Study of Acids, Bases and Salts

Acids

Acids are substances having a sour taste. The word 'acid' comes from a Latin word '***acidous'***, which means sour.

Classification of Acids:

- **Based on the source:**

Organic acids: Orange, tamarind, raw mango, etc. are sour in taste. Therefore, these contain substances that are acidic in nature. Such acids are known as organic acids. These acids are found in plants. Carbon atoms are also present in such acids besides hydrogen atoms.

The given table lists some organic acids.

Acid	Substance
Acetic acid	Vinegar
Citric acid	Lemon, orange
Tartaric acid	Tamarind, grapes
Ascorbic acid (Vitamin C)	All citrus fruits
Lactic acid	Milk, yoghurt
Malic acid	Apple and Pear
Formic acid	Ant Sting

Mineral/Inorganic acids: These are inorganic acids and are obtained from minerals. Therefore, these acids are called mineral acids. These are acids that dissociate to give a proton. Carbon atoms are not present in such acids.

Some examples of mineral acids are given in the following table.

Hydrochloric acid	HCl
Nitric acid	HNO_3

Sulphuric acid	H_2SO_4
Sulphurous acid	H_2SO_3
Carbonic acid	H_2CO_3

When HCl is added to water, it gives H^+ and Cl^- ions. The chemical equation for the process is:

$$HCl \longrightarrow H^+ + Cl^-$$

Similarly, sulphuric acid gives two protons and one sulphate ion.

$$H_2SO_4 \longrightarrow 2H^+ + SO_4^{2-}$$

Inorganic acids are strong acids. They undergo complete ionisation in solution.

There are few acids containing oxygen atoms too, these are called oxy-acids. For example, sulphuric acid (H_2SO_4), nitric acid (HNO_3), etc.

- **Based on concentration:**

Concentration defines the amount of an acid present in a given amount of aqueous solution of the acid. Based on concentration acids are divided as:

Concentrated acid: Those acids that have very less amount of water are known as concentrated acids.

Dilute acid: Those acids that have a larger amount of water are known as dilute acids. Concentrates acids can be diluted by adding them slowly to water with constant stirring. One should never add water to acid, as it is an exothermic process. A large amount of heat being released causes the acid to spill out.

- **Based on basicity:**

Basicity of an acid:
It can be defined by the number of hydrogen ions furnished by a molecule of an acid in an aqueous solution. You can observe in the above equations that one molecule of hydrochloric acid gives only one proton whereas one molecule of sulphuric acid gives two protons.

Depending upon the number of protons furnished, the acids have been classified into three types.

- **Monobasic acids:** They have only one replaceable hydrogen atom. For example, HCl
- **Dibasic acids:** They have two replaceable hydrogen atoms. For example, H_2SO_4
- **Tribasic acids:** They have three replaceable hydrogen atoms. For example, H_3PO_4

Preparation of Acids

Acids can be prepared in many ways. The most common methods of obtaining acids are discussed below.

- **By combining an oxide of a non-metal with water**

We know that elements combine with oxygen to form oxides. When oxides of non-metals react with water, acids are obtained.

$SO_2 + H_2O \rightarrow H_2SO_3$

$CO_2 + H_2O \rightarrow H_2CO_3$

$N_2O_5 + H_2O \rightarrow HNO_3$

This method is used to prepare oxy-acids only.

- **By reaction of sulphuric acid with salts**

Sulphuric acid reacts with various salts to give various acids.

$2\ NaCl + H_2SO_4 \rightarrow Na_2SO_4 + 2\ HCl$

$2\ NaNO_3 + H_2SO_4 \rightarrow Na_2SO_4 + 2\ HNO_3$

- **By direct combination (synthesis)**

Hydrogen combines directly with non-metals like chlorine, bromine etc. to form binary (two elements) acids.

$H_2 + Cl_2 \rightarrow 2\ HCl$

- **By oxidation of non-metals**

Non-metals are oxidised to form acids with concentrated nitric acid.

$S + 6\ HNO_3 \rightarrow H_2SO_4 + 2\ H_2O + 6\ NO_2$
$P + 5\ HNO_3 \rightarrow H_3PO_4 + H_2O + 5\ NO_2$

Physical Properties

Various physical properties of acids are given below.

- Acids are sour to taste.
- They exist as solids or liquids at room temperature.
- They have a pH value less than 7.
- They are soluble in water.
- They are good conductors of electricity.
- Strong mineral acids are corrosive in nature and can cause painful burns on the skin.

Chemical properties

Reaction of acids with metals

Metals react with acids to form salts and hydrogen gas. We know that acids contain hydrogen atom(s). Metals replace these hydrogen atoms to form metal salts and hydrogen gas.

$$\underset{\text{Zinc}}{Zn} + \underset{\text{Sulphuric acid}}{H_2SO_{4(aq)}} \longrightarrow \underset{\text{Zinc sulphate}}{ZnSO_{4(aq)}} + \underset{\text{Hydrogen}}{H_2}$$

$$\underset{\text{Sodium}}{Na} + \underset{\text{Hydrochloric acid}}{HCl_{(aq)}} \longrightarrow \underset{\text{Sodium chloride}}{NaCl_{(aq)}} + \underset{\text{Hydrogen}}{H_2}$$

As metal atoms replace hydrogen atoms, these reactions are examples of displacement reactions.

Reaction of acids with metal oxides

Acids react with metal oxides such as copper oxide, zinc oxide, etc. to produce metal salts. The reaction between a metal oxide and an acid can be written as:

$$\text{Metal oxide} + \text{Acid} \rightarrow \text{Salt} + \text{Water}$$

For example, HCl reacts with copper oxide (CuO) to produce a metal salt i.e., copper chloride and water. It is observed that copper chloride dissolves in water and forms a solution that is blue-green in colour.

$$CuO_{(s)} + 2HCl_{(dil)} \rightarrow CuCl_{2(aq)} + H_2O_{(l)}$$

Reaction of acids with metal carbonates

You have already read about acids. Now, let us learn more about them by exploring their chemical properties.

You must have observed that when chalk (calcium carbonate) is treated with sulphuric acid, effervescence takes place. **Do you know why this happens? Which gas is evolved in this process?**

All metal carbonates react with acids to give a corresponding salt, carbon dioxide, and water. Thus, the reaction can be summarised as:

$$\text{Metal carbonate} + \text{Acid} \rightarrow \text{Salt} + \text{Water} + \text{Carbon dioxide}$$

For example, zinc carbonate on reacting with sulphuric acid produces zinc sulphate, water, and carbon dioxide as follows:

$$\underset{\text{Zinc carbonate}}{ZnCO_{3(s)}} + \underset{\text{Sulphuric acid}}{H_2SO_{4(aq)}} \longrightarrow \underset{\text{Zinc sulphate}}{ZnSO_{4(aq)}} + \underset{\text{Carbon dioxide}}{CO_{2(g)}} + \underset{\text{Water}}{H_2O_{(l)}}$$

DO YOU KNOW?

Acid rain contains mainly nitric acid and sulphuric acid, which are formed by the dissolution of nitrogen oxides and sulphur dioxide in the air. Acid rain corrodes buildings and statues made of marble and stone. Marble and stone generally contain carbonates of metals. Hence, they react with acid rain. The Taj Mahal (situated in Agra), which is a heritage building, is being corroded due to acid rain.

The following activity can be performed to confirm that carbon dioxide gas is produced when acids react with metal carbonates.

Carbon dioxide reacts with calcium hydroxide (limewater) to form calcium carbonate (white precipitate). The reaction of carbon dioxide gas with limewater is as follows:

$$\underset{\text{(Lime water)}}{Ca(OH)_2(aq)} + CO_2(g) \rightarrow \underset{\text{(White precipitate)}}{CaCO_3(s)} + H_2O(l)$$

Sodium chloride salt produced in the reaction dissolves in water.

Hence, this activity shows that acids react with metal carbonates and metal hydrogen carbonates to produce salts, carbon dioxide gas, and water.

Reaction of acids with bases

The reaction between acids and bases is known as neutralisation reaction. In this process, acids react with bases neutralising each other to form salt and water.

$$\underset{\text{Hydrochloric acid}}{HCl} + \underset{\text{Sodium hydroxide}}{NaOH} \longrightarrow \underset{\text{Sodium chloride(Salt)}}{NaCl} + \underset{\text{Water}}{H_2O}$$

Reaction with sulphites and bisulphites

Acids release sulphur dioxide gas on reaction with sulphites and bisulphites.

$CaSO_3 + 2\ HCl \rightarrow CaCl_2 + H_2O + SO_2$
$NaHSO_3 + HCl \rightarrow NaCl + H_2O + SO_2$

Reaction with sulphides

Acids release hydrogen sulphide gas on reaction with sulphides.

$ZnS + 2\ HCl \rightarrow ZnCl_2 + H_2S$
$FeS + H_2SO_4 \rightarrow FeSO_4 + H_2S$

Reaction with chlorides

Sulphuric acid reacts with chloride salts to form sulphate salt and hydrogen chloride.

$$2\ NaCl + H_2SO_4 \xrightarrow[> 200\,^{\circ}C]{\Delta} Na_2SO_4 + 2\ HCl$$

Reaction with nitrates

Generally, nitrates react only with concentrated sulphuric acid to form nitric acid. However, lead nitrate reacts with dilute mineral acids to form an insoluble lead salt.

$$2\ KNO_3 + H_2SO_4 \longrightarrow K_2SO_4 + 2\ HNO_3$$
$$Pb(NO_3)_2 + H_2SO_4 \longrightarrow PbSO_4 + 2\ HNO_3$$

Uses of various acids

- **Hydrochloric acid (HCl)**
- It is used in small-scale applications such as leather processing, household cleaning, etc.
- It is used as a catalyst in certain reactions.

- It is used in preparing metal chlorides.
- It is used as a refining ore in the production of tin.
- **Sulphuric acid (H_2SO_4)**
- It is used to manufacture paints, plastics, explosives, drugs, detergents, etc.
- It is used in large quantities by the iron and steel making industry to remove rust and prevent oxidation.
- It is used in petroleum refining.
- It is used in lead accumulators.
- It is used largely in the industry for cleaning.
- **Nitric acid (HNO_3)**
- It is used in the preparation of drugs, dyes, and explosives.
- It is used in manufacturing fertilizers.
- It is used in the purification of gold and silver.
- It is used as an oxidiser in liquid fuel rockets.

Bases

We know that acids are sour to taste. Now, there are certain substances that are bitter to taste and soapy to touch. These chemicals are known as **bases**. For example, soap, limewater, baking soda, etc. are basic in nature.

The given table lists some bases that are present in common substances.

Base	Substance
Calcium hydroxide	Lime water
Sodium hydroxide	Soap
Magnesium hydroxide	Milk of magnesia
Potassium hydroxide	Soap

Although acids and bases were initially classified on the basis of their tastes, one should never taste a new substance to find out its nature. The substance might be toxic or harmful.

We know that acids are substances that can donate a proton. Now, bases are substances that can donate a hydroxyl group i.e., they dissociate in their aqueous solutions to furnish OH^-.

For example, bases such as sodium hydroxide (NaOH), potassium hydroxide (KOH), and calcium hydroxide ($Ca(OH)_2$) furnish OH^- ions when added to water. These are often referred to as alkalis.

$$NaOH \longrightarrow Na^+ + OH^-$$

$$KOH \longrightarrow K^+ + OH^-$$

$$Ca(OH)_2 \longrightarrow Ca^{2+} + 2\ OH^-$$

Not all bases are soluble in water, hence it can be said that all alkalis are bases but all bases are not alkalies.

Classification of Bases

- **Based on their strength**

Strong bases: They completely dissociate in aqueous solution and give a large concentration of hydroxyl ions. For example sodium hydroxide (NaOH), potassium hydroxide (KOH), etc.

Weak bases: They do not dissociate completely in aqueous solution and give a small concentration of hydroxyl ions. For example, ammonium hydroxide (NH_4OH), ferric hydroxide ($Fe(OH)_3$), etc.

- **Based on acidity**

It can be defined as the number of hydroxyl groups present in one molecule of a base that can be donated.

Depending upon the hydroxyl groups that can be donated, the bases have been classified into three types on the basis of their acidity.

- **Monoacidic bases:-**They have only one replaceable hydroxyl group. For example, NaOH

- **Diacidic bases:**- They have two replaceable hydroxyl groups. For example, $Mg(OH)_2$

- **Triacidic bases:**- They have three replaceable hydroxyl groups. For example, $Fe(OH)_3$

Preparation

Bases can be prepared in many ways. The most common methods are given below.

- By reaction of metallic oxides with water

$Na_2O + H_2O \rightarrow 2\ NaOH$

- By reaction of metals with water

$2\ Na + 2\ H_2O \rightarrow 2\ NaOH + H_2$

- By reaction of metals with oxygen

$4\ Na + O_2 \rightarrow 2\ Na_2O$

- By double decomposition of salts with alkalies

$FeCl_3 + 3\ NaOH \rightarrow Fe(OH)_3 + 3\ NaCl$

- By reaction of oxygen with metal sulphides

$2\ ZnS + 3\ O_2 \rightarrow 2\ ZnO + 2\ SO_2$

- By decomposition of carbonates and nitrates

$CaCO_3 \rightarrow CaO + CO_2$
$Ca(NO_3)_2 \rightarrow CaO + NO_2 + O_2$

Physical properties

Various physical properties of bases are listed below.

- They are bitter in taste.
- They are soapy to touch.
- They have a pH value greater than 7.
- They turn red litmus to blue.
- They are strong electrolytes.
- They are mildly corrosive in nature.

Chemical Properties

Reaction with acids:

Bases react with acids to form salts and water.

The reaction of an acid and a base to give salt and water is called **neutralisation reaction.**

The general reaction for the process is:

$$\text{Acid} + \text{Bases} \longrightarrow \text{Salt} + \text{Water}$$

For example, hydrochloric acid reacts with sodium hydroxide to form water and sodium chloride.

$HCl + NaOH \rightarrow NaCl + H_2O$

Reaction with carbon dioxide

Bases absorb carbon dioxide from air to form carbon dioxide.

$2\ NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O$

Reaction with heavy metal salts

Alkalis undergo reactions with heavy metal salts to form insoluble hydroxides.

$ZnSO_4 + 2\ NaOH \rightarrow Na_2SO_4 + Zn(OH)_2$

This is an amphoteric hydroxide so it dissolves in excess of NaOH to form sodium zincate.

$Zn(OH)_2 + 2\ NaOH \rightarrow Na_2SO_4 + Na_2ZnO_2 + 2\ H_2O$

Reaction with non-metal oxides

Non-metallic oxides react with bases to produce salt and water.

For example, a reaction between a non-metallic oxide such as carbon dioxide and a base such as calcium hydroxide produces salt and water. This reaction can be written as:

$$\underset{\text{(Lime water)}}{Ca(OH)_2(aq)} + CO_2(g) \rightarrow \underset{\text{(White precipitate)}}{CaCO_3(s)} + H_2O(l)$$

Reaction with ammonium salts

Alkalies on warming with ammonium salts release ammonia gas and form salt and water.

$NH_4Cl + NaOH \rightarrow NaCl + H_2O + NH_3$

Uses

Base	Use
Sodium hydroxide	In manufacturing of soap, paper, artificial silks, medicines, etc.
Ammonium hydroxide	In removing grease and ink spots
Calcium hydroxide	In manufacturing of mortar, plaster, bleaching powder As an antidote for food poisoning
Magnesium hydroxide	As an antacid (as milk of magnesia)

Strengths of Acids and Bases

Acids and bases can be distinguished from each other with the help of acid-base indicators such as litmus. Litmus is a natural indicator, which can be used to distinguish between an acid and a base. Acids change the colour of blue litmus paper to red, while bases change the colour of red litmus paper to blue.

Do you know that the strength of all acids is not equal?

You must have observed how sulphuric acid is stored in a school laboratory. In all probability, you would notice that there is a bottle labelled as concentrated sulphuric acid and another labelled as dilute sulphuric acid. **What does this mean? Why is the same acid stored in two different bottles?**

There are a large number of chemicals that act as acids or bases. However, the strength of all these acids is not equal. A given acid may be stronger than some acids and weaker than others. For example, sulphuric acid is a stronger acid than acetic acid, which is a very weak acid.

Similarly, the strength of all bases is also not equal. For example, sodium hydroxide is a strong base, whereas magnesium hydroxide is a weak base.

The strength of an acid in a solution is determined by the concentration of H^+ ions present in the solution. An increase in the concentration of H^+ ions increases the strength of an acid.

Similarly, an increase in the concentration of OH^- ions increases the strength of a base.

Now, we know that different acids and bases have different strengths.

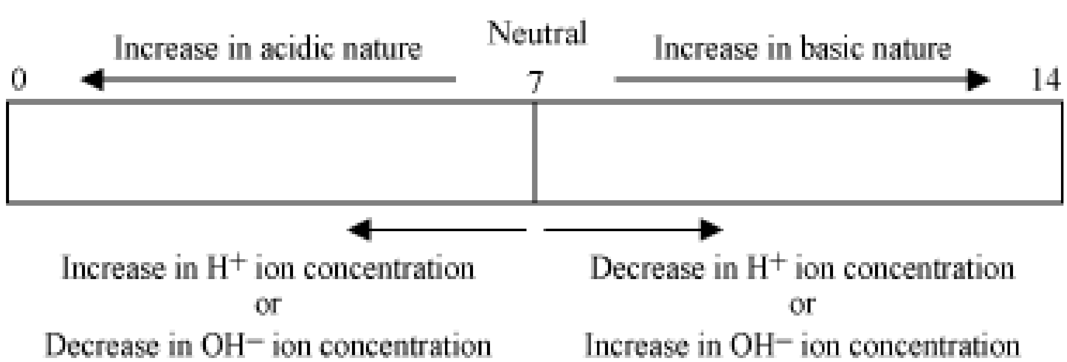
Can the relative strength of an acid be determined?

Or, Is there a way to find out whether a given acid is weaker or stronger than other acids?

pH is the measure of the acidity or alkalinity of a solution. The term pH stands for **'Potential of Hydrogen'**. The pH scale varies from 0 to 14. A pH value from 0 to 6.9 represents acidic solutions, while a pH value from 7.1 to 14 represents basic solutions. A pH value of 7 indicates that a solution is neither acidic nor basic i.e. it is neutral.

Acidity is the measure of H^+ ions and alkalinity is the measure of OH^- ions in an aqueous solution. If the pH value of an aqueous solution increases, then it represents an increase in the concentration of OH^- ions. When the pH value decreases, it represents an increase in H^+ ion concentration. Thus, we can say that the higher the H^+ ion concentration, the lower is the pH value.

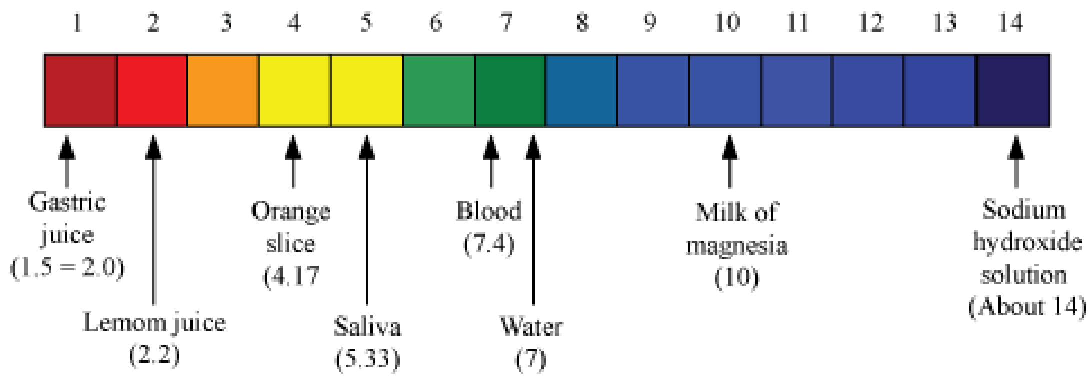
Acids which give rise to more H^+ ions are said to be strong acids, while acids that give rise to less H^+ ions are said to be weak acids. Hence, hydrochloric acid, which gives rise to more H^+ ions, is a strong acid. On the other hand, acetic acid having the same concentration as that of hydrochloric acid is a weak acid, as it gives rise to less H^+ ions. The figure given below represents the variation of pH with a change in the concentration of H^+ and OH^- ions.



$[H_3O^+]$ in aquous solution (In molarity)	pH= -$\log_{10}$ $[H_3O^+]$	pH of aquous solution
10^{-4}	pH= -log10^{-4} = 4 log 10= 4	4
10^{-3}	pH= -log 10^{-3} = 3 log 10= 3	3
10^{-2}	pH= -log 10^{-2} = 2 log 10= 2	2
10^{-1}	pH= -log 10^{-1} = 1 log 10= 1	1

pH of aquous acidic solutions

In laboratories, we use a pH paper or universal indicator to measure the pH. This gives an approximate measure of the pH. The pH values of some common substances are indicated in the pH paper as shown in the following figure.



$[H_3O^+]$ in aquous solution (In molarity)	pH= -$\log_{10}$ $[H_3O^+]$	pOH of aquous solution	pH of aquous solution
10^{-4}	pH= -log10^{-6} = 6 log 10= 6	6	8
10^{-3}	pH= -log 10^{-5} = 5 log 10= 5	5	9
10^{-2}	pH= -log 10^{-4} = 4 log 10= 4	4	10

10^{-1}	pH= -log 10^{-3} = 3 log 10= 3	3	11

pH of aquous basic solutions

Chemical properties of salts

- **Reaction of salt with acid:**

Salt + Acid ⟶ other salt + acid

H_2SO_4 + NaCl → Na_2SO_4 + 2 HCl

- **Reaction of salt with base:**

Salt + Base ⟶ other salt + base

Na_2SO_4 + $Ba(OH)_2$ →⟶ $BaSO_4$ + 2 NaOH

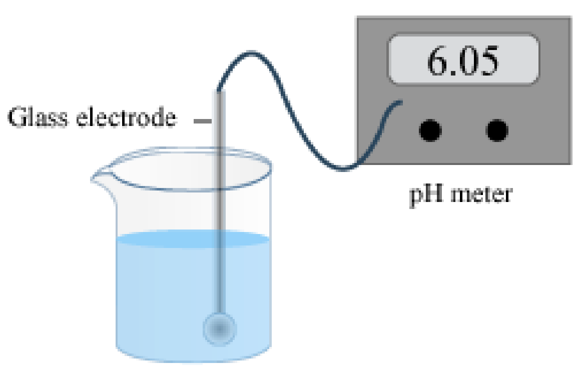
- **Reaction of salt with another salt:**

Salt + other salt ⟶ New salt + New salt

$AgNO_3$ + NaCl→⟶AgCl + $NaNO_3$

Let Us Explore:

pH can be accurately detected by using a pH meter. A typical pH meter consists of a glass electrode connected to an electronic meter that measures and displays the pH readings.



Importance Of pH In Everyday Life

Do you know why it is advised to clean your mouth after consuming food?

Acids are produced in the mouth due to the degradation of sugar and food particles by certain bacteria. As a result, the pH of mouth is lowered.

pH is the measure of the acidity or alkalinity of a solution. The pH scale varies from 0 to 14. A pH value from 0 to 6.9 represents an acidic solution, whereas a pH value from 7.1 to 14 represents a basic solution. A pH value of 7 represents neutral solutions.

Tooth enamel, which is made of calcium phosphate, is sensitive to pH.It does not dissolve in water (neutral pH), but gets corroded when pH in the mouth is below 5.5. Hence, tooth decay starts when the pH of mouth is lower than 5.5.

Do You Know:

pH change as the cause of tooth decay:

Toothpastes used by us for cleaning our teeth are generally basic in nature. Hence, it can neutralize excess acid present in the mouth and prevent tooth decay.

Let us study the **role of pH in our daily life**.

All living organisms are pH sensitive and can survive only in a narrow range of pH.

Most reactions in the human body take place in a pH range of 7.0 to 7.8. A change in the pH value inside the body can alter the biochemical reactions and prove fatal.

If the pH of rain water is less than 5.6, it is called **acid rain**. Acid rain contains mainly nitric and sulphuric acids, which are formed by the dissolution of nitrogen oxides and sulphur dioxide (respectively) in the atmosphere. When water from acid rain flows into the rivers, it results in a decrease in the pH value of river water. This decrease in the pH makes the survival of aquatic life very difficult.

Thus, acid rain causes extensive harm to soil, water resources, forests, and human health.

pH in our digestive system:

We know that our stomach produces gastric juice during digestion. Gastric juice contains hydrochloric acid, which helps in the digestion of food without harming the stomach. When the stomach produces an excess of acid, it causes irritation and pain and results in indigestion.

Gastric juice in our stomach has a pH value that falls in the range of 1.5 − 2.0.

Indigestion can be treated by taking antacids. Magnesium hydroxide called milk of magnesia is a mild base. It is used as an antacid, and can be used to neutralize the effect of excess acid in the stomach and cure indigestion.

Do You Know:

Sodium hydrogen carbonate, commonly known as baking soda, is also used as an antacid to neutralize stomach acidity. When sodium hydrogen carbonate is taken orally, it reacts with excess hydrochloric acid present in the stomach, and reduces its strength by neutralizing its effect.

Self defence by animals and plants through chemical warfare:
Baking soda is also used to neutralize the effect of a bee sting. A bee sting leaves methanoic acid inside our body, which causes pain and irritation. Thus, baking soda neutralizes the effect of methanoic acid.

Plants also require a specific value of pH for healthy growth. For example, there are a few plants that require a pH of 4.5 to 5.5. Such plants are called **acid loving plants.** Some evergreen shrubs and bushes are acid loving plants.

Plants are sensitive to pH changes:
Soil pH and plant growth:
pH of soil, which is required for healthy growth of plants can be easily measured. **Do you know how?**

To measure the pH of soil, take 2g of soil to be measured in a test tube. Add 5 mL water to it and shake the contents for some time. Now, filter the contents of the test tube and collect the filtrate in another test tube. You can measure the pH of the filtrate using a universal indicator.

Salts

- An ionic substance produced in the neutralisation of a base by an acid is a salt.
- Salt is a compound formed by the partial or total replacement of the ionisable H atoms of an acid.
- Salts dissociate in water into cation and anion.

$$NaCl \xrightarrow{Water} Na^+ + Cl^-$$

- Salts can also be prepared by the process of neutralisation reactions. For example, sodium chloride (NaCl) can be prepared by reacting hydrochloric acid (HCl) and sodium hydroxide (NaOH)

Classification of Salts

1. Normal salts
2. Acid slats
3. Basic salts

Salts	Formation	Examples	Remark
Normal salts	Formed by the complete replacement of the ionisable H atoms of an acid	NaCl, Na_2SO_4	These salts do not have any ionisable H atoms.
Acid salts	Formed by the partial replacement of the H atoms of a polybasic acid	$NaHSO_4$ $NaHSO_3$ Na_2HPO_4 NaH_2PO_4	These salts are formed by the incomplete neutralisation of acid
Basic salts	Formed by the partial replacement of the OH group of a polyacid base	[Pb(OH)Cl] [Mg(OH)Cl] $[Cu(OH)NO_3]$ [Cu(OH)Cl]	They contain hydroxyl ion, anion of acid and metallic cation

Other types of salts

- **Double salts**: Set of two simple salts that dissolve in water

  Example: Potash alum K_2SO_4. $Al_2(SO_4)_3$. $24H_2O$; Mohr's salt $FeSO_4$. $(NH_4)_2SO_4$. $6H_2O$

- **Mixed salts**: Salts that contain more than one basic or acid radical

  Example: $CaOCl_2$, $NaKCO_3$

- **Complex salts**: Salts that dissociate into one simple and one complex ion

  Example: $Na[Ag(CN)_2]$, $[Ag(NH_3)_2]$

General Properties of Salts

- They conduct electricity in the aqueous and molten state.
- They are non-volatile

- Most of the salts are soluble in water. On the basis of solubility, salts are soluble, partially soluble and insoluble.

Hydrolysis of the salts

- Hydrolysis: Interaction of the anion or the cation (or both) of a salt with water to produce an acidic or a basic solution.

- Salts of strong acids and strong bases are neutral (pH = 7)

- Reason: The cations of strong bases and the anions of strong bases do not undergo hydrolysis; they only get hydrated.

(a) Hydrolysis of salts of strong acids and strong base:

For example, NaCl

- Completely dissociates into ions

$NaCl_{(aq)} \rightarrow Na^{+}_{(aq)} + Cl^{-}_{(aq)}$

Sodium chloride undergoes hydrolysis in water

$Na^{+}_{(aq)} + Cl^{-}_{(aq)} + H_2O \rightleftharpoons HCl_{(aq)} + NaOH_{(aq)}$
$Na^{+}_{(aq)} + Cl^{-}_{(aq)} + H_2O \rightleftharpoons H^{+}_{(aq)} + Cl^{-}_{(aq)} + Na^{+}_{(aq)} + OH^{-}_{(aq)}$

- pH is 7 (neutral)

Reason:

- Identical ions presence in both side reactant and product (Na^+ and Cl^-).
- In salt neither cation nor anion reacts with water.
- No hydrolysis occurs because of ($[H^+] = [OH^-]$)
- Neutral solution and no effect on litmus.

(b) Hydrolysis of the salts of a weak acid and a strong base:

For example, CH_3COONa

- Completely ionised

$$CH_3COONa_{(aq)} \longrightarrow CH_3COO^{-}_{(aq)} + Na^{+}_{(aq)}$$

Acetate ion undergoes hydrolysis in water

$$CH_3COO^-_{(aq)} + H_2O_{(l)} \longleftrightarrow CH_3COOH_{(aq)} + OH^-_{(aq)}$$

- pH is more than 7

Reason:

Acetic acid is a weak acid
↓
Remains mainly un-ionised in solution
↓
Increase in concentration of OH− ion in solution
↓
Solution becomes alkaline (pH > 7)

(c) Hydrolysis of the salts of a strong acid and a weak base:

For example, NH_4Cl

- Completely ionised

$$NH_4Cl_{(aq)} \longrightarrow NH_4^+{}_{(aq)} + Cl^-_{(aq)}$$

- Ammonium ion undergoes hydrolysis in water

$$NH_4^+{}_{(aq)} + H_2O_{(l)} \longleftrightarrow NH_4OH_{(aq)} + H^+_{(aq)}$$

- pH is less than 7
- Reason:

Ammonium hydroxide is a weak base
↓
Remains mainly un-ionised in solution
↓

Increase in concentration of H+ ion in solution
↓
Solution becomes acidic (pH < 7)

(d) Hydrolysis of the salts of a weak acid and a weak base:

For example, CH_3COONH_4

- Is not completely ionised
- The ions undergo hydrolysis in water

$$CH_3COO^- + NH_4^+ + H_2O \longleftrightarrow CH_3COOH + NH_4OH$$

- CH_3COOH and NH_4OH remain partially ionised in solution

$$CH_3COOH \longleftrightarrow CH_3COO^- + H^+$$
$$NH_4OH \longleftrightarrow NH_4^+ + OH^-$$
$$H_2O \longleftrightarrow H^+ + OH^-$$

Preparation of Soluble Salts

(1) Direct Combination Method

$$2\ Na + Cl_2 \rightarrow 2\ NaCl$$

(2) Simple Displacement Method

$$Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$$

(3) Decomposition by Acids Method

$$NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2$$

(4) Neutralisation Method

$$HNO_3 + NaOH \rightarrow NaNO_3 + H_2O$$

(5) Action of Alkali on some metals, their oxides and their hydroxides

$$2\ Al + 2\ NaOH + 2\ H_2O \rightarrow 2\ NaAlO_2 + 3\ H_2$$
$$Al_2O_3 + 2\ NaoH \rightarrow 2\ NaAlO_2 + H_2O$$
$$Al(OH)_3 + NaoH \rightarrow NaAlO_2 + 2\ H_2O$$

Preparation of Insoluble Salts

(1) Direct Combination Method

$$Pb + S \xrightarrow{\Delta} PbS$$

(2) Acidic Oxide-Basic Oxide Combination Method

$$CO_2 + CaO \xrightarrow{\Delta} CaCO_3$$

(3) Double Decomposition (Precipitation Reaction) Method

$$AgNO_3 + HCl \rightarrow AgCl\downarrow + HNO_3$$
$$PbO + 2\ HNO_3 \xrightarrow[-H_2O]{} Pb\left(NO_3\right)_2 \xrightarrow{H_2SO_4} PbSO_4\downarrow + 2\ HNO_3$$

Laboratory Preparation of Some salts

(1) Iron(III) chloride [$FeCl_3$]

When dried chlorine gas is passed over heated iron, it forms anhydrous iron (III) chloride.

$$2\ Fe + 3\ Cl_2 \rightarrow 2\ FeCl_3$$

Steps:

- Powdered iron ore is taken in combustion tube
- Dry chlorine gas is passed through it.
- When iron turns red hot external heating is stopped
- iron(III) chloride is formed
- It is condensed in the receiver as brown scale
- Since it is deliquescent, it is kept dry by using drying agent such as calcium chloride
- Simple heating of hydrated ferric chloride is not preferred since the product formed is $Fe_2O_3.H_2O$ instead of $FeCl_3$

(2) Copper(II) Sulphate (Blue Vitriol)

Copper sulphate is prepared in the reaction that takes place between copper oxide and dilute sulphuric acid.

Reactions:

$$CuO + dil.\ H2SO4 \rightarrow CuSO4 + H2O$$

Steps:

- Black copper(II) oxide is added to the sulphuric acid.
- Mild heating is required for complete reaction.
- The mixture is then filtered to remove the excess black solid and leave a clear blue solution.
- If the blue solution is heated gently, to remove some of the water and allowed to cool down slowly, crystals will appear.
- The slower this crystallisation is allowed to occur, the larger the crystals that will be produced.
- Collect the bright blue crystals of copper(II)sulphate penta-hydrate ($CuSO_4.\ 5H_2O$).

(3) Zinc Sulphate (White Vitriol)

Steps:

- Some granulated zinc pieces are taken in a beaker containing dilute sulphuric acid with constant stirring.
- Effervescence is observed. Zinc is added till it settles at the base.
- The excess of zinc is filtered off.
- The solution is evaporated to get white, needle-shaped crystals.
- Filter, wash and dry them between the folds of a filter paper.

Reactions:

$$Zn(s) + H_2SO_4\ (aq) \rightarrow ZnSO_4 + H_2 \uparrow$$

$$ZnSO_4 + 7H_2O \rightarrow \underset{\text{(white vitriol)}}{ZnSO_4.H_2O}$$

(4) Iron(II) Sulphate (Green Vitriol)

Iron (II) sulphate is prepared in the displacement reaction that takes place between iron metal and dilute sulphuric acid.

Reactions:

$$Fe + H_2SO_4 \rightarrow FeSO_4 + H_2$$
$$FeSO_4 + 7\ H_2O \rightarrow FeSO_4.H_2O$$

Steps:

- Iron (II) sulphate is prepared by the same method as white vitriol.
- Hot solution is filtered and filtrate is evaporated.
- Green crystals of iron (II) sulphate are obtained.

(5) **Lead Chloride**

Steps:

- Dil. hydrochloric acid or sodium chloride solution is added to solution of lead nitrate.
- The solution is filtered.
- The residue, a white precipitate, is washed.
- The precipitate is taken in a china dish with water and is heated till the precipitate of lead chloride dissolves. The solution is then cooled.
- Needle shaped crystals of lead chloride are obtained.

Reactions:

$$Pb(NO_3)_2\ +\ 2\ HCl\ \rightarrow PbCl_2\ +\ 2\ HNO_3$$
$$Pb(NO_3)_2\ +\ 2\ NaCl\ \rightarrow PbCl_2\ +\ 2\ NaNO_3$$

(6) **Calcium Carbonate**

Steps:

- Sodium carbonate solution is added to a hot solution of calcium chloride solution.
- The white precipitates are obtained.
- They are washed and dried.
- An amorphous powder of calcium carbonate is finally obtained.

Reaction:

$CaCl_2 + Na_2CO_3 \rightarrow CaCO_3 \downarrow + 2NaCl$

(7) **Sodium Bicarbonate**

It is obtained by passing carbon dioxide gas into a cold solution of sodium carbonate.

Reaction: $Na_2CO_3 + CO_2 + H_2O \rightarrow 2\ NaHCO_3$

Steps:

- Anhydrous sodium carbonate is added to distilled water.
- The solution is cooled.
- Carbon dioxide gas is passed in the solution.
- The crystals of sodium bicarbonate are obtained.

(8) **Sodium Sulphate**
Sodium sulphate is prepared by the neutralisation of sodium hydroxide base with dilute sulphuric acid.

$$2NaOH + H_2SO_4 \xrightarrow{\Delta} Na_2SO_4 + 2H_2O$$

Neutralisation of an acid by base:

Since, both the reactants and products are soluble, a titration is conducted to determine the composition of the neutralisation reaction.

- A solution of sodium hydroxide is taken into a conical flask.
- A drop of phenolphthalein is added. The solution turns pink.
- Dil. sulphuric acid is taken in a burette and reading is noted.
- The acid is run in drops into conical flask till the last drop of the acid turns the solution colourless. This is known as end point.
- Burette point is noted at the end point.
- The difference between the two readings is the volume of the acid required.

Water of Crystallization

We know that washing soda is produced by mixing water and sodium carbonate. The molecular formula of washing soda is $Na_2CO_3.10H_2O$.

Sodium carbonate is obtained by heating sodium hydrogencarbonate.

$$\underset{\text{(Sodium Hydrogen carbonate)}}{2NaHCO_3} \rightarrow \underset{\text{(Sodium carbonate)}}{Na_2CO_3} + H_2O + CO_2$$

The re-crystallization of sodium carbonate then produces washing soda.

$$Na_2CO_3 + 10H_2O \rightarrow Na_2CO_3 \cdot 10H_2O$$

Ten water molecules are present in the formula of washing soda. These water molecules are called **water of crystallization.**

Water of crystallization refers to a fixed number of water molecules present in one formula unit of salt.

The following experiment will help in understanding the concept of water of crystallization.

Aim: To prepare crystals of copper sulphate ($CuSO_4$)

Material required: Beaker, distilled water, copper sulphate ($CuSO_4$) crystals, glass rod, thread, watch glass

Theory: Water of crystallization imparts the characteristic blue colour to copper sulphate ($CuSO_4$) crystals. These crystals are obtained by the process of *seeding*. In this process crystallization is induced with the help of small crystal of pure hydrated copper sulphate ($CuSO_4.5H_2O$) which is added in the saturated copper sulphate solution.

Procedure:

1. Take a beaker and prepare a saturated solution of copper sulphate ($CuSO_4$) at 80º C and filter the solution to remove any undissolved impurity.

2. Cover the filtrate with watch glass.

3. Cool down the filtrate and leave it undisturbed for 24 hours.

4. Some crystals of copper sulphate ($CuSO_4.5H_2O$) will be formed at the bottom of the beaker. Collect a few of them.

5. Suspend one of the well formed small crystal in the saturated solution by tying to a glass rod using a thread.

6. Again cover the beaker with watch glass to avoid dust entering the solution.

7. Leave it undisturbed.

Observation: The suspended crystal grows in size with each passing day.

Water of crystallization is the fixed number of water molecules present in one formula unit of salt.

It is in chemical combination with a crystal
It is necessary for the maintenance of crystalline properties of the crystal

It can be removed by sufficient heat

The following experiment shows the effect of heat on solids that do not contain water of crystallisation.

Aim: To show effect of heat on solids that do not contain water of crystallisation.

Material required: Test tube, burner, potassium nitrate (KNO_3)

Theory: Not all crystalline solids contain water of crystallisation. These solids when heated decompose to form new compounds.

Procedure:

1. Take some potassium nitrate crystals in a test tube.
2. Heat the tube gently.

Observation: The crystals form a colourless solution giving off a gas, that bursts the glowing splinter. It signifies that oxygen is being involved. In the end, a pale yellow residue is left in the test tube.

$$\underset{\text{Potassium nitrate}}{2\ KNO_3} \xrightarrow{\Delta} \underset{\text{Potassium nitrite}}{2\ KNO_2} + O_2$$

Hydrated Substances

Those substances which contain water of crystallization like hydrated copper sulphate ($CuSO_4.5H_2O$), are called hydrated substances. The water of crystallisation gives their crystals shape and in some cases colour.

Gypsum is another salt that possesses the water of crystallization. It has a chemical formula of $CaSO_4.2H_2O$. It is also known as hydrated calcium sulphate.

When hydrated calcium sulphate ($CaSO_4.2H_2O$) or gypsum is heated at 373K, it loses its water molecules and forms calcium sulphate hemihydrate ($CaSO_4.\frac{1}{2}H_2O$). **This hemihydrate form of calcium sulphate is known as Plaster of Paris.** It is in the form of a white powder.

When the powder of Plaster of Paris is mixed with water, it becomes hard and solid gypsum. Plaster of Paris is generally used to support fractured bones in their correct positions.

$$\underset{\text{(Plaster of Paris)}}{CaSO_4.\frac{1}{2}H_2O} + 1\frac{1}{2}\ H_2O \rightarrow \underset{\text{(Gypsum)}}{CaSO_4.2H_2O}$$

In $CaSO_4.\frac{1}{2}H_2O$**,** only half a water molecule is shown as the water of crystallization because two formula unit of $CaSO_4$ share one molecule of water.

Plaster of Paris is used for making toys, materials for decoration, and for making smooth surfaces.

Determination of Water of Crystallization

Heat a known weight of a hydrated substance to a temperature above 100^o C. Weigh the residue. Repeat these two steps, till the weight of the residue becomes constant. Use the following formula to obtain the percentage of water of crystallization in a link:

Initial weight of the hydrated substance = x g

Final constant weight of the substance after heating = y g

$$\%\ \text{of water of crystallization} = \frac{x-y}{x} \times 100$$

Anhydrous Substances

Those substances which do not contain any water of crystallization or the substances from which the water of crystallization have been removed like sodium chloride (NaCl) are called anhydrous substances.
The water of crystallization can be removed by using any of the following methods:

- Direct heating of the hydrated substance
- Heating the hydrated substance in dry and hot air
- Heating the hydrated substance under vacuum
- Using dehydrating/desiccating agents

Drying Agents

The substances that absorb moisture from other substances without undergoing a chemical reaction with them are called drying agents or desiccants or desiccating agents. Examples of drying agents are anhydrous calcium chloride, anhydrous zinc chloride etc. Most of the hygroscopic substances are desiccating agents like concentrated sulphuric acid, silica gel etc.

The following table illustrates the techniques used to dry certain substances.

Substance	Drying technique
Gases	By passing through concentrated sulphuric acid Used for drying acidic gases like HCl gas By passing through a drying tower or a U-tube containing anhydrous sodium sulphate By passing through a drying bulb containing anhydrous calcium chloride
Liquids	By keeping them over anhydrous sodium sulphate or calcium chloride for over a night After this, solid is removed by filtration.
Solids	By placing them in a desiccator (air-tight vessel with a drying agent like calcium chloride spread at the bottom)

Dehydrating Agents

The substances that can remove chemically bounded water from compounds are called dehydrating agents. Concentrated sulphuric acid is a strong dehydrating agent. It can remove water molecules from hydrated copper sulphate ($CuSO_4.5H_2O$).

$$\underset{\text{(blue)}}{CuSO_4.5H_2O} \xrightarrow{Conc.\ H_2SO_4} \underset{\text{(white)}}{CuSO_4} + 5H_2O$$

The following table explains the differences between drying agents and dehydrating agents.

Drying Agents	Dehydrating Agents
Removes moisture from other substances	Removes chemically bounded water molecules from substances
Performs a physical change in the substance	Performs a chemical change in the substance

Deliquescent and Efflorescent Substances

Deliquescence

• Certain substances, when kept open in atmosphere at room temperature, absorb water from the atmosphere and become moist. On further absorption of water they dissolve.

• Such substances which absorb water from the atmosphere are known as deliquescent substances and the phenomenon is known as deliquescence. Examples of such substances are sodium hydroxide, potassium hydroxide, calcium chloride, zinc chloride, ferric chloride, sugars etc.

• It is necessary to keep the deliquescent substances in a special type of closed container known as desiccators. They keep the deliquescent substance dry.

• Certain substances like concentrated sulphuric acid and calcium chloride, which keep the atmosphere dry, are known as desiccants or drying agents.

Efflorescence

• Certain hydrated compounds lose water when exposed to air with moderate humidity. Such substances, which lose their water of hydration to the surroundings, are known as efflorescent substances and the phenomenon is known as efflorescence. Sodium sulphate ($Na_2SO_4.10\ H_2O$) and washing soda ($Na_2CO_3.10\ H_2O$) are some examples of efflorescent substances.

Hygroscopy

- Certain substances tend to absorb moisture from the air upon exposure. Such substances are known as hygroscopic substances and the phenomenon is known as hygroscopy. Concentrated sulphuric acid (H_2SO_4), phosphorous pentoxide (P_2O_5), and quicklime (CaO) are some examples of hygroscopic substances.