

## REVISION: ACIDS AND BASES

24 JUNE 2014



### Lesson Description

In this lesson we revise:

- Theory of acids and bases
- How to solve acids and bases problems



### Summary

#### Properties of Acids and Bases

Acids have the following properties:

- Have an acidic (sour) taste
- Conducts electricity in solution
- Neutralises a base to produce a metal salt and water
- Increase the concentration of the  $H^+$  ions ( $H_3O^+$  ions) in solution

Bases have the following properties

- Have a bitter taste
- Feel soapy
- Conducts electricity in solution
- Neutralise an acid to produce a metal salt and water
- Alkalis increase the concentration of the  $OH^-$  ions in solution (or decreases the  $H^+$  ion concentration)

#### Definitions of Acids and Bases

- Arrhenius
  - Acid - a substance that releases  $H^+$  ions in an aqueous solution
  - Base – a substance that releases  $OH^-$  ions in an aqueous solution
- Brønsted-Lowry
  - An acid is a proton donor
  - A base is a proton acceptor

#### Conjugate Acid-Base Pairs

During an acid-base reaction there is a transfer of one or more proton ( $H^+$  ion) from the acid to the base and is called a protolytic reaction.

When an acid donates a proton, a conjugate base is formed

Example:  $HCl \rightleftharpoons H^+ + Cl^-$

HCl is the acid and  $Cl^-$  is the conjugate base

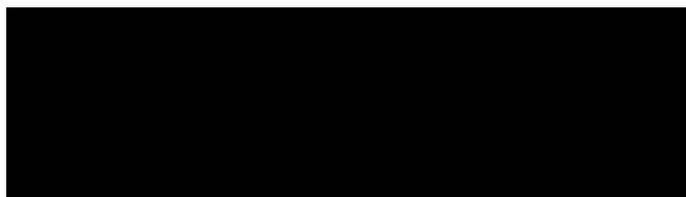
When a base accepts a proton, a conjugate acid is formed

Example:  $OH^- + H^+ \rightleftharpoons H_2O$

$OH^-$  is the base and  $H_2O$  is the conjugate acid

Brønsted-Lowry acid-base reactions are equilibrium reactions in a system in which two conjugate acid-base pairs are involved.

Example:



### Ampholytes

An ampholyte is a substance that either act as an acid or a base. In the presence of a strong acid, the ampholyte is a base. In the presence of a strong base, the ampholyte is an acid.

Example:  $H_2O$

As an acid:  $H_2O(\ell) + NH_3(g) \rightarrow OH^-(aq) + NH_4^+(aq)$

As a base:  $HCl(g) + H_2O(g) \rightarrow Cl^-(aq) + H_3O^+(aq)$

### Strength of Acids and Bases

A **strong acid** is an acid that ionises almost completely in water. It has a high percentage of ionisation and a high  $[H_3O^+]$

A **weak acid** is an acid that ionises only slightly in water. It has a low percentage of ionisation and a low  $[H_3O^+]$

A **strong base** is a base that dissociates (or ionises) almost completely in water. It has a high percentage dissociation.

A **weak base** is a base that dissociates (or ionises) only slightly in water. It has a low percentage dissociation.

### Reactions of Acids

In general:

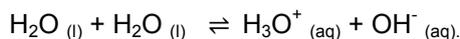
- 1) Acid + metal  $\rightarrow$  salt + hydrogen
- 2) Acid + metal oxide  $\rightarrow$  salt + water
- 3) Acid + metal hydroxide  $\rightarrow$  salt + water
- 4) Acid + metal carbonate  $\rightarrow$  salt + water + carbon dioxide
- 5) Neutralisation – acid + base  $\rightarrow$  salt + water

### Indicators

An indicator is a weak acid in equilibrium with its conjugate base of which the colour changes if it is added an acid or a base.

## Equilibrium constant for water ( $K_w$ )

In auto-ionisation of water, a proton is transferred between two molecules of water.



The equilibrium constant ( $K_w$ ) for this reaction is  $K_w = [\text{H}_3\text{O}^+][\text{OH}^-]$

$K_w$  is the ionic product of water.  $K_w = 1 \times 10^{-14}$  at  $25^\circ\text{C}$ .

In pure water,  $[\text{H}_3\text{O}^+] = 1 \times 10^{-7} \text{ mol}\cdot\text{dm}^{-3}$  and  $[\text{OH}^-] = 1 \times 10^{-7} \text{ mol}\cdot\text{dm}^{-3}$

## pH and concentration of solutions

- In **acidic** solutions,  $[\text{H}_3\text{O}^+] > [\text{OH}^-]$  and  $\text{pH} < 7$
- In **neutral** solutions,  $[\text{H}_3\text{O}^+] = [\text{OH}^-]$  and  $\text{pH} = 7$
- In **alkaline** solutions,  $[\text{H}_3\text{O}^+] < [\text{OH}^-]$  and  $\text{pH} > 7$

## Calculations

### Concentration

The unit of concentration is  $\text{mol}\cdot\text{dm}^{-3}$ , which is also written as M (stated as molar)

A concentrated acid or base contains a large quantity of solute (acid or base) per volume of solution.

A dilute acid or base contains a small quantity of solute (acid or base) per volume of solution.

When a solution is diluted, the number of moles of the original solution stays the same even though the volume of the solution changes. The following equation is used.

$$c_1V_1 = c_2V_2$$

$c_1$  = concentration of solution 1 ( $\text{mol}\cdot\text{dm}^{-3}$ )

$c_2$  = concentration of solution 2 ( $\text{mol}\cdot\text{dm}^{-3}$ )

$V_1$  = volume of solution 1 ( $\text{dm}^3$ )

$V_2$  = volume of solution 2 ( $\text{dm}^3$ )

For a titration reaction the following equation is used.

$$\frac{n_a}{n_b} = \frac{c_aV_a}{c_bV_b}$$

$n_a$  = number of moles of acid (mol)

$n_b$  = number of moles of base (mol)

$c_a$  = concentration of acid ( $\text{mol}\cdot\text{dm}^{-3}$ )

$c_b$  = concentration of base ( $\text{mol}\cdot\text{dm}^{-3}$ )

$V_a$  = volume of acid ( $\text{dm}^3$ )

$V_b$  = volume of base ( $\text{dm}^3$ )

## pH calculations

The pH of a solution is an indication of the acidity or alkalinity of a solution. It is the negative logarithm of the hydronium ion concentration in a solution.

$$\text{pH} = -\log[\text{H}^+]$$

$[\text{H}^+]$  = concentration of  $\text{H}^+$  or  $\text{H}_3\text{O}^+$  ions

If the pH is known,  $[\text{H}^+]$  is found by:

$$[\text{H}^+] = 10^{-\text{pH}}$$



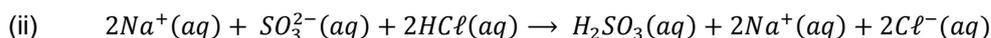
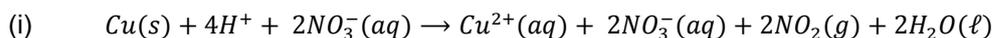
## Improve your skills

### Acids and Bases

#### Question 1

(Adapted from Transvaal Paper 2 HG 1995)

Nitrogen dioxide and sulphur dioxide can be prepared according to the following equations respectively:

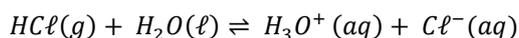


- 1.1. What is an acid – base reaction?
- 1.2. Which of the above reactions represent an acid – base reaction?
- 1.3. Write down the acid – base conjugate pairs.
- 1.4. Identify a spectator ion in this reaction.

#### Question 2

(Adapted from House of Delegates Paper 2 HG 1995)

When HCl(g) is bubbled through distilled water it ionises as a result of proton transfer. The equation for the ionisation process is:



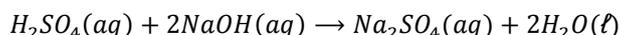
- 2.1. Provide a suitable name for the  $H_3O^+$  ion
- 2.2. What causes the solution to have acidic properties?
- 2.3. Would the resulting solution be strongly acidic or weakly acidic? Explain your answer.
- 2.4. What do we call a reaction in which proton transfer occurs?

### Acids and Bases Calculations

#### Question 1

(Taken from Eastern Cape Paper 2 HG November 2000)

In an acid-base reaction,  $500 \text{ cm}^3$  of a solution of sodium hydroxide is completely neutralised by  $680 \text{ cm}^3$  of a solution of sulphuric acid. The equation for the reaction is



The pH of the base solution before any acid is added is 13,80 at  $25^\circ\text{C}$ .

- 1.1. Show by calculation that the concentration of the NaOH solution will be  $0,631 \text{ mol}\cdot\text{dm}^{-3}$ .
- 1.2. What is the difference between a strong base and a concentrated base?
- 1.3. Calculate the mass of salt used to prepare the base solution.
- 1.4. Calculate the number of moles of  $H_3O^+(aq)$  effectively used in the neutralisation process.