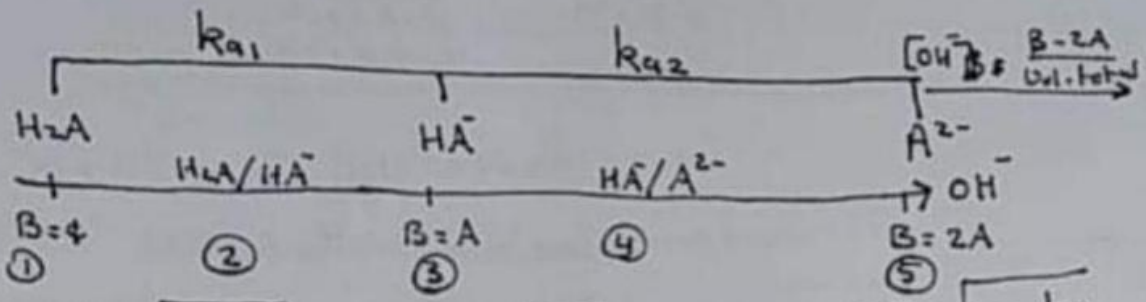
CHEM 233 — Solution to Sample Exam

Q1-12



① $[H^+] = \sqrt{C_{H_2A} \cdot K_{a1}}$ ③ $[H^+] = \sqrt{K_{a1} K_{a2}}$ $[OH^-] = \sqrt{C_{A^{2-}} \cdot \frac{K_w}{K_{a2}}}$

② $pH = pK_{a1} + \log \frac{HA^-}{H_2A}$ ④ $pH = pK_{a2} + \log \frac{A^{2-}}{HA^-}$

$A > B > 0$ $2A > B > A$, $C_{A^{2-}} = \frac{A}{\text{Vol. total}}$

Where A = mmols H_2A B = mmols OH^- added

$HA^- = B$, $H_2A = A - B$ $HA^- = 2A - B$, $A^{2-} = B - A$

$K_{a1} = 5.0 \times 10^{-4}$, $K_{a2} = 1.0 \times 10^{-8}$, $K_w = 1.0 \times 10^{-14}$

Q1: $[H_2A] = 0.05$ M, $[HA^-] = 0.15$, $pK_{a1} = 3.30$, $pK_{a2} = 8.00$

$\therefore H_2A/HA^- \Rightarrow pH = pK_{a1} + \log \frac{HA^-}{H_2A} = 3.30 + \log \frac{0.15}{0.05} = \boxed{3.78}$

Q2: $[A^{2-}] = 0.10$, $[HA^-] = 0.20$,

$\therefore HA^-/A^{2-} \Rightarrow pH = pK_{a2} + \log \frac{A^{2-}}{HA^-} = 8.00 + \log \frac{0.1}{0.2} = \boxed{7.70}$

Q3: $A^{2-} = 0.15$ M, $H_2A = 0.15$ M

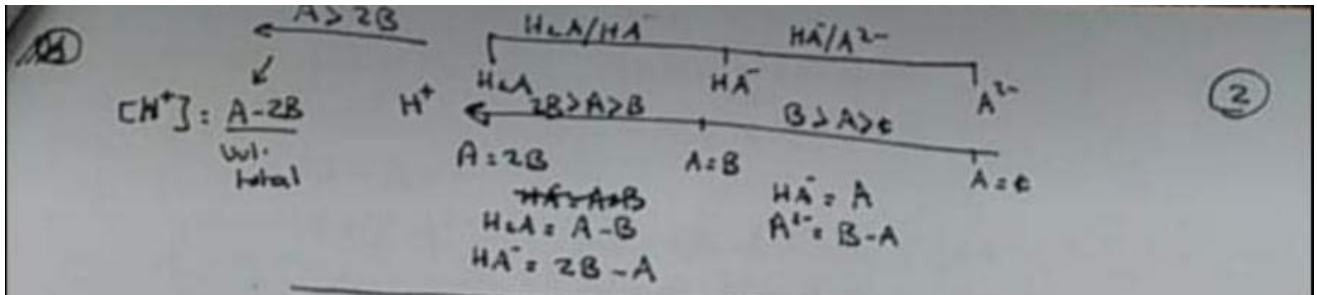
A^{2-} and H_2A are not conjugates

H_2A	+ A^{2-}	⟶ 2 HA^-
0.15	0.15	-
−0.15	−0.15	2(0.15)
0	0	0.30

result: HA^- only

$[H^+] = \sqrt{K_{a1} \cdot K_{a2}} = \sqrt{(5.0 \times 10^{-4})(1.0 \times 10^{-8})}$

$pH = \boxed{5.65}$



(2)

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(4) $A^{2-} = 40 * 0.1 = 4.0$ $[OH^-] = 50 * 0.1 = 5.0$

A^{2-}/OH^- mixture of weak base and strong base

ignore weak base $[OH^-] = \frac{50 * 0.1}{50+40} \Rightarrow pH = \boxed{12.74}$

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(5) 50 mL 0.1M A^{2-} + 40.0 mL 0.1M HCl

B = 5.0 A = 4.0

B > A > 0, ~~HA^-/H_2A~~ HA^-/A^{2-}

$HA^- = 4.0$, $A^{2-} = 5.0 - 4.0 = 1.0$

$pH = pka_2 + \log \frac{A^{2-}}{HA^-} = 8.00 + \log \frac{1.00}{4.00} = \boxed{7.40}$

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(6) For titration of A^{2-} with H^+

$pH = pka_2$, mmols $H^+ = \frac{B}{2}$

$pH = pka_1$ = mmols $H^+ = \frac{3B}{2}$

$B = 50 * 0.1 = 5.0$, mmols $H^+ = \underset{(U)}{Vol.} * \underset{(0.08)}{M} = \frac{5.0}{2}$

$V = \boxed{31.3 \text{ mL}}$

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(7) 50 mL 0.1 M H_2A + 50 mL 0.1 M HCl

H_2A/H^+ mixture of weak acid and strong acid

ignore weak acid $[H^+] = \frac{50 * 0.10}{100} \Rightarrow pH = \boxed{1.30}$

⑧ 50 mL 0.10 M $H_2C_2O_4$, 70 mL 0.1 M NaOH

$A = 5.0$ $B = 7.0$

$2A > B > A$

HA^-/A^{2-}, $HA^- = 2B - A = 3.0$

$A^{2-} = B - A = 2.0$

$pH = pk_{a2} + \log \frac{A^{2-}}{HA^-} = 8.00 + \log \frac{2.0}{3.0} = \boxed{7.82}$

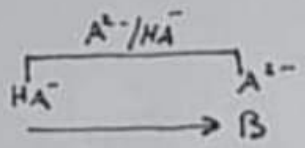
⑨ $B) = \frac{A}{2.0} = \frac{50\,mL\ 0.10\,M\ H_2A}{A = 5.0}$

$B = \frac{3A}{2.0} = \frac{15}{2} = 7.5 = \underset{NaOH}{Vol.} * \underset{0.12}{M}$

$Vol = \frac{7.5}{0.12} = \boxed{62.5\,mL}$

⑩ $HA^- + OH^- \rightarrow A^{2-}$

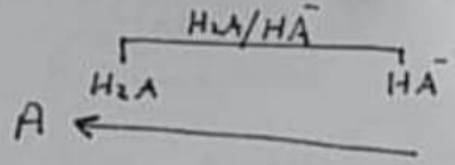
$\underset{5.0}{\underset{50*0.1}{HA^-}} + \underset{5.0}{\underset{50*0.1}{OH^-}} \rightarrow A^{2-}$ A^{2-} only



$[A^{2-}] = \frac{5.0}{50+50} = 0.05$

$[OH^-] = \sqrt{\frac{k_w}{k_{a2}} \cdot C_{A^{2-}}} = \sqrt{\frac{1.0\times10^{-14}}{1.0\times10^{-8}} * 0.05} \Rightarrow pH = \boxed{10.35}$

⑪



$\underset{⑧}{HA^-} = 50 * 0.1 = 5.0$, $A = 25 * 0.1 = 2.5$

⑧ $HA^- \rightarrow H_2A$

$\underset{-2.5}{\underset{5.0}{HA^-}} \rightarrow \underset{+2.5}{H_2A}$

$\underset{2.5}{\underset{2.5}{HA^-}} \rightarrow \underset{2.5}{\underset{2.5}{H_2A}}$

$pH = pk_{a1} + \log \frac{HA^-}{H_2A} = 3.30$

⑫ 50 mL 0.1M HA^-, 50 mL 0.10 M A^{2-}

HA^-/A^{2-}

$pH = pka_2 + \log \frac{A^{2-}}{HA^-} = 8.00 + \log \frac{5.0}{5.0} = \boxed{8.00}$

⑬ $ka_1 = 1.0\times10^{-3}$ $ka_2 = 1.0\times10^{-5}$

$pH = 5.0 \Rightarrow [H^+] = 1.0\times10^{-5}$

$\alpha_{A^{2-}} = \frac{ka_1 ka_2}{[H^+]^2 + ka_1[H^+] + ka_1 ka_2} = \boxed{0.50}$

⑭ $pH = 2.5 \Rightarrow [H^+] = 3.16\times10^{-3}$

$\alpha_{HA^-} = \frac{(3.16\times10^{-3})(1\times10^{-3})}{(3.16\times10^{-3})^2 + (1\times10^{-3})(3.16\times10^{-3}) + (1\times10^{-3})(1\times10^{-5}}$

$= \boxed{0.24}$

⑮ $ka = 1.8\times10^{-5} \Rightarrow pka = 4.744$

$pH = pka + \log \frac{CH_3COO^-}{CH_3COOH} = 4.744 + \log \frac{(20/82)}{(0.04*3.}$ $= \boxed{5.05}$

⑯ $k_b = 1.8\times10^{-5}$, $ka = \frac{1.0\times10^{-14}}{1.8\times10^{-5}} \Rightarrow pka = 9.255$

$pH = pka + \log \frac{NH_3}{NH_4^+} = 9.255 + \log \frac{(0.04\times2)}{(13/53.5)} = \boxed{8.95}$

⑰ $ka = 6.8\times10^{-4} \Rightarrow pka = 3.167$

$HF \rightleftharpoons F^-$

$\underbrace{0.1*1}_{0.10}$ $\quad$ $\underbrace{0.1\times0.75}_{0.075}$

$+ H^+$ $\quad$ $- H^+$

0.11 $\quad$ 0.065

$H^+ = 0.01 * 1 = 0.01$

$pH = 3.167 + \log \frac{0.065}{0.11}$

$= \boxed{2.94}$

(18) $HNO_2 + OH^- \rightarrow NO_2^-$ $\quad k_a = 4.5\times10^{-4}$ (5)

$C_{NO_2^-} = \frac{50\times0.05}{100} = 0.025$, $[OH^-] = \sqrt{\frac{k_w}{k_a}\cdot C_{NO_2^-}} = 7.45\times10^{-7}$

~~pH = 6.12~~ $pH = 7.87$

⇒ closest **pka = 8.0** (A)

(19)

$$H_2O \rightleftharpoons H^+ + OH^-$$
$$1.0\times10^{-7}$$
$$-x \quad +x \quad +x$$
$$x \quad (1.0\times10^{-7}+x)$$

$k_w = (x)(1.0\times10^{-7}+x) \Rightarrow x^2 + 1.0\times10^{-7}x - 1.0\times10^{-14} = 0$

$[H^+] = x = \frac{-b \pm \sqrt{b^2-4ac}}{2a} = 6.18\times10^{-8}$, $\Rightarrow pH = $ **7.20**

(20) $\frac{mg\ N}{mL} = \frac{(10\times0.01 - 10\times0.006)\times14.0}{0.75} =$ **0.746**

(21) 55 mg NaCl + 55 mg $CaCl_2$

$55\left(\frac{35.5}{58.5}\right)$ $\quad 55\left(\frac{2\times35.5}{111}\right)$

$\frac{mg\ Cl}{L}$: $\frac{(33.7 + 35.18)}{0.25} =$ **275 ppm**

(22) Molarity $= \frac{(5.5\times\frac{65}{100}\times\frac{1}{63})}{0.50} = 0.113$ mol/L

(23) from Calculator. $\bar{X} = 75.48$, $S = 2.249$

$CV = \frac{2.249}{75.48}\times100 =$ **3.00 %**