Buffer Problems

1) **A buffer is prepared by adding 0.60 moles of $HC_2H_3O_2$ and 2.0 moles of $NaC_2H_3O_2$ to enough water to make 1.0 dm^3 of solution. What is the pH? ($K_a = 1.8 \times 10^{-5}$)**

2) **What is the pH of a solution prepared by dissolving 15.0 g of $NaHCO_3$ and 15.0 g of Na_2CO_3 in enough water to make a 0.250 dm^3 solution? ($K_a = 5.6 \times 10^{-11}$)**

3) **4.13 g of $NaC_9H_7O_4$ is added to 250. mL of a 0.150 M $HC_9H_7O_4$ solution. What is the pH of the buffer? $K_a = 2.75 \times 10^{-5}$**

4) **A buffer is made by adding 0.200 M $HC_2H_3O_2$ and 0.150 M $NaC_2H_3O_2$. If 0.005 mol of NaOH is added to 125 mL of this buffer, what is the pH? $K_a = 1.8 \times 10^{-5}$.**

5) **A buffer is made by adding 0.200 moles of NH_4Br and 0.075 moles of NH_3 to a sufficient amount of water. If 0.015 moles of HCl are added to the buffer solution, what is the pH? $K_a = 5.6 \times 10^{-10}$.**

Solutions

1) $n_a = 0.60$ mol $HC_2H_3O_2$ $V = 1.0\ dm^3$

$n_b = 2.0$ mol $NaC_2H_3O_2$ $K_a = 1.8 \times 10^{-5}$

$[HC_2H_3O_2] = n/V$

$[HC_2H_3O_2] = 0.60\ mol\ HC_2H_3O_2/(1.0\ \cancel{dm^3} \times 1\ L/1\ \cancel{dm^3}) = 0.60\ M$

$[C_2H_3O_2^-] = n/V$

$[C_2H_3O_2^-] = 2.0\ \cancel{mol\ NaC_2H_3O_2}/(1.0\ \cancel{dm^3} \times 1\ L/1\ \cancel{dm^3}) \times$

$1\ mol\ C_2H_3O_2^-/1\ \cancel{mol\ NaC_2H_3O_2} = 2.0\ M$

	$HC_2H_3O_2(aq)$	$\leftrightarrow$	$H^+(aq)$	$+\ C_2H_3O_2^-(aq)$
$[\ ]_i$	0.60		0	2.0
$[\ ]_c$	-x		+x	+x
$[\ ]_e$	0.60 - x		x	x

$K_a = [H^+] \times [C_2H_3O_2^-]/[HC_2H_3O_2]$

$[H^+] = K_a \times [HC_2H_3O_2]/[C_2H_3O_2^-]$

$[H^+] = 1.8 \times 10^{-5} \cdot (0.60 - x)/(2.0 + x) \approx 1.8 \times 10^{-5} \times 0.60/2.0$

$[H^+] = 5.4 \times 10^{-6}\ M$

% ion = $[H^+]/[HC_2H_3O_2] \times 100\%$

% ion = $(5.4 \times 10^{-6}\ \cancel{M})/(0.60\ \cancel{M}) \times 100\% = 9.0 \times 10^{-4}\%$

Because the % ion < 5%, 0.60 - x ≈ 0.60 is a valid assumption.

$pH = -\log[H^+] = -\log(5.4 \times 10^{-6}) =$ 5.27

2) $m_a = 15.0$ g $NaHCO_3$ $\qquad$ $V = 0.250\ dm^3$

$m_s = 15.0$ g Na_2CO_3 $\qquad$ $K_a = 5.6 \times 10^{-11}$

$[NaHCO_3] = n/V$

$[NaHCO_3] = (15.0\ \cancel{g\ NaHCO_3} \times 1\ mol\ NaHCO_3/84.01\ \cancel{g\ NaHCO_3})/$

$(0.250\ \cancel{dm^3} \times 1\ L/1\ \cancel{dm^3}) = 0.714\ M$

$[HCO_3^-] = 0.714\ \cancel{mol\ NaHCO_3}/L \times 1\ mol\ HCO_3^-/1\ \cancel{mol\ NaHCO_3} = 0.714\ M$

$[Na_2CO_3] = n/V$

$[Na_2CO_3] = (15.0\ \cancel{g\ Na_2CO_3} \times 1\ mol\ Na_2CO_3/105.99\ \cancel{g\ Na_2CO_3})/$

$(0.250\ \cancel{dm^3} \times 1\ L/1\ \cancel{dm^3}) = 0.566\ M$

$[CO_3^{2-}] = 0.566\ \cancel{mol\ Na_2CO_3}/L \times 1\ mol\ CO_3^{2-}/1\ \cancel{mol\ Na_2CO_3} = 0.566\ M$

	$HCO_3^-(aq)$	$\leftrightarrow$	$H^+(aq)$	+ $CO_3^{2-}(aq)$
$[\ ]_i$	0.714		0	0.556
$[\ ]_c$	-x		+x	+x
$[\ ]_e$	0.714 - x		x	0.566 + x

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

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

$[H^+] = 5.6 \times 10^{-11} \cdot (0.714 - x)/(0.566 + x) \approx 5.6 \times 10^{-11} \times 0.714/0.566$

$[H^+] = 7.1 \times 10^{-11}$ M

% ion = $[H^+]/[HCO_3^-] \times 100\%$

% ion = $(7.1 \times 10^{-11}\ \cancel{M})/(0.714\ \cancel{M}) \times 100\% = 9.9 \times 10^{-7}\%$

Because the % ion < 5%, 0.714 - x ≈ 0.714 is a valid assumption.

$pH = -\log[H^+] = -\log(7.1 \times 10^{-11}) =$ 10.15

3) $[HC_9H_7O_4] = 0.150$ M $m_s = 4.13$ g $NaC_9H_7O_4$

$V_a = 250.$ mL $K_a = 2.75 \times 10^{-5}$

$n_s = 4.13 \text{ } \cancel{g\ NaC_9H_7O_4} \times 1 \text{ mol } NaC_9H_7O_4 / 202.15 \text{ } \cancel{g\ NaC_9H_7O_4}$

$n_s = 0.0204 \text{ mol } NaC_9H_7O_4$

$[C_9H_7O_4^-] = n/V$

$[C_9H_7O_4^-] = 0.0204 \text{ } \cancel{mol\ NaC_9H_7O_4} / (250. \text{ } \cancel{mL} \times 1 L/10^3 \text{ } \cancel{mL}) \times$

$1 \text{ mol } C_9H_7O_4^- / 1 \text{ } \cancel{mol\ NaC_9H_7O_4} = 0.0816$ M

$$HC_9H_7O_4(aq) \leftrightarrow H^+(aq) + C_9H_7O_4^-(aq)$$

	$HC_9H_7O_4$	H^+	$C_9H_7O_4^-$
$[\ ]_i$	0.150	0	0.0816
$[\ ]_c$	-x	+x	+x
$[\ ]_e$	0.150 - x	x	0.0816 + x

$K_a = [H^+] \times [C_9H_7O_4^-]/[HC_9H_7O_4]$

$[H^+] = K_a \times [HC_9H_7O_4]/[C_9H_7O_4^-]$

$[H^+] = 2.75 \times 10^{-5} \cdot (0.150 - x)/(0.0816 + x) \approx 2.75 \times 10^{-5} \times 0.150/0.0816$

$[H^+] = 5.06 \times 10^{-5}$ M

% ion = $[H^+]/[HC_9H_7O_4] \times 100\%$

% ion = $(5.06 \times 10^{-5} \text{ } \cancel{M})/(0.150 \text{ } \cancel{M}) \times 100\% = 3.37 \times 10^{-2}\%$

Because the % ion < 5%, $0.150 - x \approx 0.150$ is a valid assumption.

pH = $-\log[H^+] = -\log(5.06 \times 10^{-5}) =$ 4.296

4) $[HC_2H_3O_2]$ = 0.200 M n_b = 0.005 mol NaOH

$[NaC_2H_3O_2]$ = 0.150 M $K_a = 1.8 \times 10^{-5}$

V = 125 mL

$[HC_2H_3O_2]$ = n/V

n_a = $[HC_2H_3O_2]$ x V = 0.200 mol $HC_2H_3O_2$/~~L~~ x 125 ~~mL~~ x 1 ~~L~~/10^3 ~~mL~~

n_a = 0.025 mol $HC_2H_3O_2$

$[C_2H_3O_2^-]$ = 0.150 ~~mol $NaC_2H_3O_2$~~/L x 1 mol $C_2H_3O_2^-$/1 ~~mol $NaC_2H_3O_2$~~

$[C_2H_3O_2^-]$ = 0.150 M

$[C_2H_3O_2^-]$ = n/V

n_b = $[C_2H_3O_2^-]$ x V = 0.150 mol $C_2H_3O_2^-$/~~L~~ x 125 ~~mL~~ x 1 ~~L~~/10^3 ~~mL~~

n_b = 0.0188 mol $C_2H_3O_2^-$

n_b = 0.005 ~~mol NaOH~~ x 1mol OH^-/1 ~~mol NaOH~~ = 0.005 mol OH^-

	$HC_2H_3O_2(aq)$ +	$OH^-(aq)$ →	$C_2H_3O_2^-(aq)$ + $H_2O(l)$
mol before rxn:	0.025	0.005	0.0188
mol after rxn:	0.020	0	0.0238

	$HC_2H_3O_2(aq)$ ↔	$H^+(aq)$ +	$C_2H_3O_2^-(aq)$
$[\ ]_i$	0.020/~~125~~	0	0.0238/~~125~~
$[\ ]_c$	-x	+x	+x
$[\ ]_e$	(0.020 – x)/~~125~~	x	(0.0238 + x)/~~125~~

$K_a = [H^+] \times [C_2H_3O_2^-]/[HC_2H_3O_2]$

$[H^+] = K_a \times [HC_2H_3O_2]/[C_2H_3O_2^-]$

$[H^+] = 1.8 \times 10^{-5} \cdot (0.020 - x)/(0.0238 + x) \approx 1.8 \times 10^{-5} \times 0.020/0.0238$

$[H^+] = 1.5 \times 10^{-5}$ M

% ion = $[H^+]/[HC_2H_3O_2] \times 100\%$

% ion = $(1.5 \times 10^{-5}\ \cancel{M})/(\ 0.020\ \cancel{mol}/125\ \cancel{mL} \times 1\ \cancel{L}/10^3\ \cancel{mL}) \times 100\%$

% ion = $9.4 \times 10^{-3}\%$

Because the % ion < 5%, 0.020 - x ≈ 0.020 is a valid assumption.

pH = $-\log[H^+] = -\log(1.5 \times 10^{-5})$ = 4.82

5) **n_a = 0.200 mol NH_4Br** **n_a = 0.015 mol HCl**

n_b = 0.075 mol NH_3 **$K_a = 5.6 \times 10^{-10}$**

n_a = 0.200 ~~mol NH_4Br~~ x 1 mol NH_4^+/1 ~~mol NH_4Br~~ = 0.200 mol NH_4^+

n_a = 0.015 ~~mol HCl~~ x 1 mol H^+/1 ~~mol HCl~~ = 0.015 mol H^+

	$NH_3(aq)$ +	$H^+(aq)$ →	$NH_4^+(aq)$
mol before rxn:	0.075	0.015	0.200
mol after rxn:	0.060	0	0.215

Assume 1.00 L, therefore: $[NH_3]$ = 0.060 M, $[NH_4^+]$ = 0.215 M

	NH_4^+ (aq) ↔	$H^+(aq)$ +	$NH_3(aq)$
$[\ ]_i$	0.215	0	0.060
$[\ ]_c$	-x	+x	+x
$[\ ]_e$	0. 215 – x	x	0.060 + x

$K_a = [H^+] \times [NH_3]/[NH_4^+]$

$[H^+] = K_a \times [NH_4^+]/[NH_3]$

$[H^+] = 5.6 \times 10^{-10} \cdot (0.215 - x)/(0.060 + x) \approx 5.6 \times 10^{-10} \times 0.215/0.060$

$[H^+] = 2.0 \times 10^{-9}$ M

% ion = $[H^+]/[NH_4^+] \times 100\%$

% ion = (2.0 x 10^{-9} ~~M~~)/0.215 ~~M~~ x 100% = 9.3 x 10^{-7}%

Because the % ion < 5%, 0.215 - x ≈ 0.215 is a valid assumption.

pH = $-\log[H^+] = -\log(2.0 \times 10^{-9})$ = 8.70