

Unit	Teaching (Periods)	Assessment (periods)	Weightage %
10 Acids Bases and Salts	16	3	14

Introduction

How many foods items are sour? In taste lemons, oranges, grapefruits and other citrus fruits have sour taste. This sour taste is due to an acid called citric acid present in them.

Bases (alkalis), on the other hand, have bitter taste and are soapy to touch. When you wash your hands with soap or brush your teeth with toothpaste, you are using a base. Whereas, salts are formed by the reaction of an acid and base. Table salt, baking products etc are some of the salts which are commonly used. In this unit, you will learn about different concepts of acids and bases, pH, neutralization reaction and salts and its types.

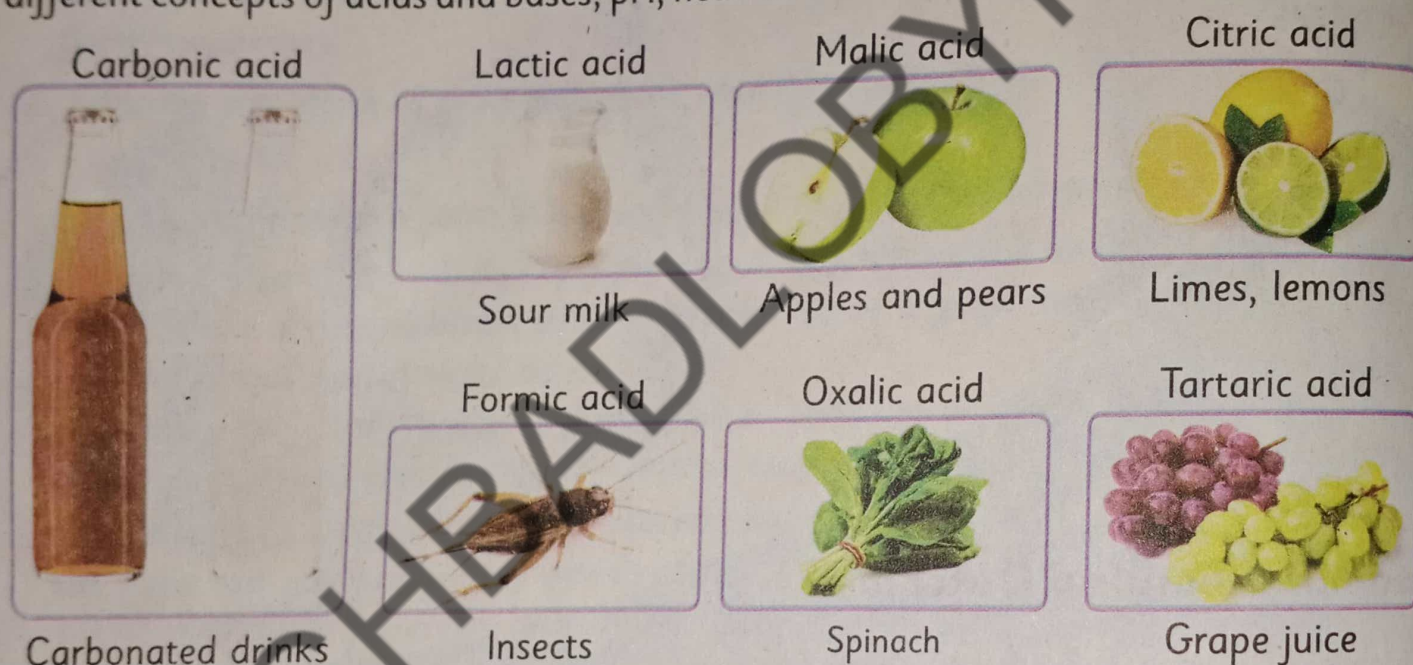


Fig.10.1 Some acids with their sources

Real world reading link

Sour milk contains **lactic acid**. Apples contain **malic acid** and grape juice contains **tartaric acid**. The substance produced by ants is an acid called **formic acid**; Bee sting is also acidic in nature, due to presence of formic acid.

Household products, such as **ammonia** (NH_3) is used for cleaning purposes, **Sodium hydroxide** (NaOH) commonly known as lye, is used as drain cleaner and for cleaning ovens. Milk of magnesia is a suspension in water of **magnesium hydroxide**, $\text{Mg}(\text{OH})_2$ and **Aluminum hydroxide**, $\text{Al}(\text{OH})_3$ are used as an antacid to relieve discomfort caused by excess of hydrochloric acid in the stomach. All are bases.



(a) Ammonia



(b) sodium hydroxide



(c) Baking Soda

Fig.10.2 Some bases and salt

10.1 Concepts of Acids and Bases

1. Acids

The word acid is derived from a Latin word "**acidus**" which means sour. Acids have sour taste. It turns blue litmus paper red. It changes the colour of acid-base indicators. This reaction is demonstrated in Fig.10.3. Aqueous solution of acids conduct electric current and strong acids are very corrosive (destroy fabric and cause burns on the skin).



Fig.10.3 pH paper turns red in vinegar solution

2. Bases and Alkalis

A base is any metal oxide or hydroxide that reacts with an acid to produce salt and water. A water soluble base is called an alkali. In aqueous solution it produces hydroxide ions (OH^-). All alkalis are bases but all bases are not alkalis.

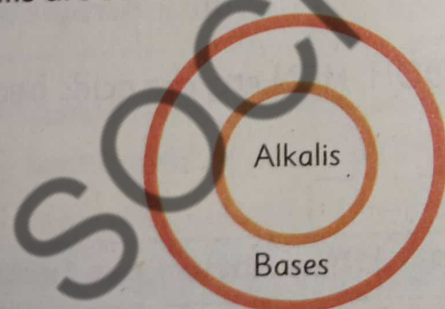


Fig.10.4 The venn diagram shows the relationship between bases and alkalis

Properties of Bases

Bases have bitter taste and feel soapy. It turns red litmus paper blue. It changes the colour of acid-base indicators. This reaction is demonstrated in Fig.10.5. Strong bases are corrosive and conduct electricity when dissolved in water.

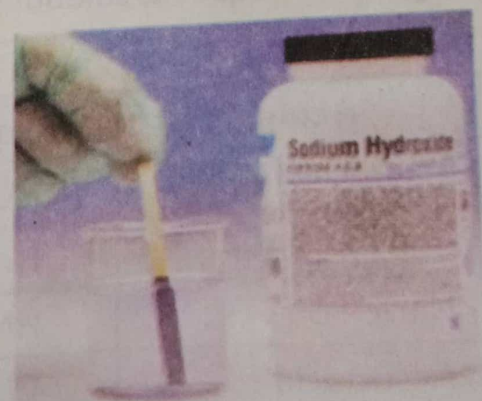


Fig.10.5 pH paper turns blue in the presence of sodium hydroxide solution

Activity 10.1

Reaction of Lemon Juice(acid) with Baking Soda

You will need: ■ A Balloon ■ A Soft drink bottle ■ Lemon Juice ■ Baking soda

Instructions

1. Before you start, make sure that you stretch out the balloon to make it as easy as possible to inflate.

2. Pour the lemon juice into the soft drink bottle.

3. Add the baking soda into balloon.

4. Put the balloon over the mouth of the bottle, and observe. What happened?

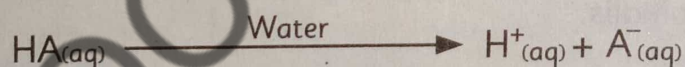
Write down your own observation and the reaction.



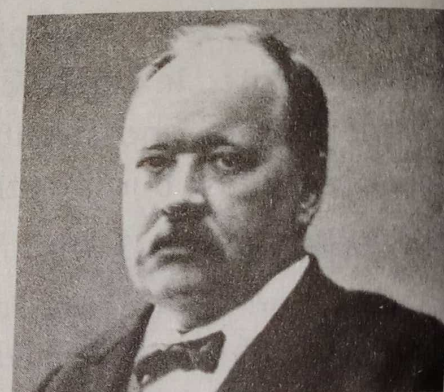
10.1.1 Arrhenius Concept of Acids and Bases

Svante Arrhenius, a Swedish chemist explained that aqueous solutions of acids and bases can conduct electric current by producing ions in aqueous solution. According to Arrhenius concept (1884), *An acid is a chemical substance that dissociates in aqueous solution to give hydrogen ions (H^+)*.

Generally the ionization of acids, take place as follows.



For example, substances such as HCl , H_2SO_4 , HNO_3 , CH_3COOH , HCN etc, are acids because they ionize in aqueous solutions to produce H^+ ions.



Svante Arrhenius

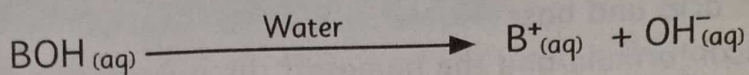
Table 10.1 Few Acids and Their Ionization

Acids	Formulae		Dissociation products
Hydrochloric acid	HCl	$\xrightarrow{\text{Water}}$	$\text{H}^+(\text{aq}) + \text{Cl}^-(\text{aq})$
Sulphuric acid	H_2SO_4	$\xrightarrow{\text{Water}}$	$\text{H}^+(\text{aq}) + \text{HSO}_4^-(\text{aq})$
Nitric acid	HNO_3	$\xrightarrow{\text{Water}}$	$\text{H}^+(\text{aq}) + \text{NO}_3^-(\text{aq})$
Acetic acid	CH_3COOH	$\xrightarrow{\text{Water}}$	$\text{CH}_3\text{COO}^-(\text{aq}) + \text{H}^+(\text{aq})$
Phosphoric acid	H_3PO_4	$\xrightarrow{\text{Water}}$	$3\text{H}^+(\text{aq}) + \text{PO}_4^{3-}(\text{aq})$

An Arrhenius base is a chemical substance that dissociates in aqueous solution to give hydroxide ions (OH^-). Most of the bases dissociate in a solution to release hydroxide ions. Other bases are substances that react with water to remove a hydrogen ion, leaving hydroxide ions in the solution. Generally the ionization of bases, take place as follows.

Tidbit

H^+ ion is unstable, so it reacts with H_2O to form hydronium ion (H_3O^+).



The substances such as NaOH , KOH , NH_4OH , $\text{Mg}(\text{OH})_2$, $\text{Ca}(\text{OH})_2$ etc, are bases because they ionize in aqueous solutions to provide OH^- ions.

Table 10.2 Few acids and their ionization

Acids	Formulae		Dissociation products
Sodium Hydroxide	NaOH	$\xrightarrow{\text{Water}}$	$\text{Na}^+_{(\text{aq})} + \text{OH}^-_{(\text{aq})}$
Potassium Hydroxide	KOH	$\xrightarrow{\text{Water}}$	$\text{K}^+_{(\text{aq})} + \text{OH}^-_{(\text{aq})}$
Ammonium Hydroxide	NH_4OH	$\xrightarrow{\text{Water}}$	$\text{NH}_4^+ + \text{OH}^-_{(\text{aq})}$
Magnesium Hydroxide	$\text{Mg}(\text{OH})_2$	$\xrightarrow{\text{Water}}$	$\text{Mg}^{2+}_{(\text{aq})} + 2\text{OH}^-_{(\text{aq})}$
Calcium Hydroxide	$\text{Ca}(\text{OH})_2$	$\xrightarrow{\text{Water}}$	$\text{Ca}^{2+}_{(\text{aq})} + 2\text{OH}^-_{(\text{aq})}$
Aluminum Hydroxide	$\text{Al}(\text{OH})_3$	$\xrightarrow{\text{Water}}$	$\text{Al}^{3+}_{(\text{aq})} + 3\text{OH}^-_{(\text{aq})}$

Summary of the Arrhenius concept

Acids give H^+ in water, bases give OH^- in water

Limitations of Arrhenius concept

The limitations of the Arrhenius concept are:

- Arrhenius concept is only limited to aqueous medium and does not explain the acidity and basicity of the substance in non-aqueous mediums.
- In Arrhenius concept acids are limited to hydrogen ion (H^+) only and bases are limited to hydroxide ion (OH^-). It cannot explain the acidic nature of carbon dioxide (CO_2) and basic nature of ammonia (NH_3).

Example 10.1

Which one(s) of the following is (are) Arrhenius acids and bases?

- (a) $\text{Ca}(\text{OH})_2$ (b) HNO_3 (c) NaOH (d) H_2SO_4 (e) KOH

Solution

- i. (b) and (d) are acids; they are the compounds which have the ability to donate hydrogen ion in an aqueous solution.
- ii. (a), (c) and (e) are bases; they are the compounds which have the ability to donate hydroxide ion (OH^-) in an aqueous solution.

Self Assessment

1. Define Arrhenius acid and base.
2. Write the chemical formula and the names of three Arrhenius acids and bases.
3. What are the limitations of the Arrhenius concept?

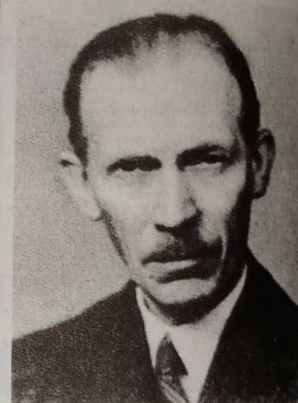
10.1.2 Bronsted-Lowry Concept of Acids and Bases

In 1923, the Danish chemist J. N. Bronsted and an English chemist T. M. Lowry independently expanded the Arrhenius acid and base definitions. According to this concept,

A Bronsted-Lowry acid is a substance (molecule or ion) that is a proton (H^+) donor, whereas a Bronsted-Lowry base is a substance (molecule or ion) that is a proton (H^+) acceptor.



T. M. Lowry

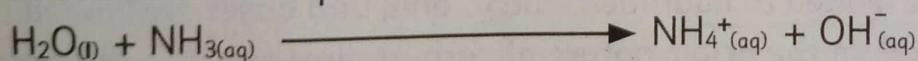


J. N. Bronsted



Hydrochloric acid acts as a Bronsted-Lowry acid when it reacts with ammonia. In this example, HCl donates a proton and acts as an acid, while ammonia (NH_3) accepts a proton to form ammonium ion (NH_4^+) and serves as a base.

Water can also act as a Bronsted-Lowry acid. For example, the following reaction, in which the water molecule donates a proton to the ammonia molecule.



In another example, water acts as a Bronsted-Lowry base as it accepts a proton from HCl , which act as an acid.



Therefore, water (H_2O) molecule acts both as an acid as well as a base (amphoteric).



Fig. 10.6 Hydrochloric acid gas combines with ammonia gas resulting in white smoke of solid ammonium chloride.

Some Arrhenius hydroxide bases, such as NaOH, are not Bronsted-Lowry bases. It is because these compounds are not proton acceptors whereas, the OH^- ion produced in a solution is the Bronsted-Lowry base because it is the species that can accept a proton.

Reading Check

1. Define Lowry – Bronsted acids and bases.
2. Differentiate between Arrhenius and Lowry – Bronsted acids and bases.

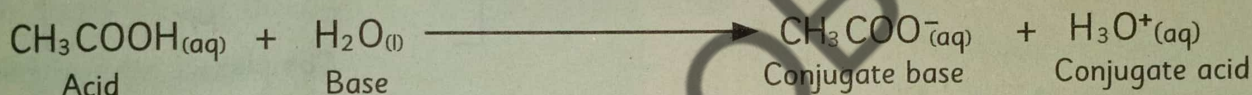
Summary of the Lowry – Bronsted concept

Acid is a proton (H^+) donor, base is a proton (H^+) acceptor

Tidbit

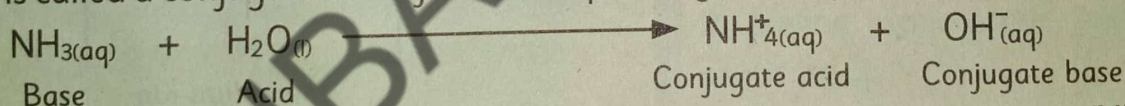
Conjugate Acids and Bases

When an acid gives a proton (H^+) it forms negatively charged species which can accept proton and act as a base and is called a Conjugate base of the corresponding acid e.g.



When acetic acid (CH_3COOH) loses a proton it forms CH_3COO^- ion which can take a proton and acts as a base and thus CH_3COO^- is called conjugate base of the acid (CH_3COOH).

When a base takes a proton then it forms positively charge species which can act as an acid and is called a conjugate acid of the corresponding base e.g.



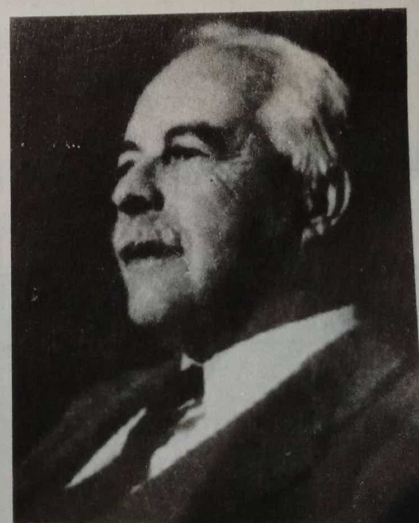
In this reaction ammonium ion (NH_4^+) is called a conjugate acid of ammonia (NH_3).

10.1.3 Lewis concept of acids and bases

The Arrhenius and Bronsted-Lowry definitions can explain most acids and bases. Both definitions believe that an acid contains or produces hydrogen ions or proton. A third classification of acids and bases was introduced in 1923 by G. N. Lewis. His definition emphasizes upon the role of electron pairs in an acid-base reactions.

Lewis acid is a species (ion, or molecule) that accepts or tends to accept a pair of electron.

Whereas, Lewis base is a species (ion or molecule) that donates or tends to donate a pair of electrons.



G. N. Lewis

Point to Ponder!

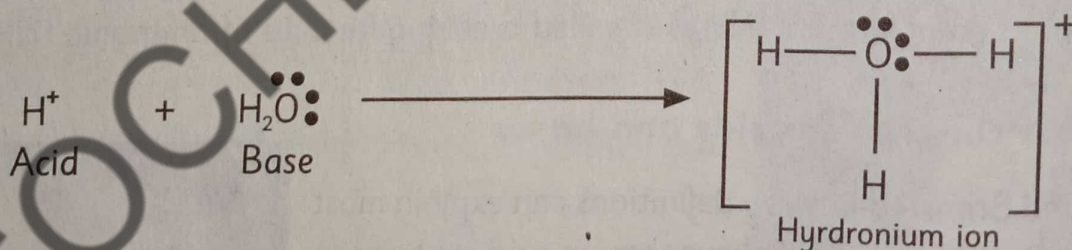
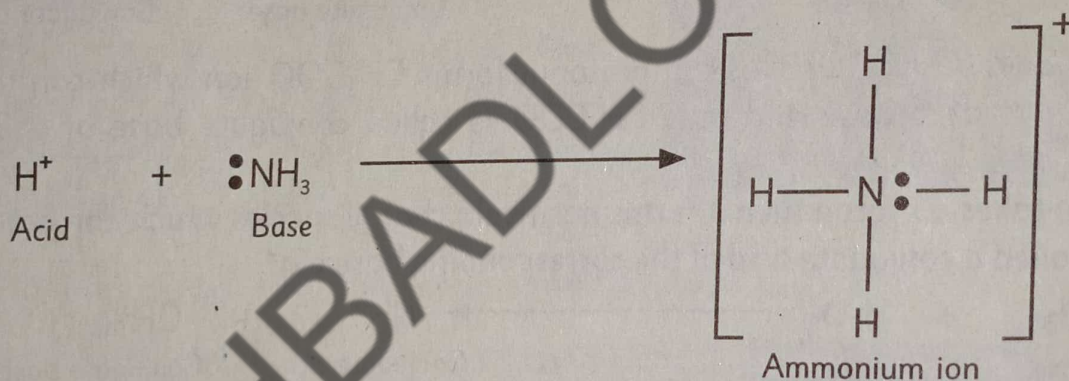
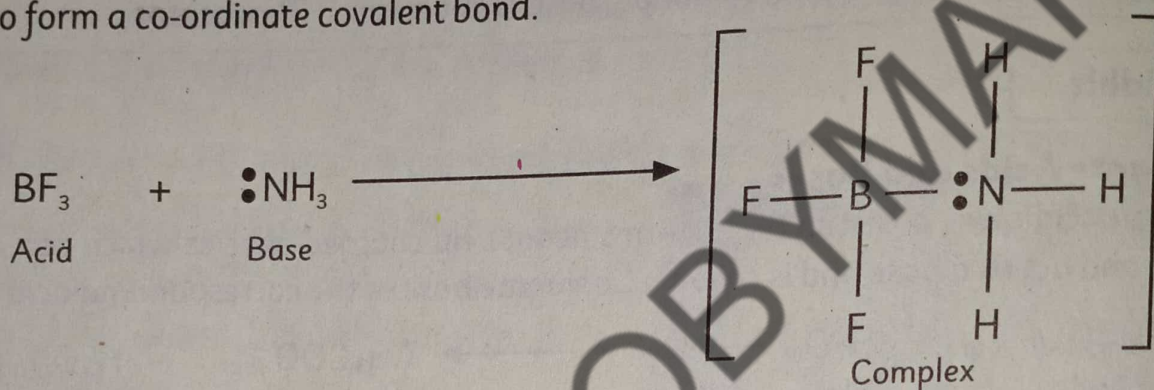
What is an alkali?

An acid-base reaction involves the donation of electrons pair from a base to an acid and forming a coordinate covalent bond.

Compounds having less than eight electrons in their valance shell or positively charged ions that can accept an electron pair can act as Lewis acids.

Whereas, compounds having lone pair of electrons in the valence shell or negatively charged ions that can donate an electron pair can behave as Lewis bases.

For example, An acid base reaction involves the donation of an electron pair from the base to an acid to form a co-ordinate covalent bond.



A comparison of the three acid-base definitions is given in Table 10.3

Table 10.3 Acid-Base Concept

Type of concept	Acid	Base
Arrhenius	H ⁺ or H ₃ O ⁺ producer	OH ⁻ producer
Bronsted-Lowry	proton (H ⁺) donor	proton (H ⁺) acceptor
Lewis	electron-pair acceptor	electron-pair donor

Society, Technology And Science

Analytical chemistry has applications forensic science, bio-analysis, clinical analysis, environment analysis, quality control of industrial manufacturing and materials analysis.

The areas in which analytical chemists work are as diverse as,

- Drug formation and development
- Process development
- Quality control /assurance
- Extraction and purification of raw compounds.
- Chemical or forensic analysis
- Product validation
- Toxicology

Types of acids

Acids can be classified in terms of number of protons that can be given by per molecule of an acid when added to water. Acids are classified as,

i. Mono-protic acids

ii. Poly-protic acids

i. Mono-protic acids

The acids which produce one proton per molecule are called monoprotic acids. For example, HCl , HNO_3 , HCN and CH_3COOH etc.

ii. Poly-protic acids

The acids which produce more than one proton per molecule are called polyprotic acid. For example, H_2SO_4 (diprotic acid), H_3PO_4 (triprotic acid) etc.

Reading Check

1. What are the characteristics of Lewis acids and bases?
2. Define mono-protic and poly-protic acids.

Types of bases

Bases are classified in terms of the OH^- that can be given by per molecule of base when added to water. The bases are classified as,

i. Mono-acid bases

ii. Poly-acid bases

i. Monoacid bases

The bases which produce one OH^- ion per molecule in an aqueous solution are called monoacid bases. For example: NaOH , KOH , NH_4OH etc are mono-acid bases, because these bases produce only one OH^- ion in an aqueous solution.

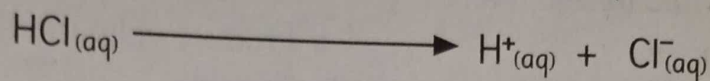
ii. Poly-acid bases

The bases which produce more than one OH^- ion per molecule in aqueous solution are called poly-acid bases. For example, $\text{Ba}(\text{OH})_2$, $\text{Ca}(\text{OH})_2$, $\text{Fe}(\text{OH})_3$, $\text{Al}(\text{OH})_3$ etc. these bases produce more than one OH^- per molecule.

Strength of Acids

Strong acid

A strong acid is one that ionizes completely in an aqueous solution and gives a higher concentration of H^+ ions. A strong acid is a strong electrolyte. For example, Hydrochloric acid (HCl) is a strong acid because when hydrochloric acid (HCl) is added into water, all the molecules of HCl are dissociated completely into $H^+_{(aq)}$ and $Cl^-_{(aq)}$ ions.



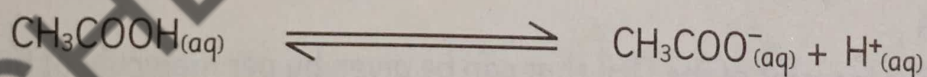
Some strong acids are,

Strong Acids	Chemical formula
Hydrochloric acid	HCl
Nitric Acid	HNO_3
Sulphuric Acid	H_2SO_4
Perchloric acid	$HClO_4$

Weak acid

The acids which do not completely dissociate in an aqueous solution and give lower concentration of H^+ ions are called weak acids. For example,

Acetic acid (CH_3COOH) is a weak acid because when Acetic acid is added into water, very few molecule of the CH_3COOH are dissociated.



Some weak acids are,

Weak Acids	Chemical formula
Nitrous Acid	HNO_2
Sulphurous Acid	H_2SO_3
Carbonic Acid	H_2CO_3
Phosphoric acid	H_3PO_4
Propanoic acid	C_2H_5COOH

Strength of Bases

Strong bases

The bases which completely dissociate in an aqueous solution and give a higher concentration of OH^- ions are called strong bases.

Some strong bases are,

Strong Bases	Chemical formula
Sodium Hydroxide	NaOH
Potassium Hydroxide	KOH
Lithium Hydroxide	LiOH

Weak bases

The bases which do not completely dissociate in an aqueous solution and give a lower concentration of OH^- ions are called weak bases.

Some weak bases are,

Weak bases	Chemical formula
Ammonium Hydroxide	NH_4OH
Calcium Hydroxide	$\text{Ca}(\text{OH})_2$
Aluminium Hydroxide	$\text{Al}(\text{OH})_3$

Interesting facts

Some acids like Hydrochloric Acid (HCl), Hydrobromic Acid (HBr), Nitric acid (HNO_3), Sulphuric Acid (H_2SO_4), Phosphoric Acid (H_3PO_4), Carbonic Acid (H_2CO_3) etc. are known as mineral acids and some acids like Formic Acid (HCOOH), Acetic acid (CH_3COOH), Propanoic Acid ($\text{C}_2\text{H}_5\text{COOH}$) etc., are called organic acids.

Self Assessment

1. Define weak and strong acids and bases.
2. Why NH_3 acts as a Lewis base?
3. Write some examples of Lewis acids and bases.
4. What are mono-acid bases and poly acid bases?

Society, Technology And Science

Explain process of etching in art and industry

Etching is the process of using a strong acid to cut the unprotected part of a metal or glass surface to create a design or an image by cutting, carving or engraving into a flat surface.

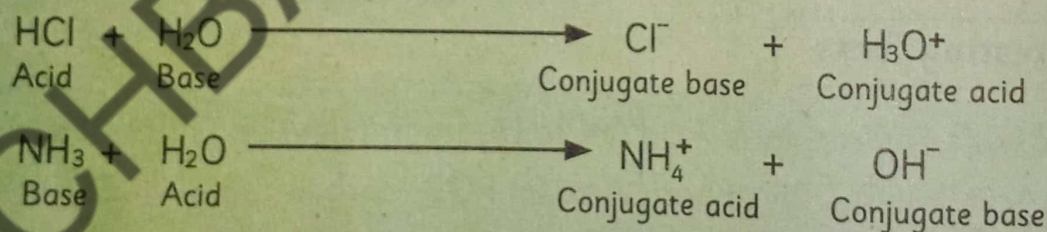
In the process of etching, a metal or glass is covered with wax, which is resistant to an acid. The artist then scratches off the ground with a pointed etching needle where the artist wants a line to appear on the finished piece, so exposing that part of metal or glass. The plate is then dipped on a bath of an acid. The acid bites into the plate, where it is exposed, leaving behind lines sunk into the plate. The remaining ground is then cleaned off the plate. The plate is inked all over and then the ink is wiped off the surface, leaving only the ink in the etched lines.

This plate is then put in a printing press together with a sheet of paper. The paper picks up the ink from the etched lines, making a print. This process is repeated many times in order to prepare a quality artwork.

Tidbit**Amphoteric Substances**

Those substances which can act both as an acid and a base are called amphoteric substances e.g. water.

When water is treated with an acid it acts as a base but when it is treated with a base, it acts as an acid e.g. HCl

**Self-Ionization or auto ionization of Water**

Electrical-conductivity experiments have shown that pure water is an extremely weak electrolyte. Water undergoes self-ionization to a very small extent. Pure water contains equal number of hydrogen ion (H^+) and hydroxide ions (OH^-) as shown in the model in Fig. 10.7.

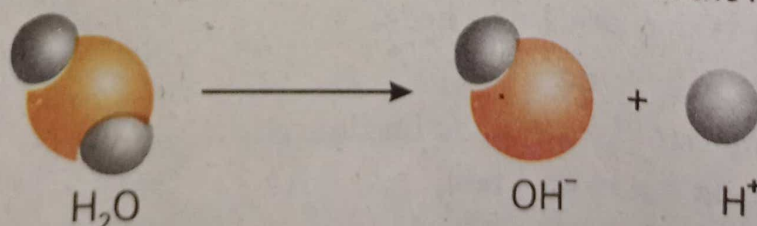
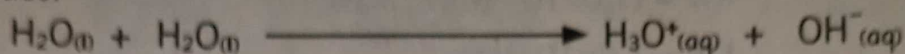


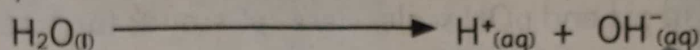
Fig. 10.7 Self-ionization of water

In the **self-ionization of water or auto ionization**, two molecules of water produce a hydronium ion (H_3O^+) and a hydroxide ion (OH^-) by the transfer of a proton. Pure water contains equal number of hydronium ion (H_3O^+) and hydroxide ions (OH^-). The following reaction takes place.



The reaction in which two water molecules produce ions is called as the self-ionization or auto ionization of water.

In order to understand the concept of self-ionization of water, we take one molecule of water and its dissociation at 25°C , as



The equilibrium expression of this reaction may be written as,

$$K_c = \frac{[\text{H}^+][\text{OH}^-]}{[\text{H}_2\text{O}]}$$

As concentration of water (H_2O) is almost constant, so the above equation may be written as,

$$K_c \cdot [\text{H}_2\text{O}] = [\text{H}^+][\text{OH}^-]$$

Where,

$$K_c \cdot [\text{H}_2\text{O}] = K_w$$

The mathematical product of $[\text{H}^+]$ and $[\text{OH}^-]$ remains constant in water and dilute aqueous solutions at a constant temperature. This constant mathematical product is called the ionization constant of water, K_w , and is expressed by the following equation. So, we can write the above equation as,

$$K_w = [\text{H}^+][\text{OH}^-]$$

Conductivity experiments show that the product of concentrations of H^+ and OH^- ions in pure water is always $1.0 \times 10^{-14} \text{ mol/dm}^3$ of water at 25°C and is called water dissociation constant ' K_w '.

$$K_w = [\text{H}^+][\text{OH}^-] = 1.0 \times 10^{-14} \text{ mol/dm}^3 \text{ of water at } 25^\circ\text{C}$$

As we know that one molecule of water produces one H^+ and one OH^- ion on dissociation. Therefore, we can say that,

$$[\text{H}^+][\text{OH}^-] = 1.0 \times 10^{-14}$$

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

or

$$[\text{H}^+][\text{H}^+] = 1.0 \times 10^{-14}$$

$$[\text{H}^+]^2 = 1.0 \times 10^{-14}$$

$$\sqrt{[\text{H}^+]^2} = \sqrt{1.0 \times 10^{-14}}$$

Therefore,

$$[\text{H}^+] = 1.0 \times 10^{-7}$$

and

$$[\text{OH}^-] = 1.0 \times 10^{-7}$$

In water at 25°C,

$$[\text{H}^+] = 1.0 \times 10^{-7} \text{ M and } [\text{OH}^-] = 1.0 \times 10^{-7} \text{ M.}$$

$$K_w = [\text{H}^+][\text{OH}^-]$$

$$K_w = (1.0 \times 10^{-7} \text{ M})(1.0 \times 10^{-7} \text{ M})$$

$$K_w = 1.0 \times 10^{-14} \text{ M}^2$$

10.2 The pH and pOH Scale

Soren Peter Lauritz Sorenson, in 1909, proposed a scale for the measurement of strength of acids and bases called pH and pOH scale. Here “p” stands for “potenz” (the potential to be) and H^+ stands for hydrogen ion and OH^- stands for hydroxyl ion. The pH scale measures the acidic or basic nature of solution. It ranges from 0 (zero) to 14. The acidity or basicity of an aqueous solution depends upon the relative numbers of hydrogen ions (H^+) and hydroxide ions (OH^-) present in it.

The pH of a solution is defined as the negative logarithm of the molar hydrogen ion $[\text{H}^+]$ concentration $[\text{H}^+]$. The pH is expressed by the following equation.

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

According to this scale, pH of water is calculated as,

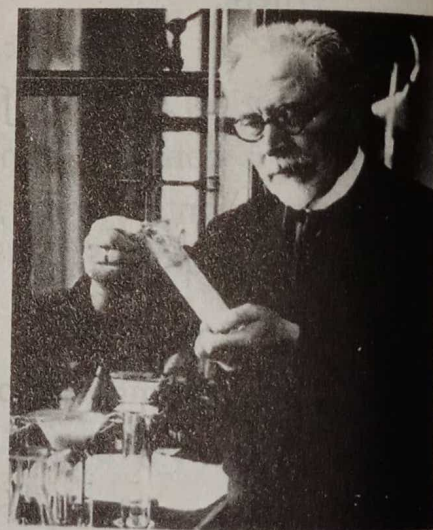
$$\text{pH} = -\log [\text{H}^+]$$

Putting the value of $[\text{H}^+]$,

$$\text{pH} = -\log [1.0 \times 10^{-7}]$$

$$\text{pH} = -(-7.0) \log 10 \quad \log 10 = 1$$

$$\text{pH} = 7.0$$



Soren Peter Lauritz Sorenson

The relationship between the pH and $[\text{H}^+]$ is shown on the scale in Fig.10.8.

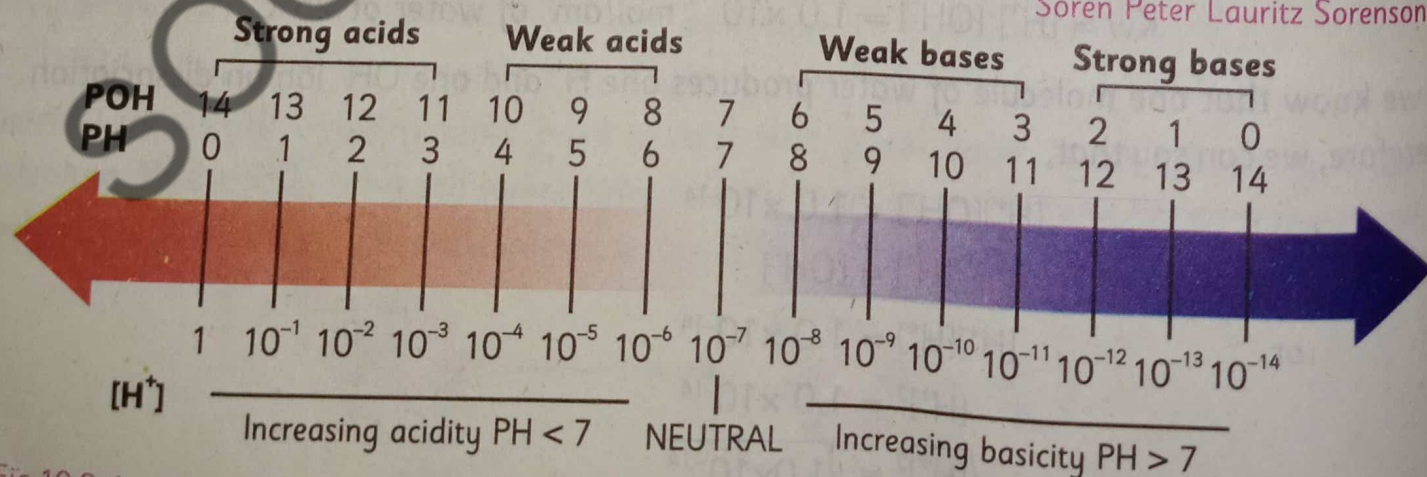


Fig.10.8 As the concentration of hydrogen ions increases, the solution becomes more acidic and the pH decreases and vice versa.



Fig.10.9 The pH value of common substances

Likewise, the pOH of a solution is defined as the negative of logarithm of the molar hydroxide ion concentration, $[\text{OH}^-]$.

$$\text{pOH} = -\log[\text{OH}^-]$$

$$\text{pOH} = -\log [1.0 \times 10^{-7}]$$

$$\text{pOH} = -(-7.0) \log 10$$

$$\text{pOH} = 7.0$$

$$\log 10 = 1$$

A neutral solution at 25°C has a $[\text{OH}^-]$ of $1.0 \times 10^{-7} \text{ M}$.

Therefore, the pOH is 7.0. Remember that the values of $[\text{H}^+]$ and $[\text{OH}^-]$ are related by K_w .

The negative logarithm of K_w at 25°C , 1.0×10^{-14} , is 14.0. You may have noticed that the sum of the pH and the pOH of a neutral solution at 25°C is also equal to 14.0. The following relationship is true at 25°C .

For a neutral solution

$$\text{pH} + \text{pOH} = 14.0$$

$$7.0 + 7.0 = 14$$

At 25°C the range of pH values of aqueous solutions generally falls between 0 and 14, as shown in Table 10.4

Table 10.4 Approximate pH Range of Some Common Materials (at 25°C)

Material	pH	Material	pH
Gastric juice	1.0–3.0	Bread	5.0–6.0
Lemons	2.2–2.4	Rainwater	5.4–5.8
Vinegar	2.4–3.4	Potatoes	5.6–6.0
Soft drinks	2.0–4.0	Milk	6.3–6.6
Apples	2.9–3.3	Saliva	6.5–7.5
Grapefruit	3.0–3.3	Pure water	7.0
Oranges	3.0–4.0	Blood	7.3–7.5
Cherries	3.2–4.0	Eggs	7.6–8.0
Tomatoes	4.0–4.4	Sea water	8.0–8.5
Bananas	4.5–5.7	Milk of magnesia	10.5

Reading Check

1. Define pH and pOH.

2. What is K_w ?

Explain Stomach, Acidity

During the digestion process, various organs secrete numerous enzymes, which help in digestion. Stomach secretes Gastric juice. This fluid contains hydrochloric acid (HCl), which is a strong acid, has a pH of 1 to 2. In addition to that, it contains potassium chloride (KCl) and sodium chloride (NaCl). This digestive fluid plays an important role in the digestion of protein by activating digestive enzymes.

Sometimes, when we take food which are rich in acids, such as fats and proteins, which are composed of fatty acids and amino acids etc, they cause stomach acidity, also called hyperacidity. Medicines such as magnesium hydroxide, $Mg(OH)_2$ and aluminium hydroxide, $Al(OH)_3$, which are weak bases are used as antacids. These antacids neutralize the acids and the person feels relief from the feeling of burning stomach in the gastro intestinal tract or heart burning.

Example 10.2

Calculate the pH and pOH of 0.001 M solution of nitric acid (HNO_3).

Solution

$$\text{Hydrogen ion concentration} = [H]^+ = 0.001 = \frac{1}{1000} = [10^{-3}]$$

$$pH = -\log[H]^+$$

putting the value,

$$pH = -\log [10^{-3}]$$

$$pH = -(-3) \log 10$$

$$pH = 3$$

$$\log 10 = 1$$

as we know that,

$$pH + pOH = 14$$

To calculate pOH, rearranging the above equation, we get

$$pOH = 14 - pH$$

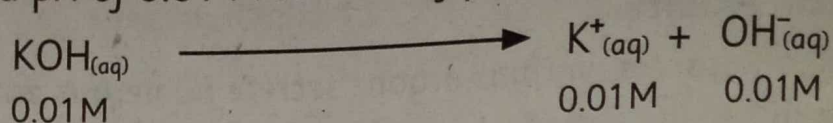
putting the value,

$$pOH = 14 - 3 = 11$$

$$pOH = 11$$

Example 10.3

Calculate the pOH and pH of 0.01 M solution of potassium hydroxide (KOH).

Solution

$$\text{Hydroxide ion concentration} = [\text{OH}]^- = 0.01 = \frac{1}{100} = [10^{-2}]$$

$$\text{pOH} = -\log[\text{OH}]^-$$

putting the value,

$$\text{pOH} = -\log [10^{-2}]$$

$$\text{pOH} = -(-2) \log 10$$

$$\text{pOH} = 2$$

as we know that, $\text{pH} + \text{pOH} = 14$

To calculate pH, rearranging the above equation, we get'

$$\text{pH} = 14 - \text{pOH}$$

putting the value,

$$\text{pH} = 14 - 2$$

$$\text{pH} = 12$$

$$\log 10 = 1$$

Tidbit

An indicator (litmus) can tell whether a substance is an acid, base (alkaline) or neutral but a universal indicator can also tell the strength of an acid or base (alkali).

Neutral, Acidic, and Basic Solutions

When the concentration of hydrogen ion and hydroxide ion is equal in a solution, as in pure water, it is called a neutral solution.

Thus, any solution in which $[\text{H}]^+ = [\text{OH}]^-$ is neutral.

As stated earlier, the $[\text{H}]^+$ and the $[\text{OH}]^-$ of a neutral solution at 25°C are equal to $1.0 \times 10^{-7} \text{ M}$ each.

$$[\text{H}^+] = [\text{OH}^-] = 1 \times 10^{-7} \text{ M.}$$

Acids increase the concentration of hydrogen ion $[\text{H}]^+$ in aqueous solutions, as shown in Fig. 10.10(a).

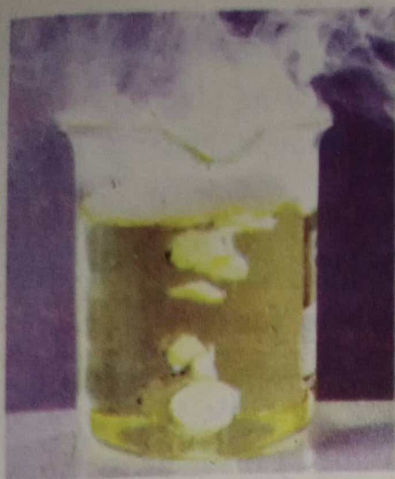
Solutions in which the concentration of hydrogen ion $[\text{H}]^+$ is greater than the concentration of hydroxide ion $[\text{OH}]^-$ are called acidic solutions.

When the $[\text{H}^+]$ is greater than $1.0 \times 10^{-7} \text{ M}$, the solution is acidic. Therefore, a solution containing $1.0 \times 10^{-5} \text{ mol H}^+ \text{ ion/dm}^3$ at 25°C is acidic because 1.0×10^{-5} is greater than 1.0×10^{-7} .

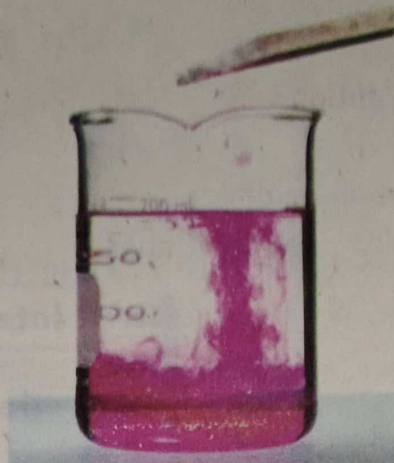
When the $[\text{OH}^-]$ is greater than $1.0 \times 10^{-7} \text{ M}$, the solution is basic.

Bases increase the concentration of hydroxide ion $[\text{OH}^-]$ in aqueous solutions, as shown in Fig. 10.10(b). In basic solutions, the concentration of hydroxide ion $[\text{OH}^-]$ is greater than the hydrogen ion $[\text{H}]^+$.

Therefore, a solution containing $1.0 \times 10^{-4} \text{ mol OH}^- \text{ ions/dm}^3$ at 25°C is basic because 1.0×10^{-4} is greater than 1.0×10^{-7} .



(a)



(b)

Fig.10.10 (a) Addition of HCl to water increases the $[\text{H}^+]$, which is shown by the colour change of the indicator Bromothymol blue to yellow.

(b) Addition of sodium hydroxide to water increases the $[\text{OH}^-]$, which is shown by the colour change of the indicator phenolphthalein to pink.

Activity 10.2

Testing the pH of household items

Materials: Red and Blue litmus paper and pH paper

Detergents, Table salt, Milk, Dishwashing soap, Tomato juice, Egg, Banana, Vinegar, Lemon juice, Carbonated drinks, tap water and shampoo.

Test tube	Solution	Blue litmus colour	Red litmus colour	pH paper colour
1	Detergents			
2	Table salt			
3	Milk			
4	Dishwashing soap			
5	Tomato juice			
6	Egg			
7	Banana			
8	Vinegar			
9	Lemon juice			
10	Carbonated drinks			
11	Tap water			
12	Shampoo			

Conclusions

- Which of the household solutions are acids? Which are bases? How can you determine?
- Describe how acids and bases affect the colour of blue and red litmus.
- Discuss the advantages and disadvantages of litmus paper and pH paper. Which indicator do you think is better?

Self Assessment

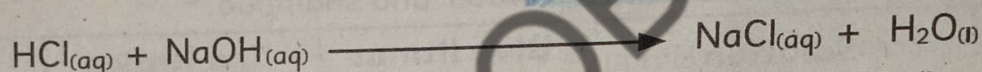
1. What is the pH of a neutral solution?
2. What is the pH of a strong acid?
3. Which ion is always present in an acid?
4. What colour change do acids cause with litmus?

Neutralization Reactions

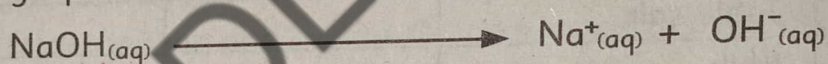
Neutralization is a chemical reaction in which an acid and a base react with each other to form water and salt.

For example,

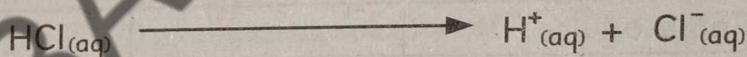
An acid-base reaction occurs in an aqueous solution between hydrochloric acid and sodium hydroxide. The equation for this reaction is written as follows.



In an aqueous solution containing 1 mol of sodium hydroxide, (NaOH), dissociates as represented by the following equation.



A solution containing 1-mol of hydrochloric acid (HCl), ionizes as represented by the following equation.



If the two solutions are mixed, as in Figure 10.11, a reaction occurs between the aqueous ions. Notice that sodium chloride (NaCl) and water are produced. The overall ionic equation is shown below.

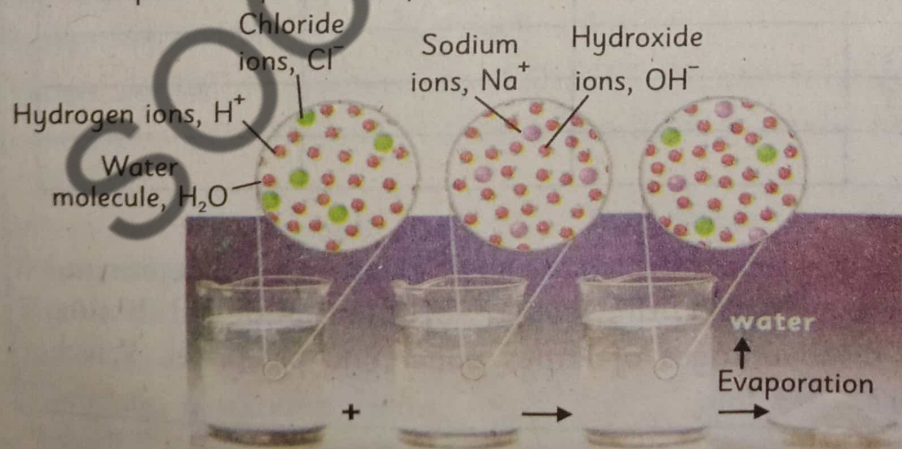
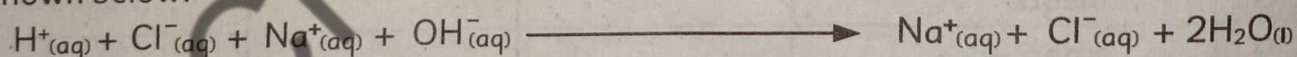
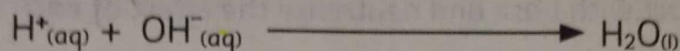


Fig. 10.11 When aqueous hydrochloric acid, (HCl) reacts with aqueous sodium hydroxide, (NaOH), the reaction produces aqueous sodium chloride, (NaCl). Ions that are present in each solution are represented by the models.

Interesting facts

Bee stings are **acidic** in nature; a household remedy for a bee sting is baking soda or sodium bicarbonate, which is a **basic** substance. A **wasp sting**, on the other hand, is mildly basic; a household remedy for this will be vinegar, also known as acetic acid.

As they appear on both sides of the overall ionic equation, Na^+ and Cl^- are called spectator ions. The only participants in the reaction are the hydrogen ions and the hydroxide ions, as shown in the following net ionic equation.



There are equal number of H^+ and OH^- ions in this reaction and they are fully converted into water. In aqueous solutions, **neutralization** is the reaction of hydrogen ions and hydroxide ions to form water molecules.

Self Assessment

1. Define self-ionization of water.
2. Differentiate between 'pH' and 'pOH'?
3. Write the neutralization reaction with examples.
4. On pH scale, identify the acidic, neutral and basic reagents.
5. Define neutralization reaction?

10.3 Salts

A compound formed due to the neutralization reaction of an acid and a base is called a salt. A salt consists of positive ion from the base and negative ion from the acid. For example, sodium chloride, (NaCl) is composed of sodium (metal) positive ion (Na^+) and chloride (non-metal) ion (Cl^-).

Some metal positive ions (Na^+ , K^+ , Ag^+ , Mg^{++} , Ca^{++})

Some negative ions (Cl^- , Br^- , SO_4^{--2} , PO_4^{--3})

Sodium chloride, (NaCl), silver bromide (AgBr), potassium sulphate (K_2SO_4) and ferric phosphate (FePO_4) etc are examples of salts.

10.3.1 Preparation of Salts

These are two types of salts.

(i). Soluble salts

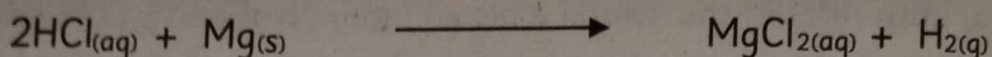
(ii). Insoluble salts

1. Preparation of Soluble Salts

Soluble salts can be prepared by four different methods, whereas, insoluble salts have only one preparation method. Soluble salts are usually prepared in water. Therefore, these salts are recovered by evaporation or crystallization processes.

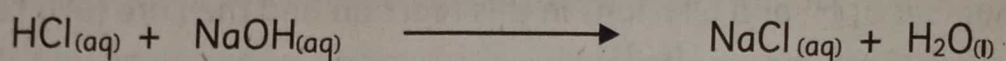
i. By the Action of an Acid and a Metal (Direct Displacement Method)

In this method of preparation hydrogen ion of an acid is replaced by a reactive metal to produce respective salt and hydrogen gas. For example, magnesium (Mg), Calcium (Ca), Zinc (Zn) etc.



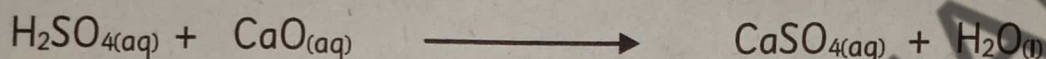
ii. By the Reaction of an Acid and Base (Neutralization Method)

In this method, acid react with base and neutralize the effect of each other to produce salt and water. For example,



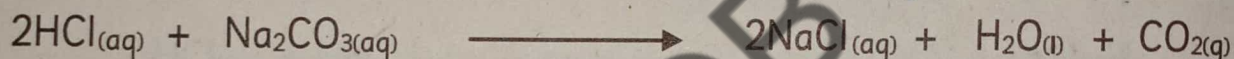
iii. By the Action of an Acid and Metallic Oxide

The metallic oxide such as copper oxide (CuO), Calcium oxide (CaO) etc. reacts with dilute acids to form salt and water.



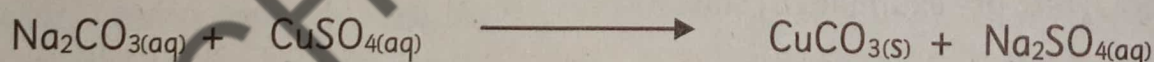
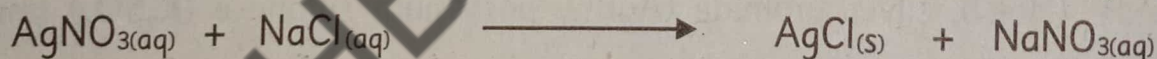
iv. By the Action of an Acid and a Carbonate

Dilute acids react with metallic carbonate such as sodium carbonate (Na_2CO_3) or metallic hydrogen carbonate (NaHCO_3) to produce salt, water, and carbon dioxide (CO_2).



2. Preparation of Insoluble Salts (Precipitation Method)

Insoluble salts are usually obtained during a chemical reaction. Solutions of soluble salts are mixed and as a result an insoluble salt is formed. During the reaction exchange of ionic radicals (i.e. metallic radicals of salts) take place and two new salts are produced. One salt is insoluble and the other is usually soluble. The insoluble salt precipitates at the bottom of the solution.



10.3.2 Types of salts

The main types of salts are,

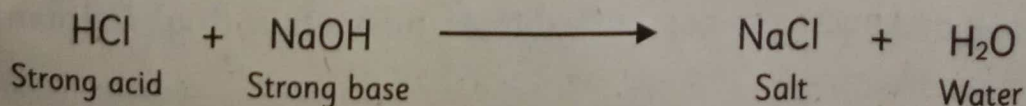
i. Neutral Salts

ii. Acidic salts

iii. Basic salts

i. Neutral Salts

These salts are formed when the hydrogen ions of an acid are **completely** replaced by metal ions or a group of atom, behaving like metal ions. Usually a neutral salt is formed when a strong acid and a strong base is neutralized in the reaction. For example, sodium chloride is formed from sodium hydroxide and hydrochloric acid.



For example, NaCl is the neutralization product of HCl and NaOH.

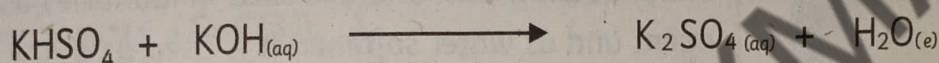
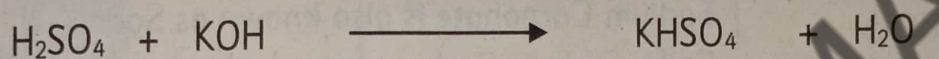
Similarly, potassium sulphate, sodium sulphate, sodium carbonate, ammonium sulphate, sodium phosphate etc. are other examples of normal salts.

ii. Acidic Salts

Salts formed when hydrogen ions of an acid are **partially** replaced by metal ions or group of atoms behaving like metal ions are called acidic salts.

For example, KHSO_4 , NaHCO_3 , $(\text{NH}_4)_2\text{HPO}_4$ etc are acidic salts. These salts can further react with bases forming neutral salts.

Acidic Salts are formed by Polybasic acids only.



iii. Basic Salts

Salts formed when OH^- ions of a base are **partially** neutralized by an acid are called basic salts.

For example, $\text{Pb}(\text{OH})\text{Cl}$, $\text{Cu}(\text{OH})\text{Cl}$



Basic salts are produced by poly acid bases.

Tidbit

Double salts

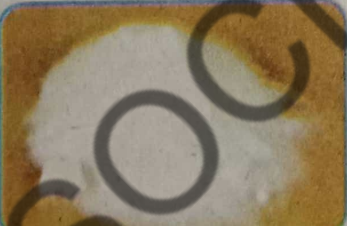
Double salts are formed by combination of two normal salts. When the mixture of equimolar saturated solution of normal salts is crystallized they produce the double salts. In these salts the individual salts components (ions) retain their properties. The anions and cations give their respective tests. For example, potash alum, $\text{K}_2\text{SO}_4 \cdot \text{Al}_2(\text{SO}_4)_3 \cdot 24\text{H}_2\text{O}$, Ferric alum $(\text{K}_2\text{SO}_4) \cdot \text{Fe}_2(\text{SO}_4)_3 \cdot 24\text{H}_2\text{O}$, Mohr's salt, $\text{FeSO}_4 \cdot (\text{NH}_4)_2\text{SO}_4 \cdot 6\text{H}_2\text{O}$ etc.

Reading Check

Define salt, with example.

10.3.3 Uses of some salts

Salts are used in different ways ranging from house hold to industry. Sodium Chloride (NaCl) is necessary for human life. Calcium Phosphate, $\text{Ca}_3(\text{PO}_4)_2$ is the main component of bones. Some salts and their uses are given below:

Name of salt	Common and industrial Uses
1. Sodium Chloride (NaCl) 	Sodium Chloride is used for seasoning and preserving food. In industry it is used as basic raw material for the extraction of sodium metal, preparation of caustic soda (NaOH), washing soda (Na₂CO₃) etc. One of the major application of sodium chloride is de-icing of roadways in sub-freezing weather.
2. Sodium Carbonate (Na₂CO₃) 	Sodium Carbonate is also known as Soda Ash or Washing Soda. Sodium Carbonate is used in laundries as a cleaning agent and as water softener. It is used as a raw material in glass manufacturing. It is also used in the paper, petroleum refining and leather industry.
3. Sodium Sulphate (Na₂SO₄) 	Sodium Sulphate is used in the manufacture of paper, detergents and glass etc.
4. Sodium Bicarbonate NaHCO₃) 	Sodium Bicarbonate or Sodium Hydrogen Carbonate is also known as baking soda as it is used in the preparation of cakes and other confectionaries. It is also used as a medicine, as an Antacid, and also in toothpastes etc.
5. Potassium Nitrate (KNO₃) 	Potassium Nitrate is used as a fertilizer and for the manufacture of flint glass.

6. Potash Alum or Alum $(K_2SO_4 \cdot Al_2(SO_4)_3 \cdot 24H_2O)$ 	Potash alum or Alum is used in the purification of water to remove the suspended impurities and as a blood coagulant.
7. Calcium Sulphate ($CaSO_4 \cdot 2H_2O$) 	Calcium Sulphate is commonly known as gypsum. It is used as fertilizer in the preparation of plaster of paris, and in cement industry.
8. Calcium Carbonate ($CaCO_3$) 	Calcium Carbonate is used in the preparation of cement and in ceramics industry.
9. Magnesium Sulphate or Epsom Salt ($MgSO_4 \cdot 7H_2O$) 	Magnesium Sulphate is used as antacid and laxative. This salt is also used in dye industry.
10. Copper Sulphate ($CuSO_4 \cdot 5H_2O$) 	Copper Sulphate is used for copper plating in electroplating process. This salt is also used to kill algae in water reservoirs. It is also used in agricultural spray.

Tidbit

Titration is a laboratory method of quantitative chemical analysis. It is the slow addition of one solution of a known concentration (called a titrant) to a known volume of another solution of unknown concentration until the reaction reaches neutralization indicated by a colour change of an indicator.

Self Assessment

1. Write examples of acidic, basic and neutral salts.
2. List five uses of salts.

Key Points

- According to the Arrhenius concept, an acid is a chemical substance that dissociates in an aqueous solution to give hydrogen ions (H^+), while a base is a chemical substance that dissociates in an aqueous solution to give hydroxide ions (OH^-).
- According to Bronsted-Lowry, an acid is a substance (molecule or ion) that is a proton (H^+) donor, whereas a base is a substance (molecule or ion) that is a proton (H^+) acceptor.
- Lewis acid is a substance (ion or molecule) that accepts or tends to accept an electron pair to form a co-ordinate covalent bond, whereas, a Lewis base is a substance (ion or molecule) that donates or tends to donate an electron pair to form a co-ordinate covalent bond.
- The acids which produce one proton per molecule are called monoprotic acids.
- The acids which produce more than one proton per molecule are called polyprotic acid.
- The bases which produce one OH^- ion per molecule in an aqueous solution are called monoacid bases.
- The bases which produce more than one OH^- ion per molecule in an aqueous solution are called poly-acid bases.
- A strong acid is one that ionizes completely in an aqueous solution and gives higher concentration of H^+ ions.
- The acids which do not completely dissociate in an aqueous solution and give lower concentration of H^+ ions are called weak acids.
- The bases which completely dissociate in an aqueous solution and give more OH^- ions, are called strong bases.
- The bases which do not completely dissociate in an aqueous solution and give less OH^- ions, are called weak bases.
- The reactions in which two water molecules produce ions is called the self-ionization or auto ionization of water.
- The pH of a solution is defined as the negative logarithm of the molar hydrogen ion $[H^+]$ concentration.
- pOH of a solution is defined as the negative logarithm of the molar hydroxide ion $[OH^-]$ concentration.
- Neutralization is a chemical reaction in which an acid and a base react with each other to form water and salt.
- Salts are ionic compounds generally formed by the neutralization of an acid with base.

Exercise

A. Choose the Correct Option.

1. According to the Arrhenius concept, which of the following is not an acid,
 a. HCl b. H_2SO_4 c. CO_2 d. HNO_3
2. AlCl_3 is an acid according to,
 a. Arrhenius b. Lowry and Bronsted c. Lewis d. all of these
3. Which of the following is a Lewis base?
 a. HCl b. AlCl_3 c. BF_3 d. F^-
4. Neutral solution has a pH value of
 a. 3 b. 5 c. 7 d. 14
5. The pOH of 0.001M solution of nitric acid is
 a. 0.001 b. 10.0 c. 11 d. 14
6. When a strong base and weak acid reacts, the only products are,
 a. neutral salt and water b. basic salt and water
 c. acidic salt and water d. acidic, basic salt and water
7. NH_3 is a base according to
 a. Arrhenius b. Lowry and Bronsted c. Lewis d. both b and c
8. Which one of the following is a basic salt?
 a. KCl b. NaCl c. $\text{Pb}(\text{OH})\text{Cl}$ d. KHSO_4
9. The bases which are soluble in water are called
 a. Acids b. Alkalies c. Salts d. Amphoteric substances
10. The example of weak acid is
 a. HNO_3 b. CH_3COOH c. HCl d. H_2SO_4

B. Short questions

1. When a clear liquid is placed in a beaker. How can you identify it as an acid, base or neutral (water)?
2. Justify H^+ ion as a Lewis acid?
3. Distinguish strong acids from weak acids. Give two examples of each.
4. Compare the physical properties of acids and bases.
5. A carbonated drink has $[\text{H}^+] = 3.2 \times 10^{-3} \text{ M}$, classify the drink as neutral, acidic or basic with reason.
6. Write the chemical name of an acid present in the following:
 (a). Apple (b). Grape Juice (c). Lemon Juice (d). Sour milk

7. What determines the strength of a base? Give one example of each solution that are strongly and weakly basic.
8. Calculate the pH and pOH of 0.5M solution of HCl. (pH = 0.301, pOH = 13.69)
9. Calculate the pOH of 0.005M H_2SO_4 . (pOH = 11.699)
10. Calculate the pH of 0.2M solution of NaOH. (pH = 13.30)

C. Long questions

1. (a). What is salt?
(b). Write down the different types of salts with examples.
2. (a). Define the auto-ionization of water. How can you find the pH of water?
(b). Why some acids are called monoprotic, diprotic and polyprotic acids? Explain your answer with suitable examples.
3. (a). Discuss the concept of Lewis acids and bases with examples.
(b). Give the Bronsted - Lowry definition of acids and bases. Write equations that explain the definition.
4. Below are two equations showing how two alkalis react with water.

$$\text{NaOH}_{(\text{aq})} + \text{H}_2\text{O}_{(\text{l})} \rightleftharpoons \text{Na}^+_{(\text{aq})} + \text{OH}^-_{(\text{aq})}$$

$$\text{NH}_3_{(\text{aq})} + \text{H}_2\text{O}_{(\text{l})} \rightleftharpoons \text{NH}_4^+_{(\text{aq})} + \text{OH}^-_{(\text{aq})}$$
 (a). Name both the alkalis.
 (b). Which is classified as weak alkali and why?
 (c). What is the likely pH of each alkali?
5. (a). Write the balanced neutralization reaction of,
 - (i). Strong acid and Strong base
 - (ii). Strong acid and Weak base
 - (iii). Weak acid and Strong base
 - (iv). Weak acid and weak base
 (b). Define pH and pOH.
6. (a). According to your understanding which one of the three acid definitions is the broadest? Explain.
(b). Write the uses of any three salts.

Project

- i. Get some pH paper from your science teacher. Find out whether the soil around your house is acidic or basic.
- ii. Find out the colour change of any three indicators in acidic and basic solutions.