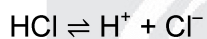
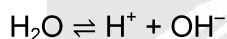


Answer Key

- | | | | | |
|--|------------------------------|---------------------------------|----------|----------|
| 1. (B) | 2. (B) | 3. (B) | 4. (C) | 5. (A) |
| 6. (C) | 7. (B) | 8. (D) | 9. (AC) | 10. (AB) |
| 11. (AC) | 12. (ACD) | 13. (CD) | 14. (AB) | 15. (AC) |
| 16. (BCD) | 17. (A) | 18. ((A) – S; (B) – S; (C) – Q) | | |
| 19. (9.04, 8.78, yes) | | | | |
| 20. (a) 8.5×10^{-16} , 5×10^{-12} , 1.7×10^{-9} | (b) I^- | (c) 1.7×10^{-5} | | |
| (d) $Br^- = 2.9 \times 10^{-8}$, $I^- = 5 \times 10^{-9}$ | | | | |
| 21. ($s = 2.236 \times 10^{-5} M$) | | | | |
| 22. ($[H_2CO_3] = 9.85 \times 10^{-6} M$, $[HCO_2^-] = 4.9 \times 10^{-4} M$, $[CO_3^{2-}] = 2.45 \times 10^{-8} M$) | | | | |
| 23. (pH = 0.908) | 24. (precipitate will occur) | | | |

Solution

1. Say $[H^+]$ contributed from H_2O and HCl be 'x' each



x x

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

$$(2x)(x) = 10^{-14}$$

$$x = \frac{10^{-7}}{\sqrt{2}} = 10^{-8} \times \sqrt{\frac{100}{2}}$$

$$= \sqrt{50} \times 10^{-8}$$

$$\therefore [HCl] = \sqrt{50} \times 10^{-8} M$$

2. buffer capacity (β) = $\frac{2.303 ab}{a+b}$, $a+b=1$

Max $\beta \Rightarrow$ when $a = b = 0.5$

$$\beta_{\max} = \frac{2.303(0.5)^2}{1} = 0.575$$

$$\beta = 2.303 ab \quad (\because a+b=1)$$

$$\beta = 2.303 (1-b)(b)$$

$$\Rightarrow b^2 - b + \frac{\beta}{2.303} = 0 \text{ parabolic equation}$$

$\therefore$ option (B) is answer.

3. Option A: 0.1 M NaHCO₃

$$P^H = \frac{1}{2}(P_{Ka_1} + P_{Ka_2})$$

Independent of concentration

Option B: 0.2 M NaOH

$$P^{OH} = -\log[OH^-]$$

P^{OH} will change $\Rightarrow P^H$ will change

Option C: 0.3 M NH₃ + 0.2 M NH₄⁺

$$P^{OH} = P^{K_b} + \log \frac{[NH_4^+]}{[NH_3]}$$

P^H of buffer does not change from small amount of addition of water

Option D: 0.4 M CH₃COONH₄

(Salt of WA + WB)

$$P^H = 7 + \frac{1}{2}(P^{K_a} - P^{K_b})$$

Independent of concentration.

4. $K = 10^{-30}$

$$[NH_4^+][NH_2^-] = 10^{-30}$$

$$[NH_4^+] = 10^{-15} (\because [NH_4^+][NH_2^-])$$

$\therefore 10^{-15}$ mol NH₄⁺ ions is present in 1 lit

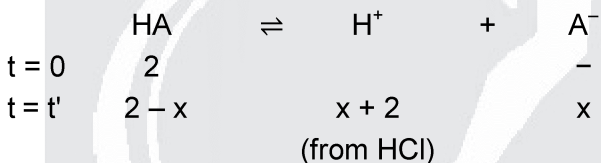
Thus, 10^{-16} mol NH₄⁺ ions, i.e., 6.022×10^7 4NH₄⁺ ions are present in 100 cm³ pure liquid.

5. 10 ml, 0.3 M HCl $\Rightarrow$ 3 mmol HCl

10 ml, 0.1 M NaOH $\Rightarrow$ 1 mmol of NaOH

When HCl, NaOH react, 2 mmol of HCl would be left unreacted

When HA 20ml, 0.1 M HA is added, H⁺ of HCl would apply common ion effect on HA.



$K_a = 10^{-5}$, total volume = 40 ml

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

$$10^{-5} = \frac{\left(\frac{x+2}{40}\right)\left(\frac{x}{40}\right)}{\left(\frac{2-x}{40}\right)}$$

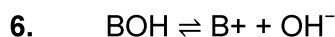
$$\Rightarrow 10^{-5}(2-x) = \frac{1}{40}(x^2 + 2x)$$

$$\Rightarrow 2 \times 10^{-5} - x \times 10^{-5} = \frac{1}{40}(2x)$$

$$\Rightarrow 2 \times 10^{-5} \approx \frac{1}{20}x$$

$$\Rightarrow x \approx 40 \times 10^{-5}$$

$$\Rightarrow \frac{[A^-]}{[HA] + [A^-]} = \frac{x}{(2-x) + x} = \frac{x}{2} = 2 \times 10^{-4}$$



$$C(1 - \alpha) \approx \alpha \approx c\alpha$$

$$K_b = c\alpha^2$$

$$\therefore \alpha\% = 100 \times \sqrt{\frac{K_b}{c}}$$

$$\alpha = \frac{[\text{B}^+]}{[\text{B}^+] + [\text{BOH}]}$$

$$\Rightarrow \alpha = \frac{1}{1 + \frac{[\text{BOH}]}{[\text{B}^+]}}$$

$$\Rightarrow \alpha = \frac{K_b}{K_b + [\text{OH}^-]} \left(\because K_b = \frac{[\text{B}^+][\text{OH}^-]}{[\text{BOH}]} \right)$$

$$\Rightarrow \alpha = \frac{1}{1 + \frac{[\text{OH}^-]}{K_b}}$$

$$\Rightarrow \alpha = \frac{K_b [\text{H}^+]}{K_b [\text{H}^+] + K_w} \left(\because K_w = [\text{H}^+][\text{OH}^-] \right)$$

7. (B)

8. $\text{Al}(\text{OH})_3$ exists as Al^{3+} and $[\text{Al}(\text{OH})_4]^-$

$$\therefore \text{solubility (s)} = [\text{Al}^{3+}] + [\text{Al}(\text{OH})_4]^-$$

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

$$K_c = \frac{[\text{Al}(\text{OH})_4]^-}{[\text{OH}^-]^3}$$

$$\therefore s = \frac{K_{sp}}{[\text{OH}^-]^3} + K_c [\text{OH}^-]$$

$$\frac{ds}{d[\text{OH}^-]} = 0 \text{ (for mins)}$$

$$0 = -3K_{sp} [\text{OH}^-]^{-4} + K_c$$

$$\therefore [\text{OH}^-] = \left(\frac{3K_{sp}}{K_c} \right)^{\frac{1}{4}}$$

9. (AC)

10. (AB)

11. (AC)

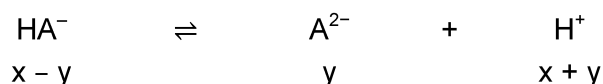
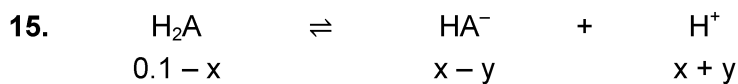
12. (ACD)

13. From the graph, there are 2 neutralisation points. Thus, the weak electrolyte should be dibasic acid. Thus, the weak electrolyte can $\text{H}_2\text{C}_2\text{O}_4$ or $\text{CH}_2(\text{COOH})_2$

14. $k_i = 1.8 \times 10^{-16}$ (At $T = 25^\circ \text{C}$)

$$k_w = 10^{-14} \text{ (At } T = 25^\circ \text{C)}$$

Thus, $k_i < k_w$ and $\text{p}k_i > \text{p}k_w$



Given $y = 10^{-12}$

$\therefore x + y \approx x$ (y is negligible)

$\therefore [\text{H}^+]_{\text{total}} = [\text{H}^+] \text{ from first ionization}$

$\text{pH} = 3$

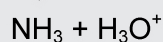
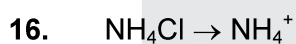
$\Rightarrow [\text{H}^+] = 10^{-3}$

$$K_{a_1} = \frac{[\text{H}^+][\text{HA}^-]}{[\text{H}_2\text{A}]}$$

neglecting $y = 10^{-12}$

$$K_{a_1} = \frac{10^{-3} \times 10^{-3}}{0.1}$$

$\therefore K_{a_1} = 10^{-5}$



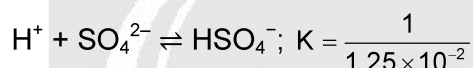
$\therefore [\text{Cl}^-] = [\text{NH}_4\text{Cl}] = 10^{-2} \text{M}$

• $[\text{NH}_4^+] < 10^{-2} \text{M}$ due to hydrolysis.

• Salt of SA and WB. Thus $\text{pH} < 7$

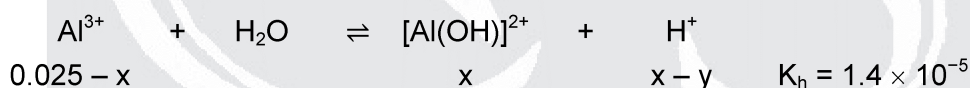
$\therefore \text{pOH} > 7$

$\therefore [\text{H}^+] > 10^{-7} \text{M}$

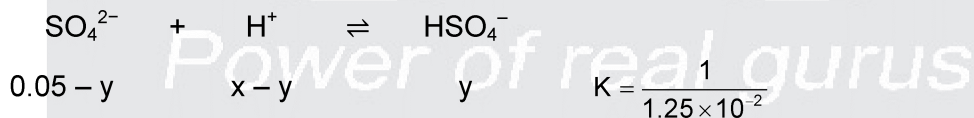


11.85 gm of potash alum is added to 1000 cm^3 water

$\therefore$ moles of potash alum $\frac{11.85}{474} = 0.025$



≈ 0.025



≈ 0.05

$\Rightarrow \frac{(x-y)x}{0.025} = 1.4 \times 10^{-5} \quad \dots\dots(1)$

$\Rightarrow \frac{y}{(x-y)0.05} = \frac{1}{1.25 \times 10^{-2}} \quad \dots\dots(2)$

Solving (1) and (2)

$(x-y) = 2.9 \times 10^{-5}$

$\therefore [\text{H}^+] = \frac{2.9 \times 10^{-5}}{0.1} = 2.9 \times 10^{-4} \text{M}$

18. (A) 200 ml, 25% H_2SO_4

$$\Rightarrow n_{\text{H}_2\text{SO}_4} = \frac{200 \times 25 \times 1.225}{100} \times \frac{1}{98} = 0.625 \text{ mol}$$

$$\Rightarrow n_{\text{H}^+} = 1.25 \text{ mol}$$

$$800 \text{ ml, } 0.525 \text{ M } \text{X(OH)}_3$$

$$n_{\text{X(OH)}_3} = 0.42 \text{ mol}$$

$$n_{\text{OH}^-} = 1.26 \text{ mol}$$

After reaction n_{OH^-} (left) = 0.01 mol

$$\therefore \text{pOH} = 2$$

$$\text{pH} = 12$$

$\therefore$ Malachite green (11.4 – 13)

$$(B) \text{ pH} = \text{pK}_a + \log \frac{[\text{CO}_3^{2-}]}{[\text{HCO}_3^-]}$$

$$\text{pK}_a = \log(2 \times 10^{-11}) = 10.7$$

$$\text{pH} = 10.7 + \log\left(\frac{40}{5}\right)$$

$$\text{pH} \approx 11.4$$

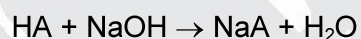
$\therefore$ Malachite green (11.4 – 13)

(C) 50 ml, 0.2 M HA ($K_a = 10^{-5}$)

$$50 \text{ ml, } 0.1 \text{ M HCl} \Rightarrow n_{\text{HCl}} = 5 \text{ mmol}$$

$$100 \text{ ml, } 0.13 \text{ M NaOH} \Rightarrow n_{\text{NaOH}} = 13 \text{ mmol}$$

After HCl and NaOH reacts, n_{NaOH} (left) = 8 mmol



$$t = 0 \quad 10 \quad 8 \quad - \quad -$$

$$t = t^1 \quad 2 \quad 1 \quad 8 \quad -$$

$$\therefore \text{pH} = \text{pK}_a + \log \frac{[\text{A}^-]}{[\text{HA}]}$$

$$= -\log(10^{-5}) + \log 4$$

$$= 5 + \log 4$$

$$\approx 5.6$$

$$\therefore \text{pH} = 5.6$$

$\therefore$ Propyl red (4.6 – 6.4)

19. Initially $[\text{NH}_4^+] = 0.1$, $[\text{NH}_3] = 0.06$

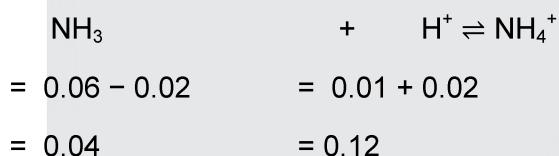
$$\text{P}^{\text{OH}} = \text{P}^{\text{K}_b} + \log \frac{[\text{NH}_4^+]}{[\text{NH}_3]}$$

$$\text{P}^{\text{OH}} = -\log(1.8 \times 10^{-5}) + \log\left(\frac{0.1}{0.06}\right) = 4.96$$

$$\therefore \text{P}^{\text{H}} = 9.04$$

$$\therefore \text{Initial } \text{P}^{\text{H}} = 9.04$$

Due to CH_3COOH , H^+ is added to system



$$\text{P}^{\text{OH}} = -\log(1.8 \times 10^{-5}) + \log\left(\frac{0.12}{0.04}\right) \approx 5.22$$

$$\text{PH} \approx 8.78$$

$$\therefore \text{Final } \text{P}^{\text{H}} = 8.78$$

$$\text{Also } \Delta \text{P}^{\text{H}} = 0.26$$

$\therefore$ The change in P^{H} is with 0.26 and thus it's a satisfactory buffer.

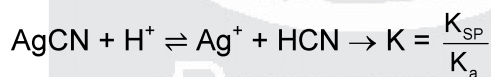
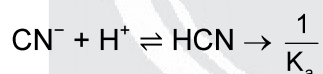
20. (a) 8.5×10^{-16} , 5×10^{-12} , 1.7×10^{-9}

(b) I^-

(c) 1.7×10^{-5}

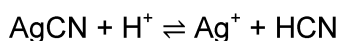
(d) $\text{Br}^- = 2.9 \times 10^{-4}$, $\text{I}^- = 5 \times 10^{-8}$

21. $\text{AgCN} \rightleftharpoons \text{Ag}^+ + \text{CN}^- \rightarrow \text{K}_{\text{SP}}$



$$\text{K} = \frac{3.2 \times 10^{-16}}{6.4 \times 10^{-10}} = 0.5 \times 10^{-6}$$

Now, at equilibrium and $\text{pH} = 3$, 'x' moles of Ag^+ & HCN form.



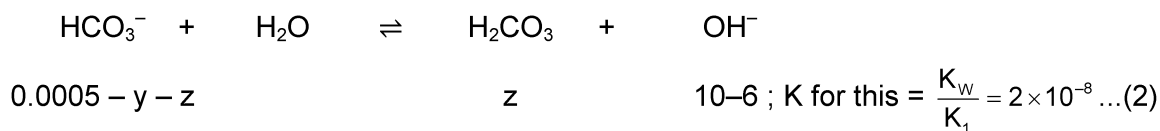
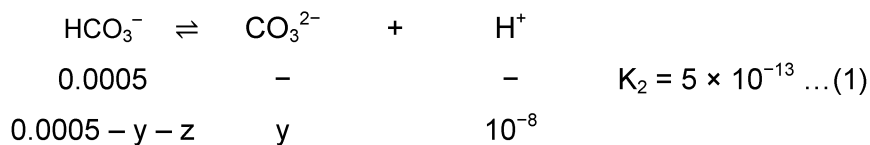
$$0.001 \times x$$

$$\text{K} = \frac{x^2}{0.001} = 0.5 \times 10^{-6}$$

$$\Rightarrow x = 2.236 \times 10^{-5} \text{ M}$$

22. $\text{pH} = 8 \Rightarrow [\text{H}^+] = 10^{-8}$ & $[\text{OH}^-]$ would be $= 10^{-6}$

NaHCO_3 added is 0.0005 M.



Comparing K_2 & K it can be said that $y \ll z$

$$\therefore K = 2 \times 10^{-8} = \frac{z(10^{-6})}{0.0005 - z} \Rightarrow z = 9.8 \times 10^{-6}$$

$$\therefore [\text{H}_2\text{CO}_3] = z = 9.8 \times 10^{-6} \text{ M}$$

$$[\text{HCO}_3^-] = 0.0005 - z = 4.9 \times 10^{-4} \text{ M}$$

$$\text{Also, } K_2 = \frac{y \times 10^{-8}}{0.0005 - y} = \frac{y \cdot 10^{-8}}{4.9 \times 10^{-4}} = 5 \times 10^{-13} \text{ M}$$

$$[\text{HCO}_3^-] = 0.0005 - y$$

$$\therefore y = [\text{CO}_3^{2-}] = 2.45 \times 10^{-8} \text{ M}$$

23. $\text{Fe}^{3+} + \text{H}_2\text{O} \rightarrow \text{Fe}(\text{OH})^{2+} + \text{H}^+$

$$\begin{array}{ccccc} 0.95x & & 0.05x & & 0.05x & & K = 6.5 \times 10^{-3} \end{array}$$

$$K = \frac{(0.05x)^2}{0.95x} = 6.5 \times 10^{-3} \Rightarrow x = 2.47$$

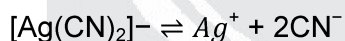
'x' is the dissociation

$$\therefore [\text{H}^+] = 0.05 \times 2.47 = 0.1235$$

$$\therefore \text{pH} = -\log[\text{H}^+] = -\log(0.1235) = 0.908$$

24. (precipitate will occur)

$$[\text{Cl}^-] \text{ from NaCl} = 0.02 \text{ M}$$



$$\begin{array}{ccccc} 0.05 & & - & & - \\ 0.05 - x & & x & & 2x \end{array}$$

$$K_{\text{diss}} = 4 \times 10^{-19} \text{ M}^2$$

Since K_{diss} is such a small number $\Rightarrow 0.05 - x \approx 0.05$

$$4 \times 10^{-19} = \frac{x \cdot (2x)^2}{0.05} \Rightarrow x = 1.7 \times 10^{-7}$$

$$[\text{Ag}^+][\text{Cl}^-] = 0.02 \times 1.7 \times 10^{-7} = 3.4 \times 10^{-9}$$

Since $[\text{Ag}^+][\text{Cl}^-]$ is greater than $K_{\text{SP}}(\text{AgCl})$

$\therefore \text{AgCl}$ will be precipitate out!