ (D) $\text{H}_3\text{BO}_3 \xrightarrow{\text{H}_2\text{O}} \text{B}(\text{OH})_4^- + \text{H}^+$

Section (B) : Properties of water, pH scale, Autoprotolysis

Commit to memory :

$K_w = [\text{H}^+][\text{OH}^-] = 10^{-14}$ at 25°C
 $[\text{H}^+] = [\text{OH}^-]$ (in water / a neutral solution)
 $\text{pH} = -\log [\text{H}^+]$; $\text{pOH} = -\log [\text{OH}^-]$
 For H_2O , pH & $\text{pOH} \downarrow$ with \uparrow in temperature
 $\text{pH} + \text{pOH} = \text{p}K_w = 14$ (for an aqueous solution at 25°C)
 $K_{\text{self ionisation of HA}} = [\text{A}^-][\text{H}_2\text{A}^+]$

- B-1.** Which of the following expression is not true ?
 (A) $[\text{H}^+] = [\text{OH}^-] = \sqrt{K_w}$ for a neutral solution at all temperatures.
 (B) $[\text{H}^+] > \sqrt{K_w}$ & $[\text{OH}^-] < \sqrt{K_w}$ for an acidic solution.
 (C) $[\text{H}^+] < \sqrt{K_w}$ & $[\text{OH}^-] > \sqrt{K_w}$ for an alkaline solution.
 (D) $[\text{H}^+] = [\text{OH}^-] = 10^{-7} \text{ M}$ for a neutral solution at all temperatures .
- B-2.** pOH of H_2O is 7 at 298 K. If water is heated to 350 K, which of the following statement should be true ?
 (A) pOH will decrease. (B) pH will increase.
 (C) pOH will remain 7. (D) Both (A) and (B).
- B-3.** K_w of H_2O at 373 K is 1×10^{-12} . Identify, which of the following is incorrect :
 (A) $\text{pH} + \text{pOH} = 12$, for every aqueous solutions.
 (B) pH of H_2O is 6.
 (C) $\alpha_{\text{H}_2\text{O}}$ has increased from its value at 298 K.
 (D) H_2O is acidic.
- B-4.** In pure HCOOH liquid, concentration of $\text{HCOO}^- = 10^{-3} \text{ M}$ at 27°C . What is the self ionisation constant at 27°C ($K = [\text{HCOOH}_2^+][\text{HCOO}^-]$) ?
 (A) 10^{-3} (B) 10^3 (C) 10^6 (D) 10^{-6}

Section (C) : Relation between K_a and K_b for conjugate acid-base pair

Commit to memory :

$K_a (\text{acid}) \times K_b (\text{conjugate base}) = K_w$
 $\text{p}K_a (\text{acid}) + \text{p}K_b (\text{conjugate base}) = \text{p}K_w = 14$ (at 25°C)

- C-1.** Given : $\text{HF} + \text{H}_2\text{O} \xrightleftharpoons{K_a} \text{H}_3\text{O}^+ + \text{F}^-$
 $\text{F}^- + \text{H}_2\text{O} \xrightleftharpoons{K_b} \text{HF} + \text{OH}^-$
 Which relation is correct.
 (A) $K_b = \frac{1}{K_a}$ (B) $K_a \cdot K_b = K_w$ (C) $K_a \cdot K_b \cdot K_w = 1$ (D) $\frac{K_a}{K_b} = K_w$



- C-2.** Which of the following is incorrect ?
 (A) K_a (weak acid). K_b (conjugate weak base) = K_w
 (B) K_a (strong acid). K_b (conjugate weak base) = K_w
 (C) K_a (weak acid). K_b (weak base) = K_w
 (D) K_a (weak acid). K_b (conjugate strong base) = K_w

Section (D) : pH calculation : Strong acid solutions, Strong base solutions, Solutions containing mixture of two or more strong acids, Solutions containing mixture of two or more strong bases, Solutions containing mixture of strong acid and strong base

Commit to memory :

Strong acid solution : $[H^+] = \text{Molarity of strong acid solution} \times \text{number of } H^+ \text{ ions per acid molecule.}$

Strong base solution : $[OH^-] = \text{Molarity of strong base solution} \times \text{number of } OH^- \text{ ions per base molecule.}$

Mixture of two strong acids : $[H^+]_f = \frac{[H^+]_1 V_1 + [H^+]_2 V_2}{V_1 + V_2}$

Mixture of two strong bases : $[OH^-]_f = \frac{[OH^-]_1 V_1 + [OH^-]_2 V_2}{V_1 + V_2}$

Mixture of a strong acid and a strong base :

If $[H^+]V_1 > [OH^-]V_2$

$$[H^+] = \frac{[H^+]V_1 - [OH^-]V_2}{V_1 + V_2}$$

final solution will be acidic in nature

If $[OH^-]V_2 > [H^+]V_1$

$$[OH^-] = \frac{[OH^-]V_2 - [H^+]V_1}{V_1 + V_2}$$

final solution will be basic in nature

Further, $[H^+]_f = \frac{10^{-14}}{[OH^-]_f}$ (at 25°C)

- D-1.** The $[OH^-]$ in 100 mL of 0.016 M HCl (aq) is :
 (A) 6.25×10^{-12} M (B) 3×10^{-10} M (C) 6.25×10^{-13} M (D) 1.6×10^{-3} M
- D-2.** How many moles of NaOH must be removed from one litre of its aqueous solution to change its pH from 12 to 11 ?
 (A) 0.009 (B) 0.01 (C) 0.09 (D) 0.1
- D-3.** Which statement/relationship is correct ?
 (A) pH of aqueous solutions of 0.1 M HNO_3 , 0.1M HCl, 0.1M HI at 25°C is not equal.
 (B) For a dilute solution, $pH = -\log \frac{1}{[H^+]}$
 (C) At 25°C, the pH of pure water is 7.
 (D) The value of pK_w at 25°C is 7.
- D-4.** Upon mixing equal volume of two solutions of strong acids having pH values 2 & 4, resulting solution will have pH :
 (A) equal to 3 (B) closer to 2 than 4
 (C) closer to 4 than 2 (D) closer to 3 than 2
- D-5.** On adding 0.04 g solid NaOH to a 100 mL, $\frac{M}{200}$ $Ba(OH)_2$ solution, determine change in pH :
 (A) 0 (B) +0.3 (C) -0.3 (D) +0.7
- D-6.** Upon mixing equal volume of a strong acid solution (HA) and a strong base (BOH) solution, pH of resulting solution :
 (A) may be less than 7 (B) may be greater than 7
 (C) will be equal to 7 (D) Both (A) & (B)

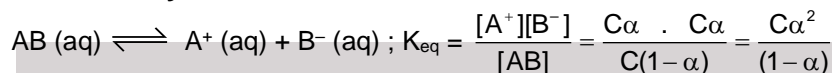


D-7. Which of the following solutions will have pH close to 1 ?

- (A) 100 mL of M/10 HCl + 100 mL of M/10 NaOH
 (B) 55 mL of M/10 HCl + 45 mL of M/10 NaOH
 (C) 10 mL of M/10 HCl + 90 mL of M/10 NaOH
 (D) 75 mL of M/5 HCl + 25 mL of M/5 NaOH.

Section (E) : Ostwald dilution law, pH calculation : Solutions of weak monoprotic acid, Solutions of weak monoacidic base

Commit to memory :



$$\alpha = \sqrt{\frac{K_{eq}}{C}}; [A^+] = [B^-] = C\alpha = \sqrt{CK_{eq}} \quad (\text{both valid if } \alpha < 0.1 \text{ or } 10\%)$$

$$\text{Weak Acid (monoprotic) solution : } \alpha = \sqrt{\frac{K_a}{C}}; pH = \frac{1}{2} (pK_a - \log C) \quad (\text{both valid if } \alpha < 0.1 \text{ or } 10\%)$$

$$\text{Weak base (monoacidic) solution : } \alpha = \sqrt{\frac{K_b}{C}}; pOH = \frac{1}{2} (pK_b - \log C) \quad (\text{both valid if } \alpha < 0.1 \text{ or } 10\%)$$

$$\frac{\text{Acid strength of } HA_1}{\text{Acid strength of } HA_2} = \frac{\alpha_1}{\alpha_2} = \sqrt{\frac{K_{a_1}}{K_{a_2}}}; \frac{\text{Basic strength of } BOH_1}{\text{Basic strength of } BOH_2} = \frac{\alpha_1}{\alpha_2} = \sqrt{\frac{K_{b_1}}{K_{b_2}}}$$

E-1. Which of the following has the maximum degree of ionisation ?

- (A) 1 M NH₃ (B) 0.001 M NH₃ (C) 0.1 M NH₃ (D) 0.0001 M NH₃.

E-2. K_a for formic acid and acetic acid are 1.8 × 10⁻⁴ and 1.8 × 10⁻⁵ respectively. The relative strength of acids is :

- (A) 10 : 1 (B) 1 : 10 (C) 1 : √10 (D) √10 : 1

E-3. K_a for a monobasic acid, whose 0.1 M solution has pH of 4.5, is :

- (A) 10⁻¹⁰ (B) 10⁻⁸ (C) √10 × 10⁻⁴ (D) √10 × 10⁻⁶

Section (F) : Salt hydrolysis, pH calculation : Solutions of salt of monoprotic acid and monoacidic base.

Commit to memory :

$$\text{Salt of strong acid and weak base : } K_h \times K_b = K_w; h = \sqrt{\frac{K_h}{c}}; pH = \frac{1}{2} [pK_w - pK_b - \log c] \quad (\text{valid if } h < 0.1 \text{ or } 10\%)$$

$$\text{Salt of strong base and weak acid : } K_h \times K_a = K_w; h = \sqrt{\frac{K_h}{c}}; pH = \frac{1}{2} [pK_w + pK_a + \log c] \quad (\text{valid if } h < 0.1 \text{ or } 10\%)$$

$$\text{Salt of weak acid and weak base : } K_h \times K_a \times K_b = K_w; \left(\frac{h}{1-h} \right) = \sqrt{K_h}; pH = \frac{1}{2} [pK_w + pK_a - pK_b]$$

F-1. Aqueous solution of NH₄Cl is _____ in nature due to behaviour of _____ ion in solution :

- (A) acidic ; NH₄⁺ (B) alkaline ; NH₄⁺ (C) acidic ; Cl⁻ (D) alkaline ; Cl⁻

F-2. The chloride salt of a certain weak monoacidic organic base is hydrolysed to an extent of 3% in its 0.1M solution at 25°C. Given that the ionic product of water is 10⁻¹⁴ at this temperature, what is the dissociation constant of the base?

- (A) ≈ 1 × 10⁻¹⁰ (B) ≈ 1 × 10⁻⁹ (C) 3.33 × 10⁻⁹ (D) 3.33 × 10⁻¹⁰

F-3. The pH of 0.1 M solution of the following salts increases in the order :

- (A) NaCl < NH₄Cl < NaCN < HCl (B) HCl < NH₄Cl < NaCl < NaCN
 (C) NaCN < NH₄Cl < NaCl < HCl (D) HCl < NaCl < NaCN < NH₄Cl



- F-4. The degree of hydrolysis of a salt of weak monobasic acid and weak monoacidic 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

PART - III : MATCH THE COLUMN

1. Match the Column. (Single matching)

	Column-I		Column-II
(A)	HCl	(p)	Lewis acid
(B)	KOH	(q)	Arrhenius acid
(C)	NH ₃	(r)	Lewis base
(D)	BF ₃	(s)	Arrhenius base

Exercise-2

Marked questions are recommended for Revision.

PART - I : ONLY ONE OPTION CORRECT TYPE

- The self ionisation constant for pure formic acid, $K = [\text{HCOOH}_2^+][\text{HCOO}^-]$ has been estimated as 10^{-6} at room temperature. The density of formic acid is 1.15 g/cm^3 . What percentage of formic acid molecules in pure formic acid are converted to formate ion ?
 (A) 0.002% (B) 0.004% (C) 0.006% (D) 0.008%
- pK_a for an acid HA is 6. The value of K for the reaction $\text{A}^- + \text{H}_3\text{O}^+ \rightleftharpoons \text{HA} + \text{H}_2\text{O}$ is :
 (A) 1×10^{-6} (B) 1×10^8 (C) 1×10^{-8} (D) 1×10^6
- 10^{-6} M HCl is diluted to 100 times. Its pH is :
 (A) 6 (B) 8 (C) 6.98 (D) 7.02
- Which of the following solutions has a pH exactly equal to 8 ?
 (A) 10^{-8} M HCl solution (B) Solution containing 10^{-8} M H^+
 (C) $2 \times 10^{-6} \text{ M Ba(OH)}_2$ solution (D) 10^{-8} M NaOH solution
- 10 mL of a strong acid solution of $\text{pH} = 2$ are mixed with 990 mL of another strong acid solution of $\text{pH} = 4$. The pH of the resulting solution will be :
 (A) 3 (B) 3.3 (C) 3.7
 (D) Molecular formula of both strong acids should be known to answer above question.
- % dissociation of a 0.024 M solution of a weak acid HA ($K_a = 2 \times 10^{-3}$) is :
 (A) 0.25% (B) $\approx 29\%$ (C) 25% (D) $\approx 0.29\%$
- For a weak base BOH, $K_b = 10^{-4}$. Calculate pH of 10^{-4} M BOH solution. (Take $\log 6.2 = 0.79$)
 (A) 10 (B) 9.79 (C) 8 (D) None of these
- Four separate solutions of sodium salts NaW, NaX, NaY and NaZ have pH 7, 9, 10 and 11 respectively, when each solution has concentration 0.1 M . Then the strongest acid is :
 (A) HW (B) HX (C) HY (D) HZ

PART - II : SINGLE AND DOUBLE VALUE INTEGER TYPE

- If an acid-base reaction $\text{HA(aq)} + \text{B}^- (\text{aq}) \rightleftharpoons \text{HB(aq)} + \text{A}^- (\text{aq})$ has $K_{\text{eq}} = 10^{-4}$, how many of the following statements are true ?
 (i) HB is stronger acid than HA (ii) HA is stronger acid than HB
 (iii) HA and HB have the same acidic strength (iv) B^- is stronger base than A^-
 (v) A^- is stronger base than B^- (vi) B^- and HB are conjugate acid-base pair
 (vii) A^- is the conjugate base of acid HA. (viii) HA can be HSO_4^- and HB can be HCOOH .
 (ix) A^- can be F^- and B^- can be CN^- .



2. What is pOH of an aqueous solution with $[H^+] = 10^{-2} \text{ M}$ and $K_w = 2 \times 10^{-12}$? Report your answer after dividing by 2 and round it off to the nearest whole number.
3. Percentage ionisation of water as follows at certain temperature is $3.6 \times 10^{-7} \%$. Calculate K_w and pH of water at this temperature. $2H_2O \rightleftharpoons H_3O^+ + OH^-$
4. 0.1 mole HCl is dissolved in distilled water of volume V. Then, at $\lim_{V \rightarrow \infty}$, $(pH)_{\text{solution}}$ is equal to
5. Determine $pK_a(H_2O) + pK_a(H_3O^+)$.
6. What volume (in L) of water must be added to 1 L of 0.1 M solution of B (weak organic monoacidic base; ionisation constant = 10^{-5}) to triple the % ionisation of base ?
7. If $pH_{x\%}$ is the pH of a 1 M weak monoprotic acid which is x % ionised, then find the value of $\left[\frac{pH_{50\%}}{pH_{10\%}} \right] \times 100$.
8. If the equilibrium constant for the reaction of weak acid HA with a strong base is 10^9 , then determine pH of 0.1 M NaA solution.
9. What is the concentration of $CH_3COOH(aq)$ in a solution prepared by dissolving 0.01 mole of $NH_4^+CH_3COO^-$ in 1 L H_2O ? Report your answer after multiplying by 9×10^5 .
 $[K_a(CH_3COOH) = 1.8 \times 10^{-5}; K_b(NH_3.H_2O) = 1.8 \times 10^{-5}]$

PART - III : ONE OR MORE THAN ONE OPTIONS CORRECT TYPE

1. Which statement(s) is/are correct ?
 (A) All Bronsted bases are also Lewis bases.
 (B) All Bronsted acids are not Lewis acids.
 (C) Most cations are acids and most anions are bases.
 (D) All Bronsted bases are also Arrhenius bases.
2. Select the incorrect statement(s) :
 (A) $NH_4^+(aq)$ is a strong acid.
 (B) $CH_3COO^-(aq)$ is a weak base.
 (C) H^- is a weak base.
 (D) HS^- is a weak acid as well as a weak base.
3. For pure water :
 (A) pK_w increases with decrease in temperature.
 (B) Absolute dissociation constant decreases with decrease in temperature.
 (C) α_{H_2O} increases with decrease in temperature.
 (D) Both pH and pOH decrease with rise in temperature.
4. One litre of a strong acid solution contains 10^{-5} moles of H^+ ions. Then :
 (A) $pOH = 9$.
 (B) Percentage ionisation of water in solution is $1.8 \times 10^{-9} \%$.
 (C) Number of OH^- ions per mL of solution = 6.022×10^{15} .
 (D) $[H^+]_{\text{from } H_2O} = 10^{-9} \text{ M}$
5. Equal volumes of 0.2 M HCl and 0.2 M $Sr(OH)_2$ are mixed. Which of the following statement is/are correct ?
 (A) $[Sr^{2+}] = 0.1 \text{ M}$
 (B) $[Cl^-] = 0.1 \text{ M}$
 (C) pH of resulting solution = 13
 (D) Solution is neutral.
6. If 0.1 M CH_3COOH ($K_a = 1.8 \times 10^{-5}$) is diluted at 25°C , then which of the following will be correct ?
 (A) $[H^+]$ will increase.
 (B) pH will increase.
 (C) number of H^+ ions will increase.
 (D) K_a will increase.



7. Degree of hydrolysis for a salt of strong acid and weak base :
 (A) is independent of dilution
 (B) increases with dilution
 (C) increases with decrease in K_b of the bases
 (D) decreases with decrease in temperature.
8. Equal volumes of following solutions are mixed, in which case the pH of resulting solution will be average value of pH of two solutions.
 (A) Aqueous HCl of pH = 2, aqueous NaOH of pH = 12
 (B) Aqueous HCl of pH = 2, aqueous HCl of pH = 4
 (C) Aqueous NaOH of pH = 12, aqueous NaOH of pH = 10
 (D) Aqueous CH_3COOH of pH = 5, aqueous NH_3 of pH = 9. [$K_a(\text{CH}_3\text{COOH}) = K_b(\text{NH}_3)$]

PART - IV : COMPREHENSION

Read the following passages carefully and answer the questions.

Comprehension # 1

pH calculation upon dilution of a strong acid solution is generally done by equating n_{H^+} in original solution & diluted solution. However, if strong acid solution is very dilute, then H^+ from water are also to be considered.

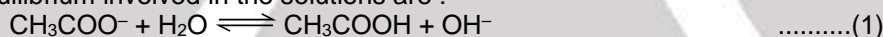
Take $\log 3.7 = 0.568$ and answer the following questions.

1. A 1 litre solution of pH = 4 (solution of a strong acid) is added to the 7/3 litre of water. What is the pH of resulting solution ?
 (A) 4.52 (B) 4.365 (C) 4.4 (D) 4.432
2. A 1 litre solution of pH = 6 (solution of a strong acid) is added to the 7/3 litre of water. What is the pH of resulting solution ? Neglect the common ion effect on H_2O .
 (A) 6.4 (B) 6.52 (C) 6.365 (D) 6.432

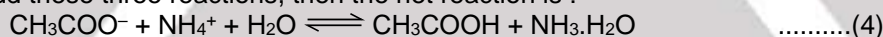
Comprehension # 2

Consider a solution of $\text{CH}_3\text{COONH}_4$ which is a salt of weak acid & weak base.

The equilibrium involved in the solutions are :



If we add these three reactions, then the net reaction is :



Both CH_3COO^- and NH_4^+ get hydrolysed independently and their hydrolysis depends on :

- (i) their initial concentration
- (ii) the value of K_h which is $\frac{K_w}{K_a}$ for CH_3COO^- and $\frac{K_w}{K_b}$ for NH_4^+ .

Since both of the ions were produced from the same salt, their initial concentrations are same.

Therefore unless & until the value of $\frac{K_w}{K_a}$ and $\frac{K_w}{K_b}$ or K_a and K_b is same, the degree of hydrolysis of ion can't be same.

To explain why we assume that degree of hydrolysis of cation and anion is same, we need to now look at the third reaction i.e., combination of H^+ and OH^- ions. It is obvious that this reaction happens only because one reaction produced H^+ ion and the other produced OH^- ions. We can also note that this reaction causes both the hydrolysis reaction to occur more since their product ions are being consumed. Keep this thing in mind that the equilibrium which has smaller value of equilibrium constant is affected more by the common ion effect. For the same reason, if for any reason a reaction is made to occur to a greater extent by the consumption of any one of the product ion, the reaction with the smaller value of equilibrium constant tends to get affected more.



Therefore we conclude that firstly the hydrolysis of both the ions occurs more in the presence of each other (due to consumption of the product ions) than in each other's absence. Secondly, the hydrolysis of the ion which occurs to a lesser extent (due to smaller value of K_h) is affected more than the one whose K_h is greater. Hence, we can see that the degree of hydrolysis of both the ions would be close to each other when they are getting hydrolysed in the presence of each other.

Now answer the following questions :

3. In the hydrolysis of salt of weak acid & weak base :
 (A) degree of hydrolysis of cation and anion is different
 (B) degree of hydrolysis of cation and anion is same
 (C) degree of hydrolysis of cation and anion is different and they can never be assumed same.
 (D) degree of hydrolysis of cation and anion is different but they are very close to each other when they are getting hydrolysed in the presence of each other.
4. For 0.1 M $\text{CH}_3\text{COONH}_4$ salt solution given, $K_a(\text{CH}_3\text{COOH}) = K_b(\text{NH}_3 \cdot \text{H}_2\text{O}) = 2 \times 10^{-5}$.
 In this case, degree of hydrolysis of cation and anion are :
 (A) exactly same
 (B) slightly different
 (C) can't say
 (D) different but can be taken approximately same

Exercise-3

JEE (MAIN) / AIEEE PROBLEMS (PREVIOUS YEARS)

JEE(MAIN) OFFLINE PROBLEMS

- The conjugate base of H_2PO_4^- is : [AIEEE-2004, 3/225]
 (1) PO_4^{3-} (2) P_2O_5 (3) H_3PO_4 (4) HPO_4^{2-}
- What is the conjugate base of OH^- ? [AIEEE-2005, 3/225]
 (1) O_2 (2) H_2O (3) O^- (4) O^{2-}
- Hydrogen ion concentration in mol/L in a solution of pH = 5.4 will be : [AIEEE-2005, 3/225]
 (1) 3.98×10^8 (2) 3.88×10^6 (3) 3.68×10^{-6} (4) 3.98×10^{-6}
- 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, 3/120]
 (1) 5.0×10^{-15} (2) 0.2×10^5 (3) 5.0×10^{-5} (4) 5.0×10^{15}
- The $\text{p}K_a$ of a weak acid, HA, is 4.80. The $\text{p}K_b$ of a weak base, BOH, is 4.78. The pH of an aqueous solution of the corresponding salt, BA, will be : [AIEEE-2008, 3/105]
 (1) 4.79 (2) 7.01 (3) 9.22 (4) 9.58
- Three reactions involving H_2PO_4^- are given below : [AIEEE-2010, 4/144]
 (i) $\text{H}_3\text{PO}_4 + \text{H}_2\text{O} \rightarrow \text{H}_3\text{O}^+ + \text{H}_2\text{PO}_4^-$
 (ii) $\text{H}_2\text{PO}_4^- + \text{H}_2\text{O} \rightarrow \text{HPO}_4^{2-} + \text{H}_3\text{O}^+$
 (iii) $\text{H}_2\text{PO}_4^- + \text{OH}^- \rightarrow \text{H}_3\text{PO}_4 + \text{O}^{2-}$
 In which of the above, does H_2PO_4^- act as an acid ?
 (1) (ii) only (2) (i) and (ii) (3) (iii) only (4) (i) only
- 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: [AIEEE-2012, 4/120]
 (1) 3×10^{-1} (2) 1×10^{-3} (3) 1×10^{-5} (4) 1×10^{-7}
- 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 ? [JEE(Main) 2013, 4/120]
 (1) 0.1 L (2) 0.9 L (3) 2.0 L (4) 9.0 L



9. 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, 4/120]**
 (1) 6.9 (2) 7.0 (3) 1.0 (4) 7.2
10. Which of the following salts is the most basic in aqueous solution? **[JEE(Main) 2018, 4/120]**
 (1) $FeCl_3$ (2) $Pb(CH_3COO)_2$ (3) $Al(CN)_3$ (4) CH_3COOK

JEE(MAIN) ONLINE PROBLEMS

1. 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 : **[JEE(Main) 2014 Online (11-04-14), 4/120]**
 (1) 5.0 (2) 6.0 (3) 8.0 (4) 9.0
2. The conjugate base of hydrazoic acid is : **[JEE(Main) 2014 Online (12-04-14), 4/120]**
 (1) N^{-3} (2) N_3^{-} (3) N_2^{-} (4) HN_3^{-}
3. What quantity (in mL) of a 45% acid solution of a mono-protic strong acid must be mixed with a 20% solution of the same acid to produce 800 mL of a 29.875% acid solution ? **[JEE(Main) 2017 Online (09-04-17), 4/120]**
 (1) 330 (2) 316 (3) 320 (4) 325
4. Following four solutions are prepared by mixing different volumes of NaOH and HCl of different concentrations, pH of which one of the them will be equal to 1? **[JEE(Main) 2018 Online (15-04-18), 4/120]**
 (1) $100 \text{ mL } \frac{M}{10} \text{ HCl} + 100 \text{ mL } \frac{M}{10} \text{ NaOH}$ (2) $75 \text{ mL } \frac{M}{5} \text{ HCl} + 25 \text{ mL } \frac{M}{5} \text{ NaOH}$
 (3) $60 \text{ mL } \frac{M}{10} \text{ HCl} + 40 \text{ mL } \frac{M}{10} \text{ NaOH}$ (4) $55 \text{ mL } \frac{M}{10} \text{ HCl} + 45 \text{ mL } \frac{M}{10} \text{ NaOH}$



Answers

EXERCISE - 1

PART - I

- A-1.** (a) H_3PO_3 , $(\text{COOH})_2$
 (b) HSO_4^- , RNH_3^+ , NH_3 , $(\text{C}_2\text{H}_5)_2\text{OH}^+$, HF
 (c) NO_2^- , O^{2-} , HCO_3^- , ClO_4^-
 (d) Conjugate acids: H_2S , NH_4^+ , $\text{C}_2\text{H}_5\text{OH}_2^+$, H_3O^+
 Conjugate base: S^{2-} , NH_2^- , $\text{C}_2\text{H}_5\text{O}^-$, OH^-
 (e) Lewis acid: H^+ , FeCl_3 , CH_2
 Lewis base: $(\text{CH}_3)_3\text{N}$, F^-
- A-2.** Acidic – (vi), (vii) ; Basic – (i), (iv) ; Amphiprotic – (ii), (iii), (v)
- A-3.** H_2O – Arrhenius acid, Arrhenius base, Bronsted–Lowry acid, Bronsted–Lowry base, Lewis base but not Lewis acid.
- B-1.** 600 ions / mm^3
- C-1.** 2.5×10^{-5} ; 4.6
- C-2.** (i) 10^{-12} (ii) 10^{-6} (iii) 10^{-11} (iv) $K_{b_1} < K_{b_2} < K_{b_3}$
- D-1.** (i) 3, (ii) 2, (iii) 12, (iv) 7.02, (v) 11.2
- D-2.** (i) 11.7, (ii) 1, (iii) 10.7, (iv) 1.92
- D-3.** 0.7 **D-4.** (a) 13 ; (b) 7 ; (c) 1.3.
- E-1.** 1.69×10^{-5}
- E-2.** Refer class notes / sheet theory.
- E-3.** 11.7
- E-4.** HCl
- F-1.** (a) Basic (b) acidic (c) basic (d) basic (e) acidic (f) basic
 (g) neutral (h) basic (i) basic (j) acidic
- F-2.** 9
- F-3.** $K_b = 8 \times 10^{-10}$ **F-4.** 0.625%, pH = 7

PART - II

- | | | | | |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| A-1. (C) | A-2. (D) | A-3. (D) | A-4. (C) | A-5. (D) |
| B-1. (D) | B-2. (A) | B-3. (D) | B-4. (D) | C-1. (B) |
| C-2. (C) | D-1. (C) | D-2. (A) | D-3. (C) | D-4. (B) |
| D-5. (B) | D-6. (D) | D-7. (D) | E-1. (D) | E-2. (D) |
| E-3. (B) | F-1. (A) | F-2. (A) | F-3. (B) | F-4. (B) |

PART - III

1. (A) \rightarrow q; (B) \rightarrow s; (C) \rightarrow r; (D) \rightarrow p

EXERCISE - 2

PART - I

- | | | | | |
|--------|--------|--------|--------|--------|
| 1. (B) | 2. (D) | 3. (C) | 4. (B) | 5. (C) |
| 6. (C) | 7. (B) | 8. (A) | | |



PART - II

- | | | |
|----------------------|----------------------------|---|
| 1. 4 (i, v, vi, vii) | 2. 5 (Actual answer = 9.7) | 3. $K_w = 4 \times 10^{-14}$, pH = 6.7 |
| 4. 7 | 5. 14 | 6. 8 |
| 8. 9 | 9. 50 | 7. 30 |

PART - III

- | | | | | |
|----------|----------|----------|----------|----------|
| 1. (ABC) | 2. (AC) | 3. (ABD) | 4. (ABD) | 5. (ABC) |
| 6. (BC) | 7. (BCD) | 8. (AD) | | |

PART - IV

- | | | | |
|--------|--------|--------|--------|
| 1. (A) | 2. (D) | 3. (D) | 4. (A) |
|--------|--------|--------|--------|

EXERCISE – 3

JEE(MAIN) OFFLINE PROBLEMS

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|--------|--------|--------|--------|---------|
| 1. (4) | 2. (4) | 3. (4) | 4. (1) | 5. (2) |
| 6. (1) | 7. (3) | 8. (4) | 9. (1) | 10. (4) |

JEE(MAIN) ONLINE PROBLEMS

- | | | | |
|--------|--------|--------|--------|
| 1. (4) | 2. (2) | 3. (2) | 4. (2) |
|--------|--------|--------|--------|