

## Friday Worksheet

Name: .....

### Acid base equilibria worksheet 2

1) Consider the two solutions below at 25°C

- i. 100.0 mL of 0.100 M HCOOH
- ii. 100.0 mL of 0.100 M HCl

a) What is the pH of each solution?

The HCl solution will have a pH of 1.000 since it is a strong acid and full ionisation will occur.

The pH of the weak methanoic acid will have to be calculated using the  $K_a$  at 25°C.  $K_a$  of methanoic acid =  $1.8 \times 10^{-4}$  at 25°C.

$\Rightarrow 1.8 \times 10^{-4} = [\text{H}_3\text{O}^+][\text{HCOO}^-] / [\text{HCOOH}]$  According to the stoichiometry

$[\text{H}_3\text{O}^+] = [\text{HCOO}^-]$  hence we can write the expression below

$1.8 \times 10^{-4} = [\text{H}_3\text{O}^+]^2 / [\text{HCOOH}]$ .

$\Rightarrow 1.8 \times 10^{-4} = [\text{H}_3\text{O}^+]^2 / [0.100]$ . Here we assume negligible ionisation hence the concentration of methanoic acid is still 0.100M.

$\Rightarrow 1.8 \times 10^{-5} = [\text{H}_3\text{O}^+]^2$

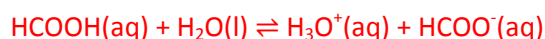
$\Rightarrow 4.24 \times 10^{-3} = [\text{H}_3\text{O}^+]$

$\text{pH} = -\log_{10}[4.24 \times 10^{-3}] = 2.37$

b) The pH of which solution will undergo the greatest change when 900 mL of water is added to the solution. Explain

The HCl is fully ionised. Hence a 1:10 dilution will drive the pH from 1 to 2 as the  $[\text{H}_3\text{O}^+]$  changes from 0.100M to 0.0100M, 10 fold reduction.

For the methanoic acid, however, being a weak acid, the reaction below



will shift to the right to increase the  $[\text{H}_3\text{O}^+]$  as the  $K_a$  remains constant at the same temperature.

The pH of a solution of 0.0100M HCOOH at 25°C is

$\Rightarrow 1.8 \times 10^{-4} = [\text{H}_3\text{O}^+]^2 / [0.0100]$

$\Rightarrow 1.8 \times 10^{-6} = [\text{H}_3\text{O}^+]^2$

$\Rightarrow 10^{-2.872} = [\text{H}_3\text{O}^+]$

$\Rightarrow \text{pH} = -\log_{10}[10^{-2.872}]$

$\Rightarrow 2.872$

- 2) The ionisation of ethanoic acid can be represented by the equation  
 $\text{CH}_3\text{COOH}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{CH}_3\text{COO}^-(\text{aq}) + \text{H}_3\text{O}^+(\text{aq})$   
 Which of the following solutions has the highest percentage ionisation. Verify mathematically and show all working out.  
 A. 50 mL 1.0 M  $\text{CH}_3\text{COOH}$  solution..  
 B. 100 mL 0.01 M  $\text{CH}_3\text{COOH}$  solution.

Dilution causes the percentage ionisation of weak acids to increase.



The above equilibrium will shift to the right when diluted. On dilution all the concentrations are decreased and the system is pushed out of equilibrium.

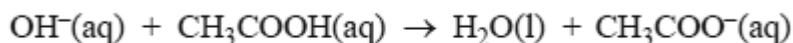
For option A.

$$\begin{aligned} \Rightarrow 1.7 \times 10^{-5} &= [\text{CH}_3\text{COO}^-] [\text{H}^+] / [\text{CH}_3\text{COOH}] \\ \Rightarrow 1.7 \times 10^{-5} &= [\text{CH}_3\text{COO}^-]^2 / [1.0] \\ \Rightarrow 0.0041\text{M} &= [\text{CH}_3\text{COO}^-] \\ \Rightarrow \% \text{ ionisation} &= (0.0041 / 1.0) \times 100 = 0.41\% \end{aligned}$$

For option B.

$$\begin{aligned} \Rightarrow 1.7 \times 10^{-5} &= [\text{CH}_3\text{COO}^-] [\text{H}^+] / [\text{CH}_3\text{COOH}] \\ \Rightarrow 1.7 \times 10^{-5} &= [\text{CH}_3\text{COO}^-]^2 / [0.01] \\ \Rightarrow 0.00041\text{M} &= [\text{CH}_3\text{COO}^-] \\ \Rightarrow \% \text{ ionisation} &= (0.00041 / 0.01) \times 100 = 4.1\% \end{aligned}$$

- 4) A 20.00 mL aliquot of a 0.200 M  $\text{CH}_3\text{COOH}$  (ethanoic acid) is titrated with 0.150 M NaOH. The equation for the reaction between the ethanoic acid and NaOH solution is represented below.



What volume of the NaOH solution is required to completely react with the ethanoic acid?

Step 1 find the mol of ethanoic acid

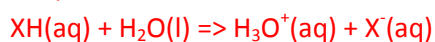
$$\Rightarrow n = C \times V = 0.200 \times 0.02000 = 0.00400$$

Step 2 find the volume of NaOH

$$\Rightarrow V = C / n = 0.150 / 0.00400 = 6.00 \times 10^{-3} \text{ L}$$

- 5) A weak monoprotic acid has a  $K_a$  of  $10^{-4.994}$  at  $25^\circ\text{C}$  and the solution has a pH of 4.523. What percentage of the acid is ionised?

Step 1 find the initial concentration of the acid



$$\Rightarrow [\text{H}_3\text{O}^+] [\text{X}^-] / 10^{-4.994} = [\text{XH}]$$

$$\Rightarrow [\text{H}_3\text{O}^+]^2 / 10^{-4.994} = [\text{XH}]$$

$$\Rightarrow 10^{-9.46} / 10^{-4.994} = [\text{XH}] = 10^{-4.466}$$

$$\Rightarrow (10^{-4.523} / 10^{-4.466}) \times 100 = 87.7\%$$