CHEM1002: Worksheet 8: Introduction to Acids and Bases

Model 1: pH

Water is able to act as both an acid and a base and it is possible for water to react with itself in an acid-base reaction called the *autoprotolysis* or *autoionization* of water:

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

The equilibrium constant for this reaction $K_w = [H_3O^+(aq)][OH^-(aq)]$. At 25 °C, $K_w = 1.0 \times 10^{-14}$. Several definitions have proven to be useful:

$pH = -\log_{10}[H_3O^+(aq)]$, $pOH = -\log_{10}[OH^-(aq)]$ $pK_w = -\log_{10}K_w$

Critical thinking questions

1. During the course of a titration, a student measures the pH several times. What is $[H_3O^+(aq)]$ for each pH value below? Use scientific notation in your answers.

pH	0.50	1.50	2.50	3.50	4.50	5.50	5.75
$[H_3O^+(aq)]$							

2. Look at the numbers you calculated in Q1. What do you notice about how the part of the number *before* and *after* the decimal point in pH affects the value of $[H_3O^+(aq)]$?

3. What is the numerical value of pK_w at 25 °C?

Model 2: Strong and Weak Acids

A **strong acid** is one that is essentially 100% dissociated in water: if 0.1 mole of the acid is added to enough water to make a 1.0 L solution, the solution will have $[H_3O^+(aq)] = 0.1$ M and will be pH = 1.

A **weak acid** is one that is *significantly* less than 100% dissociated in water: if 0.1 mole of the acid is added to enough water to make a 1.0 L solution, the solution will have $[H_3O^+(aq)] < 0.1$ M and will be pH > 1.

When an acid HA is placed in water, $H_3O^+(aq)$ ions are produced according to the reaction:

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

Critical thinking questions

1. What are the *major* species present in a solution of a strong acid like HCl?

2. What are the *major* species present in a solution of a weak acid like CH_3COOH?

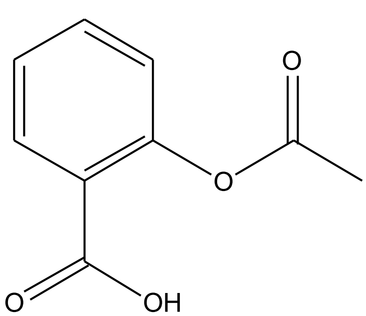
3. Under what pH conditions would $CH_3COO^-(aq)$ be the *dominant* species in a solution of CH_3COOH?

4. Write down the equilibrium expression, K_a, for CH_3COOH.

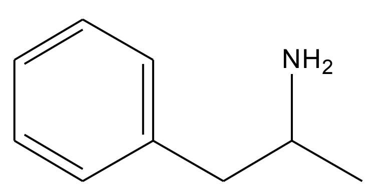
5. What are the *major* species present in a solution of a weak base like CH_3NH_2?

6. Under what pH conditions would $CH_3NH_3^+(aq)$ be the *dominant* species?

7. The extent of ionization of a drug helps determine how it is distributed in the body because ions are less likely to cross cell membranes than uncharged molecules. Are the two drugs below likely to be absorbed in (i) the acidic environment of the stomach or (ii) the basic environment of the intestine?



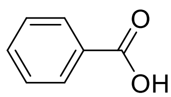
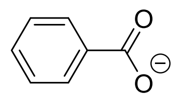
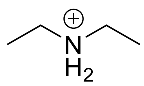
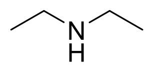
aspirin



amphetamine

Model 3: Conjugate Pairs

Certain pairs of molecules are related through their acid and base properties. These pairs are described as a **conjugate acid-base pair**. They differ by *a single proton*. A base has *one less proton* than its conjugate acid. An acid has *one more proton* than its conjugate base.

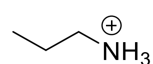
Acid	Base
H_2CO_3	HCO_3^-
HCO_3^-	CO_3^{2-}
H_3O^+	H_2O
H_2S	HS^-
	
	

Critical thinking questions

1. (a) What is the conjugate base of H_2O?

   (b) What is the conjugate acid of H_2O?

2. Write the formulae of the conjugate bases of the following acids:

   (a) CH_3COOH (b) NH_4^+ (c) 

3. Write the formulae of the conjugate acids of the following bases:

   (a) H_2S (b) HS^- (c) S^{2-}

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Marks 8

- Hydrochloric acid in a healthy human stomach leads to a pH in the range 1-2. What is the concentration of hydrochloric acid in the stomach?

Answer:

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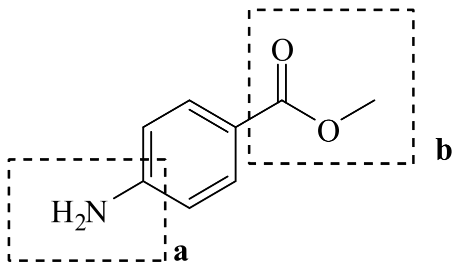
Marks 5

- The structure of methyl 4-aminobenzoate, (**E**), is given below.

(**E**)



Give the structure(s) of all organic products formed when compound (**E**) is treated with the following reagents. If no reaction occurs, write "NO REACTION".

cold HCl (1 M)	
hot NaOH (4 M)	
hot HCl (4 M)	