

Friday Worksheet

Name:

Acid Base equilibria worksheet 1

- 1) What is the pH of a 100.0 mL 0.325 M H_3BO_3 solution at 25 °C?

$$K_{a \text{ boric acid}} = 5.8 \times 10^{-10}$$
$$\text{pH} = -\log[\text{H}_3\text{O}^+]$$

Step 1 find the $[\text{H}_3\text{O}^+]$

$$\Rightarrow K_a = \frac{[\text{H}_2\text{BO}_3^-][\text{H}_3\text{O}^+]}{[\text{H}_3\text{BO}_3]} = 5.8 \times 10^{-10}$$

Since according to the stoichiometry $[\text{H}_2\text{BO}_3^-] = [\text{H}_3\text{O}^+]$ we can write the expression below.

$$\Rightarrow K_a = \frac{[\text{H}_3\text{O}^+]^2}{[\text{H}_3\text{BO}_3]} = 5.8 \times 10^{-10}$$

\Rightarrow Since K_a is very small assume that negligible amount ionises. So we can write the expression below

$$\Rightarrow \frac{[\text{H}_3\text{O}^+]^2}{0.325} = 5.8 \times 10^{-10}$$

$$\Rightarrow [\text{H}_3\text{O}^+]^2 = 5.8 \times 0.325 \times 10^{-10}$$

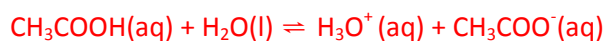
$$\Rightarrow [\text{H}_3\text{O}^+]^2 = 1.9 \times 10^{-10}$$

$$\Rightarrow [\text{H}_3\text{O}^+] = 1.4 \times 10^{-5} = 10^{0.15} \times 10^{-5} = 10^{-4.85}$$

$$\Rightarrow \text{pH} = 4.85$$

- 2) Ethanoic acid is a weak monoprotic acid.

a) Write the equation that represents the ionisation reaction of ethanoic acid.



b) Write the equilibrium expression for this reaction.

$$K_e = \frac{[\text{CH}_3\text{COO}^-][\text{H}_3\text{O}^+]}{[\text{CH}_3\text{COOH}][\text{H}_2\text{O}]}$$

c) Write the expression for the K_a of ethanoic acid

$$K_a = \frac{[\text{CH}_3\text{COO}^-][\text{H}_3\text{O}^+]}{[\text{CH}_3\text{COOH}]}$$

d) Which has the highest pH and offer an explanation.

i) 10.0 mL 0.100 M HCOOH solution or 100.0 mL 0.100 M CH₃COOH solution

Since the $K_a(\text{HCOOH}) = 1.8 \times 10^{-4}$ and the $K_a(\text{CH}_3\text{COOH}) = 1.7 \times 10^{-5}$ there will be a greater degree of ionisation, at the same concentration, in the methanoic acid solution than the ethanoic acid solution. A greater degree of ionisation leads to a higher $[\text{H}_3\text{O}^+]$ and hence a lower pH. So ethanoic acid has the higher pH.

ii) 10.0 mL of 0.01 M HCOOH solution or 10.0 mL 0.100 M HCOOH solution

Dilution increases the extent of ionisation however the $[\text{H}_3\text{O}^+]$ decreases with dilution.

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

$$\Rightarrow \frac{[\text{H}_3\text{O}^+]^2}{[0.100]} = 1.8 \times 10^{-4}$$

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

$$\Rightarrow [\text{H}_3\text{O}^+] = 10^{-2.37} \text{ pH for 0.1 M HCOOH is 2.37}$$

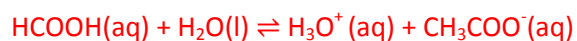
Now for the 0.01 M HCOOH

$$\Rightarrow \frac{[\text{H}_3\text{O}^+]^2}{[0.010]} = 1.8 \times 10^{-4}$$

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

$$\Rightarrow [\text{H}_3\text{O}^+] = 10^{-2.87} \\ \text{pH for 0.01 M HCOOH is 2.87}$$

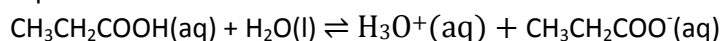
e) Explain why diluting a solution of 0.100 M HCOOH to 0.001 M HCOOH, at constant temperature, increases the percentage ionisation of HCOOH.



$$K_a = \frac{[\text{HCOO}^-][\text{H}_3\text{O}^+]}{[\text{HCOOH}]} = 1.8 \times 10^{-4}$$

Diluting the solution lowers the concentration of the ions and drives the reaction forward hence ionising a greater percentage of the HCOOH present. Dilution, however, ultimately reduces the $[\text{H}_3\text{O}^+]$ and increases pH.

- 3) A 20.00 mL aliquot of 0.200 M $\text{CH}_3\text{CH}_2\text{COOH}$ (propanoic acid) is titrated with 0.250 M NaOH. The equation for the reaction between propanoic acid and NaOH solution is represented below.



- a) Write the expression for the acidity constant.

$$K_a = \frac{[\text{CH}_3\text{CH}_2\text{COO}^-][\text{H}_3\text{O}^+]}{[\text{CH}_3\text{CH}_2\text{COOH}]}$$

- b) What volume of NaOH is required to completely react with the acid.

$$n_{\text{propanoic acid}} = C \times V = 0.02000 \times 0.200 = 4 \times 10^{-3}$$

$$n_{\text{NaOH}} = 4 \times 10^{-3} / 0.250 = 16.0 \text{ mL}$$

- c) Calculate the pH of the 0.200 M propanoic acid solution before any NaOH solution has been added.

$$K_{a_{\text{propanoic acid}}} = 1.3 \times 10^{-5}$$

$$\text{pH} = -\log[\text{H}_3\text{O}^+]$$

Step 1 find the $[\text{H}_3\text{O}^+]$

$$K_a = \frac{[\text{CH}_3\text{CH}_2\text{COO}^-][\text{H}_3\text{O}^+]}{[\text{CH}_3\text{CH}_2\text{COOH}]} = 1.3 \times 10^{-5}$$

⇒ Since according to the stoichiometry $[\text{CH}_3\text{CH}_2\text{COO}^-] = [\text{H}_3\text{O}^+]$ we can write the expression below.

$$\Rightarrow K_a = \frac{[\text{H}_3\text{O}^+]^2}{[\text{CH}_3\text{CH}_2\text{COOH}]} = 1.3 \times 10^{-5}$$

⇒ Since K_a is very small assume that negligible amount of propanoic acid ionises. So we can write the expression below

$$\Rightarrow \frac{[\text{H}_3\text{O}^+]^2}{0.200} = 1.3 \times 10^{-5}$$

$$\Rightarrow [\text{H}_3\text{O}^+]^2 = 2.60 \times 10^{-6}$$

$$\Rightarrow [\text{H}_3\text{O}^+]^2 = 1.61 \times 10^{-3}$$

$$\Rightarrow [\text{H}_3\text{O}^+] = 10^{0.207} \times 10^{-3} = 10^{-2.79}$$

$$\Rightarrow \text{pH} = 2.79$$