Marks 6

- Butyric acid, $CH_3CH_2CH_2COOH$, is found in rancid butter and parmesan cheese. The pK_a of butyric acid is 4.83.
  (a) What is the pH of a 0.10 M water solution of butyric acid?

As $pK_a = -\log K_a = 4.83$, $K_a = 10^{-4.83}$. Denoting butyric acid as HA, the initial concentration of [HA(aq)] = 0.10 M. The reaction table is then:

	[HA(aq)]	⇆	[H^+(aq)]	[A^-(aq)]
t = 0	**0.10.**		**0**	**0**
change	**-x**		**+x**	**+x**
equilibrium	**0.10 – x**		**x**	**x**

Hence, $K_a = \dfrac{[H^+(aq)][A^-(aq)]}{[HA(aq)]} = \dfrac{(x)(x)}{0.10\text{-}x} = \dfrac{x^2}{0.10\text{-}x}$

As K_z is small, the amount of dissociation, x, is also small so 0.10 – x ~ 0.10. Using this approximation, $K_z = \dfrac{x^2}{0.10} = 10^{-4.83}$ **hence** $x = 1.22 \times 10^{-3}$ **M.**

As $x = [H^+(aq)]$, $pH = -\log[H^+(aq)] = -\log(1.22 \times 10^{-3}) = 2.92$

Answer: **2.92**

(b) Calculate the pH of the solution formed when 0.050 mol of NaOH(s) is added to 1.0 L of 0.10 M butyric acid.

As NaOH is a strong base, it will dissociate completely and each mole of OH^- will react with butyric acid to form one mole of A^-(aq).

1.0 L of 0.10 M HA contains 0.10 mol. After addition of 0.050 mol of OH^-, the number of moles of HA = (0.10 – 0.050) = 0.05 mol and the number of moles of A^- = 0.050 mol.

As 1.0 L of solution is present, [HA(aq)] = 0.05 M and [A^-(aq)] = 0.05 M. Substituting into the expression for K_a gives:

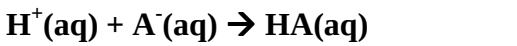
$$K_a = \frac{[H^+(aq)][A^-(aq)]}{[HA(aq)]} = \frac{[H^+(aq)]\times(0.05)}{(0.05)} = 10^{-4.83} \text{ so } [H^+(aq)] = 1.5 \text{ M}$$

Hence, $pH = -\log[H^+(aq)] = 4.83$

Answer: **4.83**

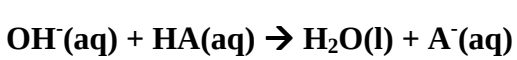
(c) Using equations, comment on how the final solution in (b) will respond to additions of small amounts of acid or base in comparison to 1 L of water.

Solution (b) consists of a mixture of a weak acid and its conjugate base: it is a buffer system and will resist changes in pH. If acid is added, the system can respond by removing it using A^-:



$H^+(aq) + A^-(aq) \rightarrow HA(aq)$

If base is added, the system can respond by removing it using HA:



$OH^-(aq) + HA(aq) \rightarrow H_2O(l) + A^-(aq)$