



## DPP-11 [Salt Hydrolysis – 2 (Calculations)-Solutions]

### Chapter: Ionic Equilibrium

*“A topper isn't born — they just do the boring things consistently.”*

#### GROUP 1: Strong Acid + Strong Base Salt

**Q1. At 90°C, the pH of 0.1 M NaCl aqueous solution is :**

- (1) < 7
- (2) > 7
- (3) 7
- (4) 0.1

NaCl is a salt of **strong acid + strong base**  $\Rightarrow$  no hydrolysis. So solution is **neutral**, but neutral pH at temperature  $T$  is  $\frac{pK_w(T)}{2}$  (not always 7).

At 90°C,  $K_w$  increases  $\Rightarrow pK_w$  decreases (from 14), hence neutral pH =  $\frac{pK_w}{2} < 7$ .

**Correct option: (1) < 7**

#### GROUP 2: Weak Acid + Strong Base Salt

**Q2. The pH of aqueous solution of sodium acetate is :**

- (1) 7
- (2) Very low
- (3) > 7
- (4) < 7

$\text{CH}_3\text{COONa}$  is **weak acid + strong base salt**  $\Rightarrow$  anion hydrolysis produces  $\text{OH}^-$ .

$\text{CH}_3\text{COO}^- + \text{H}_2\text{O} \rightleftharpoons \text{CH}_3\text{COOH} + \text{OH}^-$  so solution becomes **basic**.

**Correct option: (3) > 7**

**Q3. For anionic hydrolysis, pH is given by :-**

- (1)  $pH = \frac{1}{2}pK_w - \frac{1}{2}pK_b - \frac{1}{2}\log C$
- (2)  $pH = \frac{1}{2}pK_w + \frac{1}{2}pK_a - \frac{1}{2}pK_b$
- (3)  $pH = \frac{1}{2}pK_w + \frac{1}{2}pK_a + \frac{1}{2}\log C$
- (4) None of above

For weak acid + strong base salt:  $[OH^-] = \sqrt{\frac{CK_w}{K_a}} \Rightarrow pH = \frac{1}{2}(pK_w + pK_a + \log C)$ .

$$[OH^-] = \sqrt{C \cdot K_b}, \quad K_b = \frac{K_w}{K_a} \Rightarrow [OH^-] = \sqrt{\frac{CK_w}{K_a}}$$

So  $pOH = \frac{1}{2}(pK_w - pK_a - \log C)$  and  $pH = pK_w - pOH = \frac{1}{2}(pK_w + pK_a + \log C)$ .

**Correct option: (3)**

**Q4. If  $pK_b$  for  $CN^-$  at  $25^\circ C$  is 4.7. The pH of 0.5 M aqueous NaCN solution is :**

- (1) 12
- (2) 10
- (3) 11.5
- (4) 11

For NaCN:  $CN^-$  is a weak base with given  $pK_b$ . Use  $[OH^-] = \sqrt{CK_b} \Rightarrow pOH = \frac{1}{2}(pK_b - \log C)$ , then  $pH = 14 - pOH$  (at  $25^\circ C$ ).

$$K_b = 10^{-4.7}, \quad C = 0.5, \quad \log(0.5) = -0.301$$

$$pOH = \frac{1}{2}(pK_b - \log C) = \frac{1}{2}(4.7 - (-0.301)) = \frac{1}{2}(5.001) \approx 2.50$$

$$pH = 14 - 2.50 = 11.50$$

**Correct option: (3) 11.5**

**Q5. Assuming small hydrolysis, pH of 0.1 M sodium acetate ( $K_a = 1 \times 10^{-5}$ ) is :**

- (1) 5.0
- (2) 6.0
- (3) 8.0
- (4) 9.0

Use anionic hydrolysis formula:  $pH = \frac{1}{2}(pK_w + pK_a + \log C)$  at  $25^\circ C$ .

$$pK_w = 14, \quad pK_a = 5, \quad C = 0.1 \Rightarrow \log C = -1$$

$$pH = \frac{1}{2}(14 + 5 - 1) = \frac{1}{2}(18) = 9$$

**Correct option: (4) 9.0**

**Q6. Hydroxyl ion concentration  $[OH^-]$  in the case of sodium acetate can be expressed as :-**

- (1)  $(CK_wK_a)^{1/2}$
- (2)  $CK_w/K_a$
- (3)  $\left(\frac{CK_w}{K_a}\right)^{1/2}$
- (4)  $CK_w/K_a$

For  $A^-$  hydrolysis:  $[OH^-] = \sqrt{CK_b}$  and  $K_b = \frac{K_w}{K_a}$ .

$$[OH^-] = \sqrt{C \cdot \frac{K_w}{K_a}} = \left(\frac{CK_w}{K_a}\right)^{1/2}$$

**Correct option: (3)**

**Q7. Degree of hydrolysis of  $\frac{N}{100}$  solution of KCN is (Given  $K_a = 1.4 \times 10^{-9}$ ) :**

- (1)  $2.7 \times 10^{-3}$
- (2)  $2.7 \times 10^{-2}$
- (3)  $2.7 \times 10^{-4}$
- (4)  $2.7 \times 10^{-5}$

For weak acid + strong base salt:  $h = \sqrt{\frac{K_h}{C}}$ , where  $K_h = \frac{K_w}{K_a}$ .

$$C = \frac{N}{100} = 0.01 \text{ M}, K_h = \frac{10^{-14}}{1.4 \times 10^{-9}} = 7.14 \times 10^{-6}$$

$$h = \sqrt{\frac{7.14 \times 10^{-6}}{0.01}} = \sqrt{7.14 \times 10^{-4}} \approx 2.67 \times 10^{-2} \approx 2.7 \times 10^{-2}$$

**Correct option: (2)  $2.7 \times 10^{-2}$**

**Q8. Which of the following salts is most basic in aqueous solution?**

- (1)  $FeCl_3$
- (2)  $Pb(CH_3COO)_2$
- (3)  $Al(CN)_3$
- (4)  $CH_3COOK$

Most basic  $\Rightarrow$  strongest source of  $OH^-$  and minimum acidic hydrolysis.

$Fe^{3+}$  and  $Al^{3+}$  give strong acidic hydrolysis.  $CH_3COO^-$  is basic;  $K^+$  does not hydrolyse  $\Rightarrow$   $CH_3COOK$  is clearly basic.

Correct option: (4)  $\text{CH}_3\text{COOK}$

Q9. 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 :

- (1) HW
- (2) HX
- (3) HY
- (4) HZ

For sodium salt of acid: higher pH  $\Rightarrow$  stronger conjugate base  $\Rightarrow$  weaker acid. So lowest pH corresponds to strongest acid.

pH order: NaW (7) < NaX (9) < NaY (10) < NaZ (11). So acid strength: HW > HX > HY > HZ.

Correct option: (1) HW

Q10.  $\text{HCOO}^- + \text{H}_2\text{O} \rightleftharpoons \text{HCOOH} + \text{OH}^-$  is related :-

- (1)  $h = \sqrt{K_h}$
- (2)  $h = \sqrt{\frac{K_h}{C}}$
- (3)  $h = \sqrt{\frac{K_h}{V}}$
- (4)  $K_h = \sqrt{hC}$

This is the **anionic hydrolysis relation** (weak acid + strong base salt):  $h = \sqrt{\frac{K_h}{C}}$ .

**Note :** For salt hydrolysis we use  $\text{HCOO}^- + \text{H}_2\text{O} \rightleftharpoons \text{HCOOH} + \text{OH}^-$ . For small hydrolysis:  
$$K_h = \frac{h^2}{1-h}C \approx h^2C \Rightarrow h = \sqrt{\frac{K_h}{C}}$$

Correct option: (2)

Q11. If equilibrium constant for  $\text{HA} + \text{strong base}$  is  $10^9$ , determine pH of 0.1 M NaA.

For neutralization:  $\text{HA} + \text{OH}^- \rightleftharpoons \text{A}^- + \text{H}_2\text{O}$ , equilibrium constant  $K = \frac{K_a}{K_w} \Rightarrow$  first find  $K_a$ , then use salt pH formula.

$$K = \frac{K_a}{K_w} \Rightarrow K_a = K \cdot K_w = 10^9 \cdot 10^{-14} = 10^{-5} \Rightarrow pK_a = 5$$

Now for NaA (weak acid + strong base salt):

$$pH = \frac{1}{2}(pK_w + pK_a + \log C) = \frac{1}{2}(14 + 5 + \log 0.1) = \frac{1}{2}(14 + 5 - 1) = 9$$

$$pH = 9.0$$

**Q12. A weak acid reacts with strong base, ionisation constant of weak acid is  $10^{-4}$ . Find out equilibrium constant for this reaction :-**

- (1)  $10^{-10}$
- (2)  $10^{10}$
- (3)  $10^{-9}$
- (4)  $10^9$

Same relation:  $K = \frac{K_a}{K_w}$ .

$$K = \frac{10^{-4}}{10^{-14}} = 10^{10}$$

**Correct option: (2)  $10^{10}$**

### GROUP 3: Strong Acid + Weak Base Salt

**Q13. Aqueous solution of  $\text{NH}_4\text{Cl}$  is in nature due to behaviour of ion in solution : (A) acidic ;  $\text{NH}_4^+$  (B) alkaline ;  $\text{NH}_4^+$  (C) acidic ;  $\text{Cl}^-$  (D) alkaline ;  $\text{Cl}^-$**

Strong acid (HCl) + weak base ( $\text{NH}_4\text{OH}$ ) salt  $\Rightarrow$  cation hydrolysis produces  $\text{H}^+$ .

$\text{NH}_4^+$  hydrolyses:  $\text{NH}_4^+ + \text{H}_2\text{O} \rightleftharpoons \text{NH}_3 + \text{H}_3\text{O}^+$  hence solution is acidic.

**Correct option: (A) acidic ;  $\text{NH}_4^+$**

**Q14. The ionization constant of ammonium hydroxide is  $1.77 \times 10^{-5}$  at 298 K. Hydrolysis constant of ammonium chloride is :-**

- (1)  $5.65 \times 10^{-12}$
- (2)  $5.65 \times 10^{-10}$
- (3)  $6.50 \times 10^{-12}$
- (4)  $5.65 \times 10^{-13}$

For strong acid + weak base salt:  $K_h = \frac{K_w}{K_b}$ .

$$K_h = \frac{10^{-14}}{1.77 \times 10^{-5}} = \left( \frac{1}{1.77} \right) \times 10^{-9} \approx 0.565 \times 10^{-9} = 5.65 \times 10^{-10}$$

**Correct option: (2)**  $5.65 \times 10^{-10}$

**Q15. 0.02 M of pyridinium hydrochloride having  $[H^+] = 5.55 \times 10^{-6}$  what is ionisation constant of pyridine.**

- (1)  $1.54 \times 10^{-9}$
- (2)  $1.54 \times 10^{-7}$
- (3)  $1.54 \times 10^{-6}$
- (4)  $1.54 \times 10^{-5}$

For salt of weak base + strong acid: **conjugate acid** ( $BH^+$ ) acts as weak acid. Use  $K_a(BH^+) = \frac{x^2}{C}$  where  $x = [H^+]$ .

Here  $C = 0.02$  and  $x = 5.55 \times 10^{-6}$ :

$$K_a = \frac{x^2}{C} = \frac{(5.55 \times 10^{-6})^2}{0.02} = \frac{3.080 \times 10^{-11}}{0.02} = 1.54 \times 10^{-9}$$

**Note:** Options match  $K_a$  of pyridinium ion (conjugate acid), hence question wording has a small mismatch.

**Correct option: (1)**  $1.54 \times 10^{-9}$

**Q16. The chloride salt of a certain weak monoacidic organic base is hydrolysed to an extent of 3% in its 0.1 M solution at 25°C. Given  $K_w = 10^{-14}$ , the dissociation constant of the base is :**

- (1)  $1 \times 10^{-10}$
- (2)  $1 \times 10^{-9}$
- (3)  $3.33 \times 10^{-9}$
- (4)  $3.33 \times 10^{-10}$

Given degree of hydrolysis  $h = 0.03$  for a weak base salt:  $K_h = \frac{h^2 C}{1 - h}$  and  $K_h = \frac{K_w}{K_b} \Rightarrow K_b = \frac{K_w}{K_h}$ .

$C = 0.1$ ,  $h = 0.03$ :

$$K_h = \frac{(0.03)^2(0.1)}{1 - 0.03} = \frac{0.00009}{0.97} \approx 9.28 \times 10^{-5}$$

$$K_b = \frac{10^{-14}}{9.28 \times 10^{-5}} \approx 1.08 \times 10^{-10} \approx 1 \times 10^{-10}$$

Correct option: (1)  $1 \times 10^{-10}$

#### GROUP 4: Weak Acid + Weak Base Salt

Q17. pH of which salt is same for 1 M and 5 M solution both?

- (1) HCOONa
- (2)  $C_6H_5NH_3Cl$
- (3)  $NH_4CN$
- (4) NaCN

For weak acid + weak base salt:  $pH = \frac{1}{2}(pK_w + pK_a - pK_b)$ , independent of concentration.

Only  $NH_4CN$  is a salt of weak acid (HCN) + weak base ( $NH_3$ ). Hence its pH stays same for different molarity.

Correct option: (3)  $NH_4CN$

Q18. What will be the pH of 1.0 M ammonium formate solution, If  $K_a = 1 \times 10^{-4}$  and  $K_b = 1 \times 10^{-5}$  :

- (1) 6.5
- (2) 7.5
- (3) 8.0
- (4) 9.0

Weak acid + weak base salt:  $pH = \frac{1}{2}(pK_w + pK_a - pK_b)$ .

$$pK_w = 14, pK_a = 4, pK_b = 5$$

$$pH = \frac{1}{2}(14 + 4 - 5) = \frac{1}{2}(13) = 6.5$$

Correct option: (1) 6.5

Q19. Calculate pH of salt of weak monoacidic acid and weak monoacidic base (0.1 M),  $pK_a = 4.8$ ,  $pK_b = 5.2$  :

- (1) 7.2
- (2) 6.8
- (3) 9.6
- (4) 7

Use  $pH = \frac{1}{2}(pK_w + pK_a - pK_b)$ .

$$pH = \frac{1}{2}(14 + 4.8 - 5.2) = \frac{1}{2}(13.6) = 6.8$$

Correct option: (2) 6.8

**Q20. The  $pK_a$  of HA is 4.80;  $pK_b$  of BOH is 4.78. pH of BA salt is :**

- (1) 9.58
- (2) 4.79
- (3) 7.01
- (4) 9.22

Weak acid + weak base salt:  $pH = \frac{1}{2}(14 + pK_a - pK_b)$ .

$$pH = \frac{1}{2}(14 + 4.80 - 4.78) = \frac{1}{2}(14.02) = 7.01$$

Correct option: (3) 7.01

**Q21. Given  $K_a(\text{HA}) = 10^{-6}$ ,  $K_b(\text{MOH}) = 10^{-6}$ , pH of 0.1 M MA is :**

- (1) 5
- (2) 7
- (3) 9
- (4) 2

Weak acid + weak base salt:  $pH = \frac{1}{2}(14 + pK_a - pK_b)$ .

$pK_a = 6$ ,  $pK_b = 6$ :

$$pH = \frac{1}{2}(14 + 6 - 6) = 7$$

Correct option: (2) 7

**Q22.  $pK_a(\text{CH}_3\text{COOH}) = 4.78$  and  $pK_b(\text{NH}_4\text{OH}) = 4.7$ . pH of ammonium acetate is :**

- (1) 8.04
- (2) 6.02
- (3) 7.04
- (4) 5.04

Use  $pH = \frac{1}{2}(14 + pK_a - pK_b)$ .

$$pH = \frac{1}{2}(14 + 4.78 - 4.70) = \frac{1}{2}(14.08) = 7.04$$

Correct option: (3) 7.04

**Q23.**  $pK_a$  of weak acid 4.80,  $pK_b$  of weak base 4.78. pH of salt BA is :

- (1) 4.79
- (2) 7.01
- (3) 9.22
- (4) 9.58

Same as Q20.

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

Correct option: (2) 7.01

**Q24.**  $pK_a(\text{HA}) = 3.2$ ,  $pK_b(\text{BOH}) = 3.4$ . pH of AB salt is :

- (1) 6.9
- (2) 7.0
- (3) 1.0
- (4) 7.2

Use  $pH = \frac{1}{2}(14 + pK_a - pK_b)$ .

$$pH = \frac{1}{2}(14 + 3.2 - 3.4) = \frac{1}{2}(13.8) = 6.9$$

Correct option: (1) 6.9

**Q25.** When 10 mL of 0.1 M acetic acid ( $pK_a = 5.0$ ) is titrated with 10 mL 0.1 M ammonia ( $pK_b = 5.0$ ), equivalence pH is :

- (1) 6.0
- (2) 7.0
- (3) 9.0
- (4) 4.0

At equivalence: salt  $\text{NH}_4\text{CH}_3\text{COO}$  forms (weak acid + weak base). So  $pH = \frac{1}{2}(14 + pK_a - pK_b)$  (concentration cancels).

$$pK_a = 5.0, pK_b = 5.0:$$

$$pH = \frac{1}{2}(14 + 5 - 5) = 7.0$$

Correct option: (2) 7.0

**Q26. The degree of hydrolysis of a salt of weak monoacidic acid and weak monoacidic base in 0.1 M solution is 50%. If the molarity is 0.2 M, percentage hydrolysis is :**

- (1) 100%
- (2) 50%
- (3) 25%
- (4) None of these

For weak acid + weak base salt, degree of hydrolysis  $h$  is **independent of concentration.**

From theory:

$$\frac{h}{1-h} = \sqrt{\frac{K_w}{K_a K_b}}$$

No  $C$  term  $\Rightarrow$  changing molarity does not change  $h$ .

Correct option: (2) 50%

**Q27. What is concentration of  $\text{CH}_3\text{COOH}$  in solution prepared by dissolving 0.01 mol  $\text{NH}_4^+\text{CH}_3\text{COO}^-$  in 1 L water? Multiply final answer by  $9 \times 10^5$ .**

**Given  $K_a(\text{CH}_3\text{COOH}) = 1.8 \times 10^{-5}$ ;  $K_b(\text{NH}_3 \cdot \text{H}_2\text{O}) = 1.8 \times 10^{-5}$ .**

$\text{NH}_4\text{CH}_3\text{COO}$  is weak acid + weak base salt. First find degree of hydrolysis:

$$\frac{h}{1-h} = \sqrt{\frac{K_w}{K_a K_b}}$$

Then  $[\text{CH}_3\text{COOH}] = Ch$  (since hydrolysis produces equal HA).

$$C = \frac{0.01 \text{ mol}}{1 \text{ L}} = 0.01 \text{ M}, K_w = 10^{-14}, \text{ and } K_a = K_b = 1.8 \times 10^{-5}:$$

$$\sqrt{\frac{K_w}{K_a K_b}} = \sqrt{\frac{10^{-14}}{(1.8 \times 10^{-5})^2}} = \sqrt{\frac{10^{-14}}{3.24 \times 10^{-10}}} = \sqrt{3.086 \times 10^{-5}} \approx 5.55 \times 10^{-3}$$

So

$$\frac{h}{1-h} \approx 5.55 \times 10^{-3} \Rightarrow h \approx \frac{5.55 \times 10^{-3}}{1 + 5.55 \times 10^{-3}} \approx 5.52 \times 10^{-3}$$

$$[\text{CH}_3\text{COOH}] = Ch = 0.01 \times 5.52 \times 10^{-3} = 5.52 \times 10^{-5} \text{ M}$$

Multiply:

$$(5.52 \times 10^{-5}) \times (9 \times 10^5) = 5.52 \times 9 \approx 49.7$$

$$[\text{CH}_3\text{COOH}] \approx 5.52 \times 10^{-5} \text{ M} \quad \text{and} \quad \text{final value} \approx 49.7 (\approx 50)$$

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*Weird Chemist Tip: Formula yaad rakhne se pehle, category pehchaan—Strong/Weak ka game hi hydrolysis ka master-key hai.*