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3. Acids and bases answers

3.5. Buffer solutions

1. (a) (i) $HCOOH(aq) \rightleftharpoons HCOO^{-}(aq) + H^{+}(aq)$ *(1 mark)*

(ii) $pK_a = -\log K_a$, $\therefore$ $\underline{K_a = 10^{-3.75} = 1.78 \times 10^{-4}\ \text{mol dm}^{-3}}$ *(1 mark)*

$$K_a = \frac{[HCOO^{-}(aq)][H^{+}(aq)]}{[HCOOH(aq)]}$$

$[HCOO^{-}(aq)] = 0.450\ \text{mol} / 0.5\ \text{dm}^3 = 0.90\ \text{mol dm}^{-3}$

$[HCOOH(aq)] = 0.510\ \text{mol} / 0.5\ \text{dm}^3 = 1.02\ \text{mol dm}^{-3}$

Substituting these values in we get, $1.78 \times 10^{-4}\ \text{mol dm}^{-3} = 0.90 \times [H^{+}(aq)] / 1.02$

$\therefore$ $[H^{+}(aq)] = \underline{2.02 \times 10^{-4}\ \text{mol dm}^{-3}}$ *(1 mark)*

$\therefore$ $\underline{pH = 3.70}$ *(1 mark)*

(b) (i) On the addition of H^{+} ions, according to Le Châtelier's principle, the equilibrium shifts to the left to remove the extra H^{+} ions added and maintain the pH approximately constant. *(1 mark)*

(ii) On the addition of OH^{-} ions, the OH^{-} ions react with the HCOOH to produce water molecules and more $HCOO^{-}$;

$$HCOOH + OH^{-} \rightarrow HCOO^{-} + H_2O$$

This removes the OH^{-} and so the pH remains approximately constant. *(1 mark)*

2. (a) $H_2CO_3(aq) \rightleftharpoons HCO_3^{-}(aq) + H^{+}(aq)$

pH of desired buffer = 7.40, so $[H^{+}(aq)] = 10^{-7.40} = 3.98 \times 10^{-8}\ \text{mol dm}^{-3}$ *(1 mark)*

$$K_a = \frac{[HCO_3^{-}(aq)][H^{+}(aq)]}{[H_2CO_3(aq)]}$$

$$\therefore \frac{[HCO_3^{-}(aq)]}{[H_2CO_3(aq)]} = \frac{K_a}{[H^{+}(aq)]} = \frac{4.5 \times 10^{-7}\ \text{mol dm}^{-3}}{3.98 \times 10^{-8}\ \text{mol dm}^{-3}} = \frac{11.3}{1}$$ *(1 mark)*

Since both stock solutions are of an equal concentration they should mix the two in a ratio of

$\underline{11.3 : 1\ HCO_3^{-} : H_2CO_3}$

(b) Many reactions in the human body rely on <u>enzymes</u>. Enzymes work only under very precise conditions. If the pH moves outside of a narrow range, the <u>enzymes slow or stop working and can be denatured</u>. Hence maintaining a constant pH is essential. *(2 marks)*

3.6. More complex buffer calculations

1. $CH_3CH_2COOH + NaOH \rightarrow CH_3CH_2COO^{-}Na^{+} + H_2O$

Moles of NaOH = $0.015\ \text{dm}^3 \times 0.100\ \text{mol dm}^{-3} = 1.5 \times 10^{-3}\ \text{mol}$ *(1 mark)*

$\therefore$ moles of CH_3CH_2COOH will decrease by 1.5×10^{-3} mol and moles of $CH_3CH_2COO^{-}Na^{+}$ will increase by 1.5×10^{-3} mol. *(1 mark)*

STARTER FOR 10...

3. Acids and bases answers

	CH_3CH_2COOH	$\rightleftharpoons$	$CH_3CH_2COO^-$	$+\ H^+$
Initial moles	$0.035\ dm^3 \times 0.150\ mol\ dm^{-3}$ $= 5.25 \times 10^{-3}\ mol$		0 mol	0 mol
Change in moles	$-1.5 \times 10^{-3}\ mol$		$+1.5 \times 10^{-3}\ mol$	?
Equilibrium moles	$3.75 \times 10^{-3}\ mol$		$1.5 \times 10^{-3}\ mol$	?

$K_a = \dfrac{[CH_3CH_2COO^-][H^+]}{[CH_3CH_2COOH]} = \dfrac{(1.5 \times 10^{-3}\ mol / 0.05\ dm^3) \times [H^+]}{(3.75 \times 10^{-3}\ mol / 0.05\ dm^3)} = 1.35 \times 10^{-5}\ mol\ dm^{-3}$ *(1 mark)*

$\therefore$ $[H^+] = 3.38 \times 10^{-5}\ mol\ dm^{-3}$

$\therefore$ <u>pH = 4.47</u> *(1 mark)*

2. In a 10 cm^3 aliquot (= 1/5 th) of the buffer solution made above;

moles of $CH_3CH_2COOH = 7.5 \times 10^{-4}$ mol; moles of $CH_3CH_2COO^- = 3.0 \times 10^{-4}$ mol *(1 mark)*

(a) No. of moles of acid added = $0.0005\ dm^3 \times 0.05\ mol\ dm^{-3} = 2.5 \times 10^{-5}\ mol$

$CH_3CH_2COO^- + H^+ \rightarrow CH_3CH_2COOH$

$\therefore$ moles of CH_3CH_2COOH will increase by 2.5×10^{-5} mol and moles of $CH_3CH_2COO^-$ will decrease by 2.5×10^{-5} mol. *(1 mark)*

	CH_3CH_2COOH	$\rightleftharpoons$	$CH_3CH_2COO^-$	$+\ H^+$
Initial moles	$7.5 \times 10^{-4}\ mol$		$3.0 \times 10^{-4}\ mol$	
Change in moles	$+2.5 \times 10^{-5}\ mol$		$-2.5 \times 10^{-5}\ mol$	?
Equilibrium moles	$7.75 \times 10^{-4}\ mol$		$2.75 \times 10^{-4}\ mol$	?

$\therefore$ $1.35 \times 10^{-5}\ mol\ dm^{-3} = \dfrac{(2.75 \times 10^{-4}\ mol / 0.0105\ dm^3) \times [H^+]}{(7.75 \times 10^{-4}\ mol / 0.0105\ dm^3)}$

$\therefore$ $[H^+] = 3.80 \times 10^{-5}\ mol\ dm^{-3}$

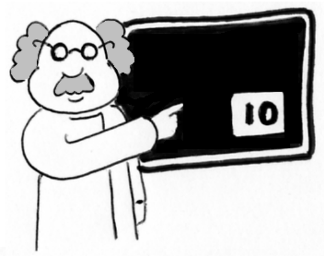
$\therefore$ <u>pH = 4.42</u> *(1 mark)*

(b) No. of moles of $Ca(OH)_2$ added = $0.0005\ dm^3 \times 0.05\ mol\ dm^{-3} = 2.5 \times 10^{-5}\ mol$

$\therefore$ no. of moles of OH^- added = $2 \times 2.5 \times 10^{-5}\ mol = 5.0 \times 10^{-5}\ mol$ (1 mark)

$CH_3CH_2COOH + OH^- \rightarrow CH_3CH_2COO^- + H_2O$

$\therefore$ moles of CH_3CH_2COOH will decrease by 5.0×10^{-5} mol and moles of $CH_3CH_2COO^-$ will increase by 5.0×10^{-5} mol. *(1 mark)*



STARTER FOR 10...

3. Acids and bases answers

	CH_3CH_2COOH	$\rightleftharpoons$	$CH_3CH_2COO^-$	+ H^+
Initial moles	7.5×10^{-4} mol		3.0×10^{-4} mol	
Change in moles	-5.0×10^{-5} mol		$+5.0 \times 10^{-5}$ mol	?
Equilibrium moles	7.0×10^{-4} mol		3.5×10^{-4} mol	?

$$\therefore\ 1.35 \times 10^{-5}\ \text{mol dm}^{-3} = \frac{(3.5 \times 10^{-4}\ \text{mol} / 0.0105\ \text{dm}^3) \times [H^+]}{(7.0 \times 10^{-4}\ \text{mol} / 0.0105\ \text{dm}^3)}$$

$\therefore$ $[H^+] = 2.7 \times 10^{-5}$ mol dm^{-3}

$\therefore$ <u>pH = 4.57</u> *(1 mark)*