CHEM1902/4 Worksheet 8 – Answers to Critical Thinking Questions

The worksheets are available in the tutorials and form an integral part of the learning outcomes and experience for this unit.

Model 1: pH

1.

pH	0.50	1.50	2.50	3.50	4.50	5.50	5.75
$[H_3O^+(aq)]$	3.2×10^{-1}	3.2×10^{-2}	3.2×10^{-3}	3.2×10^{-4}	3.2×10^{-5}	3.2×10^{-6}	1.8×10^{-6}

2. The part of the pH value *after* the decimal point affects the coefficient (i.e. the numerical value).
3. The part of the pH value *before* the decimal point affects the exponent (i.e. the position of the decimal point).

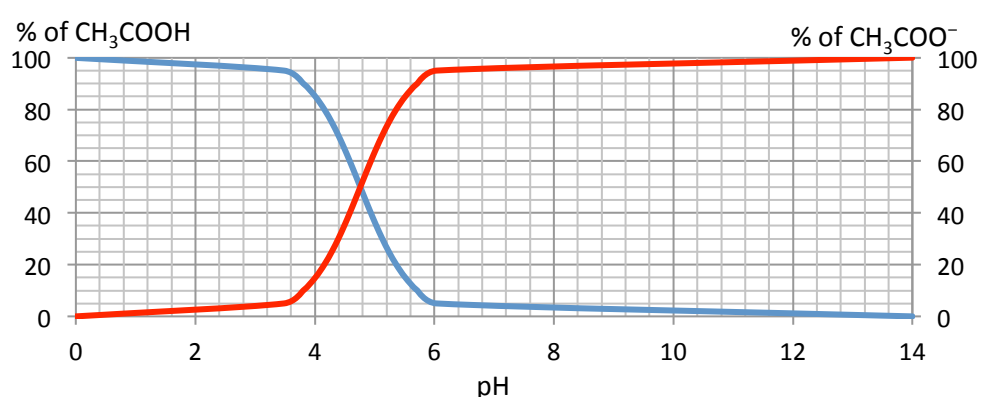
Model 2: Strong and Weak Acids

1. The major species present are $H_3O^+(aq)$, $Cl^-(aq)$ and $H_2O(l)$. There is essentially no "HCl(aq)".
2. The major species present are $CH_3COOH(aq)$ and $H_2O(l)$. The percentage ionization is very small and there is *very* little $H_3O^+(aq)$, $CH_3COO^-(aq)$.
3. $CH_3COO^-(aq)$ is the *dominant* species only at high pH.
4. $CH_3COOH(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + CH_3COO^-(aq)$ $\qquad K_a = \dfrac{[H_3O^+(aq)][CH_3COO^-(aq)]}{[CH_3COOH(aq)]}$
5. The *major* species present are $CH_3NH_2(aq)$ and $H_2O(l)$.
6. $CH_3NH_3^+(aq)$ is the *dominant* species only at low pH.
7. (a) Aspirin is absorbed in the stomach. In the intestine, it is deprotonated.

   (b) Amphetamine is absorbed in the intestine. In the stomach, it is protonated.
8. See below.

pH	0	2	4	6	8	10	12	14
$\dfrac{[CH_3COO^-(aq)]}{[CH_3COOH(aq)]}$	1.74×10^{-5}	1.74×10^{-3}	1.74×10^{-1}	$1.74 \times 10^{+1}$	$1.74 \times 10^{+3}$	$1.74 \times 10^{+5}$	$1.74 \times 10^{+7}$	$1.74 \times 10^{+9}$

9. See below.



10. $[CH_3COOH(aq)] = [CH_3COO^-(aq)]$ where the two lines cross: pH = 4.76 = pK_a.

Model 3: A Solution Containing a Weak Acid

1. $[CH_3COOH(aq)]_{initial} = 2.0$ M and $[CH_3COOH(aq)]_{equilibrium} = 2.0 - x$.

   The small x approximation corresponds to the approximation:

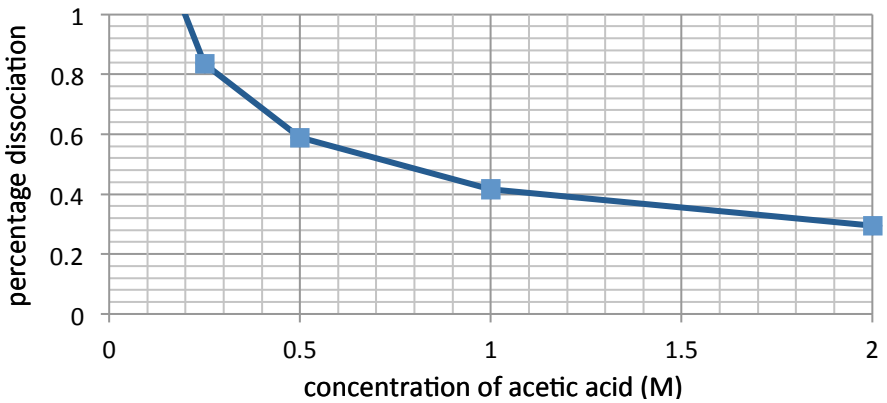
   $$CH_3COOH(aq)]_{equilibrium} = [CH_3COOH(aq)]_{initial}$$

2. $x = \sqrt{K_a \times [HA]_{initial}}$ or $pH = -\log_{10}(\sqrt{K_a \times [HA]_{initial}})$

3. (a) pH = 2.229, % dissociation = 0.30 (c) pH = 2.531, % dissociation = 0.59

   (b) pH = 2.380, % dissociation = 0.42 (d) pH = 2.681. % dissociation = 0.83

4. See below.



   The major species present $H_2O(l)$ and $CH_3COOH(aq)$. The amount of dissociation is very small (< 1%) and so the amount of $CH_3COO^-(aq)$ and $H_3O^+(aq)$ is *tiny*.

5. The *degree* of dissociation *increases* as the weak acid is diluted, even though the *amount* of dissociated acid *decreases*.

6. (a) $CH_3COOH(aq)$ and $H_2O(l)$ (b) $CH_3NH_2(aq)$ and $H_2O(l)$

7. $CH_3COO^-(aq)$, $CH_3NH_2^+(aq)$ and $H_2O(l)$

8. $K = K_a(CH_3COOH) / K_a(CH_3NH_2) = 10^{-4.76} / 10^{-10.64} = 10^{5.88}$. It is very large.

9. The reaction between a weak acid and a weak base proceeds essentially to completion.

10. $^+NH_3CH_2COO^-(aq)$ and $H_2O(l)$.

11. See below.

   $$^+NH_3CH_2COOH(aq) + H_2O(l) \rightleftharpoons {}^+NH_3CH_2COO^-(aq) + H_3O^+(aq) \qquad pK_{a1} = 2.34$$

   $$^+NH_3CH_2COO\text{-}(aq) + H_2O(l) \rightleftharpoons NH_2CH_2COO^-(aq) + H_3O^+(aq) \qquad pK_{a1} = 9.60$$

   In the first step, $^+NH_3CH_2COOH(aq)$ is the acid and $^+NH_3CH_2COO^-(aq)$ is its conjugate base.

   In the second step, $^+NH_3CH_2COO\text{-}(aq)$ is the acid and $NH_2CH_2COO^-(aq)$ is its conjugate base.