Weak Acid And Weak Base Problems

1) **Calculate the hydronium ion concentration in a 0.15 M HCN solution. ($K_a = 4.0 \times 10^{-10}$)**

2) **What is the pH of a 0.176 M solution of sodium fluoride? ($K_b = 1.4 \times 10^{-11}$)**

3) **What is the pH of a 0.136 M solution of H_2S? ($K_a = 1.00 \times 10^{-7}$)**

4) **What is the pH of a solution if 17.3 g of NaCN is added to 750. mL of water? ($K_b = 2.5 \times 10^{-5}$)**

5) **What is the concentration of carbonate in a 0.16 M solution of carbonic acid? ($K_{a1} = 4.2 \times 10^{-7}$, $K_{a2} = 4.8 \times 10^{-11}$)**

Solutions

1) **[HCN] = 0.15 M** **$K_a = 4.0 \times 10^{-10}$**

$[H_3O^+] = [H^+] = ?$

	$HCN(aq)$	$\leftrightarrow$	$H^+(aq)$	+	$CN^-(aq)$
$[\ ]_i$	0.15		0		0
$[\ ]_c$	-x		+x		+x
$[\ ]_e$	0.15 - x		x		x

$K_a = [H^+] \times [CN^-]/[HCN]$

$4.0 \times 10^{-10} = x \cdot x/(0.15 - x) \approx x^2/0.15$

$[H^+] = 7.7 \times 10^{-6}$ M

% ion = $[H^+]/[HCN] \times 100\%$

% ion = $(7.7 \times 10^{-6}$ ~~M~~$)/(0.15$ ~~M~~$) \times 100\% = 5.1 \times 10^{-5}\%$

Because the % ion < 5%, 0.15 - x ≈ 0.15 is a valid assumption.

$[H^+] = 7.7 \times 10^{-6}$ M

2) [NaF] = 0.176 M $K_b = 1.4 \times 10^{-11}$

pH = ?

$NaF(s) \rightarrow Na^+(aq) + F^-(aq)$

$[F^-] = 0.176$ ~~mol NaF~~/L x 1 mol F^-/1 ~~mol NaF~~ = 0.176 M

	$F^-(aq)$ + $H_2O(l)$	↔	HF(aq)	+ $OH^-(aq)$
$[\ ]_i$	0.176		0	0
$[\ ]_c$	-x		+x	+x
$[\ ]_e$	0.176 - x		x	x

$K_b = [HF] \times [OH^-]/[F^-]$

$1.4 \times 10^{-11} = x \cdot x/(0.176 - x) \approx x^2/0.176$

$[OH^-] = 1.6 \times 10^{-6}$ M

% ion = $[HF]/[F^-] \times 100\%$

% ion = $(1.6 \times 10^{-6}$ ~~M~~$)/(0.176$ ~~M~~$) \times 100\% = 9.1 \times 10^{-4}\%$

Because the % ion < 5%, $0.176 - x \approx 0.176$ is a valid assumption.

$K_w = [H^+] \times [OH^-] = 1.00 \times 10^{-14}$

$[H^+] = K_w/[OH^-] = (1.00 \times 10^{-14})/(1.6 \times 10^{-6}) = 6.2 \times 10^{-9}$ M

$pH = -\log[H^+] = -\log(6.2 \times 10^{-9}) =$ 8.21

3) **$[H_2S] = 0.136$ M** **$K_a = 1.00 \times 10^{-7}$**

pH = ?

	$H_2S(aq)$	$\leftrightarrow$	$H^+(aq)$	+	$HS^-(aq)$
$[\ ]_i$	0.136		0		0
$[\ ]_c$	-x		+x		+x
$[\ ]_e$	0.136 - x		x		x

$K_a = [H^+] \times [HS^-]/[H_2S]$

$1.00 \times 10^{-7} = x \cdot x/(0.136 - x) \approx x^2/0.136$

$[H^+] = 1.17 \times 10^{-4}$ M

% ion = $[H^+]/[H_2S] \times 100\%$

% ion = $(1.17 \times 10^{-4}\ \cancel{M})/(0.136\ \cancel{M}) \times 100\% = 8.60 \times 10^{-2}\%$

Because the % ion < 5%, 0.136 - x ≈ 0.136 is a valid assumption.

$pH = -\log[H^+] = -\log(1.17 \times 10^{-4}) =$ 3.932

4) **m = 17.3 g NaCN** **K_b = 2.5 x 10^{-5}**

V = 750. mL **pH = ?**

NaCN(s) → Na^+(aq) + CN^-(aq)

[NaCN] = n/V

[NaCN] = (17.3 ~~g NaCN~~/L x 1 mol NaCN/49.01 ~~g NaCN~~)/(750. ~~mL~~ x 1L/10^3 ~~mL~~)

[NaCN] = 0.471 M

[CN^-] = 0.471 ~~mol NaCN~~/L x 1 mol CN^-/1 ~~mol NaCN~~ = 0.471 M

	CN^-(aq) + H_2O(l) ↔	HCN (aq) +	OH^-(aq)
$[\ ]_i$	0.471	0	0
$[\ ]_c$	-x	+x	+x
$[\ ]_e$	0.471 - x	x	x

K_b = [HCN] x [OH^-]/[CN^-]

2.5 x 10^{-5} = x · x/(0.471 - x) ≈ x^2/0.471

[OH^-] = 3.4 x 10^{-3} M

% ion = [HCN]/[CN^-] x 100%

% ion = (3.4 x 10^{-3} ~~M~~)/(0.471 ~~M~~) x 100% = 7.2 x 10^{-1}%

Because the % ion < 5%, 0.471 - x ≈ 0.471 is a valid assumption.

pOH = -log[OH^-] = -log(3.4 x 10^{-3}) = 2.47

pH + pOH = 14.00

pH = 14.00 - pOH = 14.00 - 2.47 = 11.53

5) $[H_2CO_3] = 0.16$ M $\quad K_{a1} = 4.2 \times 10^{-7}$

$[CO_3^{2-}] = ?$ $\quad K_{a2} = 4.8 \times 10^{-11}$

	$H_2CO_3(aq)$ $\leftrightarrow$	$H^+(aq)$ +	$HCO_3^-(aq)$
$[\ ]_i$	0.16	0	0
$[\ ]_c$	-x	+x	+x
$[\ ]_e$	0.16 - x	x	x

$K_{a1} = [H^+] \times [HCO_3^-]/[H_2CO_3]$

$4.2 \times 10^{-7} = x \cdot x/(0.16 - x) \approx x^2/0.16$

$[H^+] = 2.6 \times 10^{-4}$ M

% ion = $[H^+]/[H_2CO_3] \times 100\%$

% ion = $(2.6 \times 10^{-4}$ ~~M~~$)/(0.16$ ~~M~~$) \times 100\% = 1.6 \times 10^{-1}\%$

Because the % ion < 5%, 0.16 - x ≈ 0.16 is a valid assumption.

	$HCO_3^-(aq)$ $\leftrightarrow$	$H^+(aq)$ +	$CO_3^{2-}(aq)$
$[\ ]_i$	2.6×10^{-4}	2.6×10^{-4}	0
$[\ ]_c$	-x	+x	+x
$[\ ]_e$	2.6×10^{-4} - x	2.6×10^{-4} + x	x

$K_{a2} = [H^+] \times [CO_3^{2-}]/[HCO_3^-]$

$4.8 \times 10^{-11} = (2.6 \times 10^{-4} + x) \cdot x/(2.6 \times 10^{-4} - x) \approx x$

$[CO_3^{2-}] = 4.8 \times 10^{-11}$ M