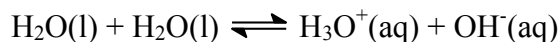


## CHEM1102 Worksheet 8: Acids and Bases

### 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:



The equilibrium constant for this reaction  $K_w = [\text{H}_3\text{O}^+(\text{aq})][\text{OH}^-(\text{aq})]$ . At 25 °C,  $K_w = 1.0 \times 10^{-14}$ . Several definitions have proven to be useful:

$$\text{pH} = -\log_{10}[\text{H}_3\text{O}^+(\text{aq})], \quad \text{pOH} = -\log_{10}[\text{OH}^-(\text{aq})] \quad \text{p}K_w = -\log_{10}K_w$$

*Significant figures*: when using logs, the number of significant figures is determined by the number of decimal points. The number to the left of the decimal point is *not* significant.

### Critical thinking questions

1. During the course of a titration, a student measures the pH several times. What is  $[\text{H}_3\text{O}^+(\text{aq})]$  for each pH value below? (Actually calculate  $[\text{H}_3\text{O}^+(\text{aq})]$  – do *not* leave in the form  $10^x$ ).

| pH                                  | 0.50 | 1.50 | 2.50 | 3.50 | 4.50 | 5.50 | 5.75 |
|-------------------------------------|------|------|------|------|------|------|------|
| $[\text{H}_3\text{O}^+(\text{aq})]$ |      |      |      |      |      |      |      |

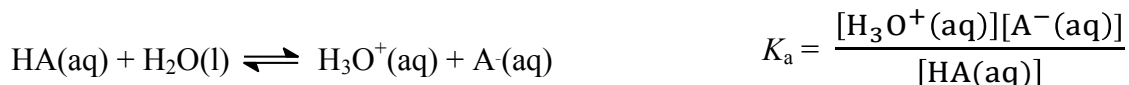
2. What is the effect of the number to the left of the decimal point in the pH on  $[\text{H}_3\text{O}^+(\text{aq})]$ ?
3. What is the effect of the number to the right of the decimal point in the pH on  $[\text{H}_3\text{O}^+(\text{aq})]$ ?

### 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  $[\text{H}_3\text{O}^+(\text{aq})] = 0.1 \text{ M}$  and will be  $\text{pH} = 1$ .

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  $[\text{H}_3\text{O}^+(\text{aq})] < 0.1 \text{ M}$  and will be  $\text{pH} > 1$ .

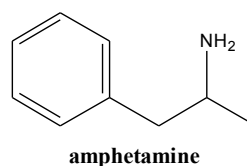
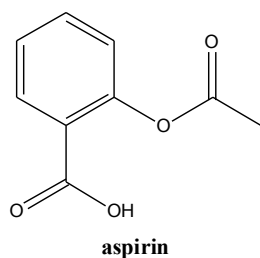
When an acid HA is placed in water,  $\text{H}_3\text{O}^+(\text{aq})$  ions are produced according to the reaction:



### 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  $\text{CH}_3\text{COOH}$ ?

- Under what pH conditions would  $\text{CH}_3\text{COO}^-$ (aq) be the *dominant* species in a solution of  $\text{CH}_3\text{COOH}$ ?
- Write down the equilibrium expression,  $K_a$ , for  $\text{CH}_3\text{COOH}$ .
- What are the *major* species present in a solution of a weak base like  $\text{CH}_3\text{NH}_2$ ?
- Under what pH conditions would  $\text{CH}_3\text{NH}_3^+$ (aq) be the *dominant* species?
- 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 acid environment of the stomach or (ii) the basic environment of the intestine?



### 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                 |
|-------------------------|----------------------|
| $\text{H}_2\text{CO}_3$ | $\text{HCO}_3^-$     |
| $\text{HCO}_3^-$        | $\text{CO}_3^{2-}$   |
| $\text{H}_3\text{O}^+$  | $\text{H}_2\text{O}$ |
| $\text{H}_2\text{S}$    | $\text{HS}^-$        |

### Critical thinking questions

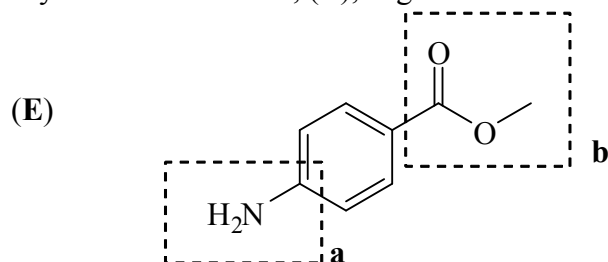
- What is the conjugate base of  $\text{H}_2\text{O}$ ?
  - What is the conjugate acid of  $\text{H}_2\text{O}$ ?
- Write the formula of the conjugate bases of the following acids:
  - $\text{CH}_3\text{COOH}$
  - $\text{NH}_4^+$
  - $\text{CH}_3\text{NH}_3^+$
- Write the formula of the conjugate acids of the following bases:
  - $\text{H}_2\text{S}$
  - $\text{HS}^-$
  - $\text{S}^{2-}$

CHEM1102

2008-J-10

June 2008

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



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)  |  |

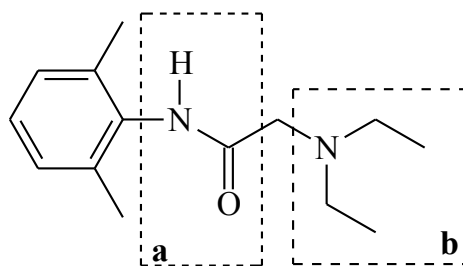
Marks  
5

CHEM1102

2006-N-7

November 2006

- The structure of lignocaine, a local anaesthetic, is given below.



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

cold HCl (1 M)

|  |
|--|
|  |
|--|

Marks  
5

hot NaOH (4 M)

hot HCl (4 M)

CHEM1102

2007-N-2

June 2007

- Often pH is used to characterise acidic solutions. Give a brief definition of pH.

**Marks**  
**5**

Describe the difference between a strong acid and a weak acid.

In general, can pH be used to define the strength of an acid? Explain your answer.