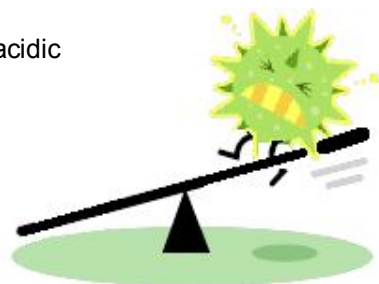




STARTER FOR 10!!!

3.6. More complex buffer calculations

Scientists wish to investigate whether certain bacteria can adapt to live in acidic conditions.



1. The scientists make up a buffer solution, by mixing 15.0 cm^3 of a $0.100 \text{ mol dm}^{-3}$ aqueous solution of NaOH with 35.0 cm^3 of a $0.150 \text{ mol dm}^{-3}$ solution of propanoic acid. Calculate the pH of the buffer solution formed.

(K_a for propanoic acid has the value $1.35 \times 10^{-5} \text{ mol dm}^{-3}$)

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..... (4 marks)

2. The scientists wish to test if the solution formed is indeed a buffer solution and will resist change in pH on the addition of small quantities of acid or base possibly formed by the bacteria. They take two separate 10 cm^3 aliquots of the buffer solution formed in question 1. and add;

- (a) 0.5 cm^3 of a 0.05 mol dm^{-3} solution of hydrochloric acid to one of the aliquots, and
- (b) 0.5 cm^3 of a 0.05 mol dm^{-3} solution of calcium hydroxide to the other aliquot.

Calculate the pH of each of the new solutions formed.

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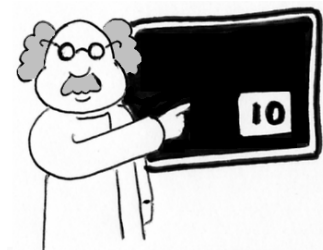
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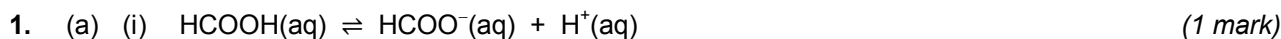
..... (6 marks)



STARTER FOR 10!!!

3. Acids and bases answers

3.5. Buffer solutions



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

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

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

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

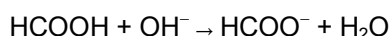
Substituting these values in we get, $1.78 \times 10^{-4} \text{ mol dm}^{-3} = 0.90 \times [\text{H}^+(\text{aq})] / 1.02$

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

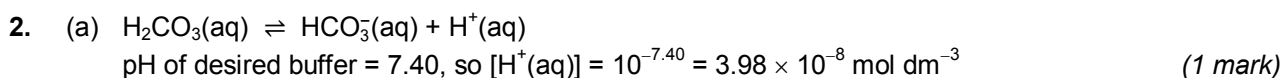
$$\therefore \text{pH} = \underline{3.70} \quad (1 \text{ mark})$$

(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^- ;



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



$$K_a = \frac{[\text{HCO}_3^-(\text{aq})][\text{H}^+(\text{aq})]}{[\text{H}_2\text{CO}_3(\text{aq})]}$$

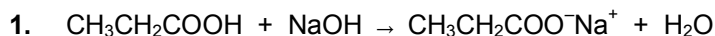
$$\therefore \frac{[\text{HCO}_3^-(\text{aq})]}{[\text{H}_2\text{CO}_3(\text{aq})]} = \frac{K_a}{[\text{H}^+(\text{aq})]} = \frac{4.5 \times 10^{-7} \text{ mol dm}^{-3}}{3.98 \times 10^{-8} \text{ mol dm}^{-3}} = \frac{11.3}{1} \quad (1 \text{ mark})$$

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

$$\underline{11.3 : 1 \text{ HCO}_3^- : \text{H}_2\text{CO}_3}$$

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

3.6. More complex buffer calculations



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

\therefore moles of $\text{CH}_3\text{CH}_2\text{COOH}$ will decrease by $1.5 \times 10^{-3} \text{ mol}$ and moles of $\text{CH}_3\text{CH}_2\text{COO}^-\text{Na}^+$ will increase by $1.5 \times 10^{-3} \text{ mol}$. (1 mark)



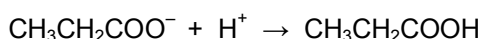
STARTER FOR 10!!!

3. Acids and bases answers

	$\text{CH}_3\text{CH}_2\text{COOH}$	\rightleftharpoons	$\text{CH}_3\text{CH}_2\text{COO}^-$	$+ \text{H}^+$
Initial moles	$0.035 \text{ dm}^3 \times 0.150 \text{ mol dm}^{-3}$ $= 5.25 \times 10^{-3} \text{ mol}$		0 mol	0 mol
Change in moles	$- 1.5 \times 10^{-3} \text{ mol}$		$+ 1.5 \times 10^{-3} \text{ mol}$?
Equilibrium moles	$3.75 \times 10^{-3} \text{ mol}$		$1.5 \times 10^{-3} \text{ mol}$?
$K_a = \frac{[\text{CH}_3\text{CH}_2\text{COO}^-][\text{H}^+]}{[\text{CH}_3\text{CH}_2\text{COOH}]} = \frac{(1.5 \times 10^{-3} \text{ mol} / 0.05 \text{ dm}^3) \times [\text{H}^+]}{(3.75 \times 10^{-3} \text{ mol} / 0.05 \text{ dm}^3)} = 1.35 \times 10^{-5} \text{ mol dm}^{-3}$				(1 mark)
$\therefore [\text{H}^+] = 3.38 \times 10^{-5} \text{ mol dm}^{-3}$				
$\therefore \text{pH} = 4.47$				(1 mark)

2. In a 10 cm^3 aliquot (= 1/5 th) of the buffer solution made above;
 moles of $\text{CH}_3\text{CH}_2\text{COOH} = 7.5 \times 10^{-4} \text{ mol}$; moles of $\text{CH}_3\text{CH}_2\text{COO}^- = 3.0 \times 10^{-4} \text{ mol}$ (1 mark)

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



\therefore moles of $\text{CH}_3\text{CH}_2\text{COOH}$ will increase by $2.5 \times 10^{-5} \text{ mol}$ and moles of $\text{CH}_3\text{CH}_2\text{COO}^-$ will decrease by $2.5 \times 10^{-5} \text{ mol}$. (1 mark)

	$\text{CH}_3\text{CH}_2\text{COOH}$	\rightleftharpoons	$\text{CH}_3\text{CH}_2\text{COO}^-$	$+ \text{H}^+$
Initial moles	$7.5 \times 10^{-4} \text{ mol}$		$3.0 \times 10^{-4} \text{ mol}$	
Change in moles	$+ 2.5 \times 10^{-5} \text{ mol}$		$- 2.5 \times 10^{-5} \text{ mol}$?
Equilibrium moles	$7.75 \times 10^{-4} \text{ mol}$		$2.75 \times 10^{-4} \text{ mol}$?

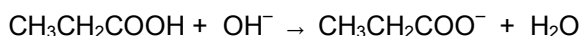
$$\therefore 1.35 \times 10^{-5} \text{ mol dm}^{-3} = \frac{(2.75 \times 10^{-4} \text{ mol} / 0.0105 \text{ dm}^3) \times [\text{H}^+]}{(7.75 \times 10^{-4} \text{ mol} / 0.0105 \text{ dm}^3)}$$

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

$$\therefore \text{pH} = 4.42 \quad (1 \text{ mark})$$

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

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



\therefore moles of $\text{CH}_3\text{CH}_2\text{COOH}$ will decrease by $5.0 \times 10^{-5} \text{ mol}$ and moles of $\text{CH}_3\text{CH}_2\text{COO}^-$ will increase by $5.0 \times 10^{-5} \text{ mol}$. (1 mark)



STARTER FOR 10!!!

3. Acids and bases answers

	$\text{CH}_3\text{CH}_2\text{COOH}$	\rightleftharpoons	$\text{CH}_3\text{CH}_2\text{COO}^-$	$+ \text{H}^+$
Initial moles	$7.5 \times 10^{-4} \text{ mol}$		$3.0 \times 10^{-4} \text{ mol}$	
Change in moles	$-5.0 \times 10^{-5} \text{ mol}$		$+5.0 \times 10^{-5} \text{ mol}$?
Equilibrium moles	$7.0 \times 10^{-4} \text{ mol}$		$3.5 \times 10^{-4} \text{ mol}$?

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

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

$$\therefore \text{pH} = 4.57$$

(1 mark)