CHEM1002 Worksheet 9: Weak Acids and Buffers

Model 1: A Solution Containing a Weak Acid

A **strong acid** is one that is 100% ionised in water:

$HA(aq) + H_2O(l) \rightarrow H_3O^+(aq) + A^-(aq)$ $[H_3O^+(aq)] = [HA]_{initial}$ and $pH = -\log[HA]_{initial}$

A **weak acid** is one that is less than 100% ionised in water and an equilibrium must be considered:

$HA(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + A^-(aq)$ $K_a = \dfrac{[H_3O^+(aq)][A^-(aq)]}{[HA(aq)]}$

From the chemical equation, at equilibrium:

$[H_3O^+(aq)] = [A^-(aq)]$ and $[HA(aq)] = [HA]_{initial} - [A^-(aq)]$

As hardly any weak acid ionises, $[HA]_{initial} - [A^-(aq)] \approx [HA]_{initial}$ and so:

$K_a = \dfrac{[H_3O^+(aq)]^2}{[HA]_{initial}}$ and $[H_3O^+(aq)] = \sqrt{K_a \times [HA]_{initial}}$

After working out $[H_3O^+(aq)]$, the pH of the weak acid can be calculated:

$pH = -\log[H_3O^+(aq)]$

Critical thinking questions

1. Calculate the pH of the acetic acid as it is diluted ($K_a = 10^{-4.76}$).

(a) 2.00 M pH =

(c) 0.500 M pH =

(b) 1.00 M pH =

(d) 0.250 M pH =

2. What are the *major* species present in a 1.00 M solution of acetic acid?

Model 2: Buffer solutions

Model 1 describes the pH of a solution of a weak acid. If the conjugate base of the weak acid is added to that solution the pH will increase, as the added weak acid will drive the equilibrium given below towards the left hand side.

$$HA(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + A^-(aq)$$

In the case of acetic acid the solution will contain appreciable amounts of both $CH_3COO^-(aq)$ and $CH_3COOH(aq)$. A solution like this containing both a weak acid and its conjugate base will have a pH given by the *Henderson-Hasselbalch* equation:

$$\mathrm{pH} = \mathrm{p}K_a + \log\frac{[\mathrm{base}]}{[\mathrm{acid}]} = \mathrm{p}K_a + \log\frac{[\mathrm{A^-(aq)}]}{[\mathrm{HA(aq)}]}$$

Critical thinking questions

3. Calculate the pH of a 1.00 L solution that is 0.100 M in $CH_3COO^-(aq)$ and 0.400 M $CH_3COOH(aq)$. ($\mathrm{p}K_a$ (CH_3COOH) = 4.76).

4. Calculate the change in pH and final pH if 0.150 mol NaOH(s) is added to that solution (*Hint*: Which of the two species will the NaOH react with?).

5. You require a stable pH = 5.00 for an experiment. How would you prepare a buffer for that pH from 1.0 M solutions of $CH_3COO^-(aq)$ and $CH_3COOH(aq)$?