CHAPTER

02

Acids, Bases and Salts

All the chemical compounds can be classified on the basis of their chemical properties as acids, bases and salts. They have certain definite properties which distinguish these compounds from each other. Most of the digestive fluids of humans and animals contain acids. The bitter taste of substances like bitter gourd, cucumber etc., is due to the bases present in them.

Chapter Checklist

- Acids
- Bases
- Indicators
- Strength of an Acid or Base
- pH Scale
- Importance of pH in Everyday Life
- Salts
- Water of Crystallisation

Acids

Acids are those chemical substances which have a sour taste and change the colour of blue litmus to red. Some common fruits such as unripe mango, lemon, orange, tamarind etc., are sour in taste. This suggests that these fruits contain acids. Some commonly used acids are hydrochloric acid (HCl), sulphuric acid (H_2SO_4), nitric acid (HNO_3) etc.

Some naturally occurring acids are:

Natural source	*Acid*
Vinegar	Acetic acid
Orange and lemon	Citric acid
Tamarind	Tartaric acid
Tomato	Oxalic acid
Curd	Lactic acid
Antsting	Methanoic acid

Chemical Properties of Acids

(*i*) **Reaction with metals** Acids like dilute HCl and dilute H_2SO_4, react with certain active metals like zinc (Zn), iron (Fe) etc., to form salt and evolves H_2 gas. Thus, these acids or substances containing these kind of acids should not be kept in metal containers.

$$\text{Metal} + \text{Dilute acid} \longrightarrow \text{Salt} + \text{Hydrogen gas}$$

e.g., $$Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2 \uparrow$$

(*ii*) **Reaction with metal carbonate and hydrogen carbonate** Limestone, chalk and marble are different forms of calcium carbonate. Acids react with metal carbonates and hydrogen carbonates (bicarbonate) to produce their corresponding salts, carbon dioxide gas and water.

Metal carbonate / Metal hydrogen carbonate + Acid $\longrightarrow$ Salt + Carbon dioxide + Water

e.g., $CaCO_3 + 2HCl \longrightarrow CaCl_2 + H_2O + CO_2 \uparrow$

The carbon dioxide gas is released with a brisk effervescence.

Test for CO_2 gas When CO_2 gas is passed through lime water, it turns milky due to the formation of white precipitate of $CaCO_3$.

But if CO_2 is passed in excess, milkiness disappears due to the formation of $Ca(HCO_3)_2$ which is soluble in water.

$$\underset{\text{Lime water}}{Ca(OH)_2(aq)} + \underset{\text{Carbon dioxide}}{CO_2(g)} \longrightarrow \underset{\substack{\text{Calcium carbonate}\\\text{(White ppt.)}}}{CaCO_3(s)} + \underset{\text{Water}}{H_2O(l)}$$

$$\underset{\substack{\text{Calcium carbonate}\\\text{(Milkiness)}}}{CaCO_3(s)} + \underset{\text{Water}}{H_2O(l)} + \underset{\substack{\text{Carbon dioxide}\\\text{(Excess)}}}{CO_2(g)} \longrightarrow \underset{\substack{\text{Calcium bicarbonate}\\\text{(Soluble in water)}}}{Ca(HCO_3)_2(aq)}$$

(*iii*) **Reaction with metal oxides** Acids react with certain metal oxides (being basic in nature also called basic oxides) to form salt and water.

Metal oxide + Acid $\longrightarrow$ Salt + Water

e.g. $CuO + 2HCl \longrightarrow CuCl_2 + H_2O$

Bases

Bases are those chemical substances which are bitter in taste, soapy to touch and turn red litmus to blue. e.g. sodium hydroxide (NaOH), calcium hydroxide $Ca(OH)_2$ etc.

Chemical Properties of Bases

(*i*) **Reaction with metals** Strong bases react with active metals to produce hydrogen gas. Thus, these bases should not be kept in metal container (active metals).

Metal + Base $\longrightarrow$ Salt + Hydrogen gas

$$\underset{\text{Zinc}}{Zn(s)} + 2\underset{\text{Sodium hydroxide}}{NaOH(aq)} \longrightarrow \underset{\text{Sodium zincate}}{Na_2ZnO_2(s)} + \underset{\text{Hydrogen gas}}{H_2(g)}$$

(*ii*) **Reaction with non-metallic oxide** Bases react with non-metallic oxides (being acidic in nature also called acidic oxides) to produce salt and water.

This reaction proves that non-metallic oxides are acidic in nature.

Base + Non-metallic oxide $\longrightarrow$ Salt + Water

$$\underset{\text{Carbon dioxide}}{CO_2(g)} + \underset{\text{Slaked lime}}{Ca(OH)_2(aq)} \longrightarrow \underset{\text{Calcium carbonate}}{CaCO_3(s)} + \underset{\text{Water}}{H_2O(l)}$$

Acids/ Bases in Water Solution

In presence of water, all acids give H^+ ion. As H^+ ion cannot exist alone so it combines with water molecules and form H_3O^+ (Hydronium ion). So, we can say in **presence of water, all acids give H^+ ion or H_3O^+ ion.**

In the same way, in presence of water, all the bases give OH^- ion.

e.g. $HCl + H_2O \longrightarrow H_3O^{\oplus} + Cl^-$

$H^+ + H_2O \longrightarrow H_3O^+$

$NaOH(s) \xrightarrow{H_2O} Na^{\oplus}(aq) + OH^-(aq)$

$KOH \xrightarrow{H_2O} K^+(aq) + OH^-(aq)$

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

Note All bases do not dissolves in water. An alkali is a base that dissolves in water. Both acids and bases conduct electric current in their aqueous solutions due to the presence of free ions.

Reaction between Acids and Bases

Acids react with bases to produce salt and water. In this reaction, an acid neutralises a base, i.e. acid nullifies or reduces the effect of a base or *vice-versa*, thus the reaction is known as **neutralisation reaction.**

In general, neutralisation reaction can be written as :

Base + Acid $\longrightarrow$ Salt + Water

$H\boxed{X+M}OH \longrightarrow MX + HOH$

Here, H represents hydrogen atom and M represents metal atom.

$$H^+(aq) + OH^-(aq) \longrightarrow H_2O(l)$$

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

Effect of Dilution on an Acid or Base

Mixing of an acid or base with water is called **dilution.** It results in decrease in the concentration of ions (H_3O^+ / OH^-) per unit volume and the acid or base is said to be diluted.

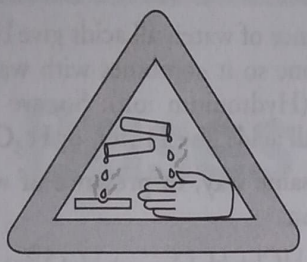
When acid or base is added to water, their molecules dissociate to form ions.

$$\underset{\text{Acid}}{HCl} + H_2O \longrightarrow H_3O^+ + Cl^-$$

$$H_2O + H^+ \longrightarrow H_3O^+ \text{(Hydronium ion)}$$

Or $\underset{\text{Base}}{NaOH(s)} \xrightarrow{H_2O} Na^+(aq) + OH^-(aq)$

Dissolving an acid or a base in water is a highly exothermic (heat generating) reaction, so care must be taken while doing it. The acids must always be added slowly to water with constant stirring.



Warning sign displayed on containers containing concentrated acids and bases (showing their corrosive nature)

Water should not be added to concentrated acid because if water is added, the heat generated may cause the mixture to splash out and cause burns.

Check Point 01

1. Which type of chemical compound found in citrus fruits?
2. Fill in the blank:
   All alkali are bases but all bases are ..... alkali?
3. Bases should not be kept in active metal container. Why?
4. Give a chemical reaction to prove that non-metallic oxides are acidic in nature.
5. State True or False for the following statement:
   Everything that tastes sour contains an acid.
6. How H_3O^+ ion is formed in water solution?
7. What is the effect of dilution on an acid or base?

Indicators

Indicators are the substances that change their colour or odour when added into an acid or an alkaline solution to indicate the presence of acid or base.

Indicators can be classified in the following ways :

Natural Indicators

These indicators are found in nature in the plants, e.g. litmus solution is a purple colour dye extracted from the lichen plant belonging to the division "Thallophyta".

Some Natural Indicators with Characteristic Colours

Indicator	*Colour in Acidic Medium*	*Colour in Alkaline Medium*
Litmus	Red	Blue
Red cabbage juice (from leaves)	Red	Green
Turmeric juice (haldi)	Yellow	Reddish brown
Flowers of *Hydrangea* plant	Blue	Pink

Synthetic Indicators

The indicators which are synthesised in the laboratory or industry are known as synthetic indicators, e.g. methyl orange, phenolphthalein, methylene blue and methyl red are synthetic indicators.

Some Synthetic Indicators with Characteristic Colours

Indicator	*Colour in Acidic Solution*	*Colour in Basic Solution*	*Colour in Neutral Solution*
Phenolphthalein	Colourless	Pink	Colourless
Methyl orange	Red	Yellow	Orange

Olfactory Indicators

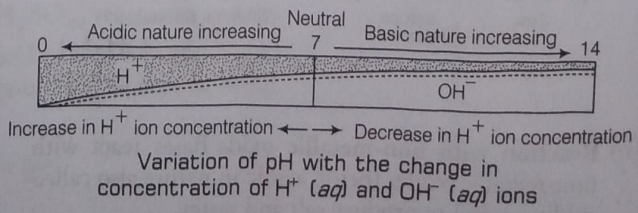
Those substances whose odour changes in acidic or basic medium are called olfactory indicators. Vanilla extract and onion can be used as olfactory indicators. The smell of these two indicators can be detected in presence of acid only but not in the presence of base.

Universal Indicators

To judge how strong a given acid or base is, a **universal indicator** is used, which is a mixture of several indicators. It shows different colours at different concentrations of hydrogen ion in a solution.

Strength of an Acid or Base

Strength of an acid or base depends on the number of H^+ ions or OH^- ions produced by them respectively. Larger the number of H^+ ions produced by an acid, stronger is the acid. Similarly, larger the number of OH^- ions produced by a base, stronger is the base.



Variation of pH with the change in concentration of H^+ (*aq*) and OH^- (*aq*) ions

The pH Scale

It is a scale used for measuring hydrogen ion concentration. The **p** in pH stands for ***potenz*** which means **power** in German.

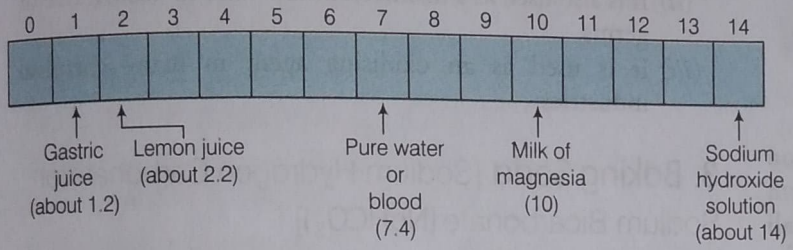
It has values ranging from 0 (very acidic) to 14 (very alkaline). **pH is a number which indicates the acidic or basic nature of a solution.**

Higher the hydronium ion concentration present in the solution, lower is its pH value [pH means power of hydrogen ions].

- If pH > 7, solution is basic.
- If pH < 7, solution is acidic.
- If pH = 7, solution is neutral.

Pure water is neutral because of the absence of free ions. A paper impregnated with the universal indicator is used for measuring pH.

Now-a-days, pH meter, an electronic device, is used to measure the pH value.



pH of some common substances shown on a pH paper

Importance of pH in Everyday Life

Following are the examples showing importance of pH in everyday life:

Plants and Animals are pH Sensitive

Living organisms can survive only in a narrow range of pH change, our body works normally within a pH range of 7.0 to 7.8.

When pH of rain water goes below 5.6, it is called acid rain. When acid rain flows into the rivers, it lowers the pH of the river water and makes survival of aquatic life difficult.

pH of the Soil

Every type of plant requires a specific pH range for healthy growth. Therefore, the nature of soil is known first by testing its pH and then a particular crop is grown in it. It is also suitable for selecting the fertiliser for a particular crop by knowing the pH of the soil.

pH in Our Digestive System

HCl present in the stomach helps in the digestion of food.

During indigestion the stomach produces too much acid, it causes pain and irritation. To correct the disturbed pH range, milk of magnesia (a mild base) is used as a medicine, which is also called **antacid** as it reduces the effect of acid (or acidity).

pH Change Leads to Tooth Decay

Tooth enamel is made up of calcium phosphate and is the hardest substance in the body. If the pH inside the mouth decreases below 5.5 (acidic), the decay of tooth enamel begins.

The bacteria present in the mouth degrades the sugar and left over food particles and produce acids that remains in the mouth after eating.

The best way to prevent this is to clean the mouth after eating food. To prevent tooth decay, toothpastes (basic) are used which neutralise the excess acid.

Self Defence by Animals and Plants through Chemical Warfare

When insects like honeybee, ant etc., bite, they inject an acid into the skin, that causes pain and irritation. If a mild base like baking soda is applied on the affected area, it gives relief.

pH in Plants

Stinging hair of nettle leaves injects methanoic acid in the skin which causes burning pain. It is cured by rubbing the affected area with the leaves of dock plant, which often grows beside the nettle plant.

Check Point 02

1. Which indicator gives pink colour in basic solution?
2. In which pH range our body works?
3. Fill in the blank:
   To prevent tooth decay, toothpaste are used which are ..... in nature.
4. Name the chemical which is injected into the skin of a person during wasp's sting and during the nettle leaf hair sting.
5. State True or False for the following statement:
   The colour of gastric juice on pH paper is blue.
6. Write the role of HCl present in the stomach.

Salts

Salts are produced by the **neutralisation reaction** between acid and base. Salts of strong acid and a strong base are neutral with pH value of 7.

Salts of a strong acid and weak base are acidic with pH value less than 7. Salts of strong base and weak acid are basic in nature with pH value more than 7. Now, we will study about preparation and properties of some salts.

Common Salt [Sodium Chloride (NaCl)]

Common salt is formed by the combination of hydrochloric acid and sodium hydroxide solution. It is the salt that we use in food. Sea water contains many salts dissolved in it. It is obtained on large scale from sea water by separating other salts from it. It may also be obtained from rock salt.

Deposits of solid salt are also found in several parts of the world. These large crystals are often brown due to impurities. This is called rock salt. Beds of rock salt were formed when seas of bygone ages dried up. Rock salt is mined like coal.

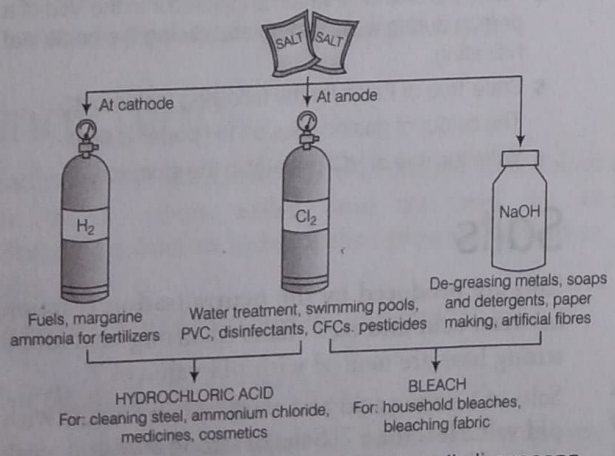
Common salt is an important raw material for various materials of daily use, like sodium hydroxide, baking soda, washing soda, bleaching powder etc.

1. Caustic Soda [Sodium Hydroxide (NaOH)]

When electricity is passed through an aqueous solution of sodium chloride (called brine), it decomposes to form sodium hydroxide. This process is called **chlor-alkali process** because of the products formed, i.e. chlor for chlorine and alkali for sodium hydroxide.

$$\underset{\text{Sodium chloride}}{2NaCl(aq)} + \underset{\text{Water}}{2H_2O(l)} \xrightarrow{\text{Electric current}} \underset{\text{Sodium hydroxide}}{2NaOH(aq)} + \underset{\text{Chlorine}}{Cl_2(g)} + \underset{\text{Hydrogen}}{H_2(g)}$$

In this process, chlorine gas is given off at the anode and hydrogen gas at the cathode and sodium hydroxide solution is formed near the cathode. The following three products produced in this process are very useful.



Important products from the chlor-alkali process

2. Bleaching Powder [Calcium Oxychloride ($CaOCl_2$)]

It is produced by the action of chlorine on dry slaked lime. It is represented as $CaOCl_2$, though the actual composition is quite complex.

$$\underset{\text{Slaked lime}}{Ca(OH)_2} + \underset{\text{Chlorine}}{Cl_2} \longrightarrow \underset{\text{Bleaching powder}}{CaOCl_2} + \underset{\text{Water}}{H_2O}$$

On standing for a longer time, it undergoes auto-oxidation due to which bleaching action decreases.

Uses of Bleaching Powder

(*i*) It is used for bleaching cotton and linen in textile industry, for bleaching wood pulp in paper industry and for bleaching washed clothes in laundry.

(*ii*) It is also used as a disinfectant for water to make it free of germs.

(*iii*) It is used as an oxidising agent in many chemical industries.

3. Baking Soda [Sodium Hydrogen Carbonate or Sodium Bicarbonate ($NaHCO_3$)]

The soda commonly used in the kitchen for making tasty crispy pakoras is baking soda. It is a mild non-corrosive base. It is the major constituent of baking powder. Sometimes, it is added for fast cooking. Chemically, it is sodium hydrogen carbonate. It is produced by using sodium chloride as one of the raw material.

Manufacture of baking soda is shown in reaction given below:

$$\underset{\text{Brine}}{NaCl(aq)} + H_2O(l) + \underset{\text{Carbon dioxide}}{CO_2(g)} + \underset{\text{Ammonia}}{NH_3(g)} \longrightarrow \underset{\text{Ammonium chloride}}{NH_4Cl(g)} + \underset{\text{Sodium hydrogen carbonate}}{NaHCO_3(s)}$$

The following reaction takes place when it is heated during cooking :

$$\underset{\text{Sodium hydrogen carbonate}}{2NaHCO_3} \xrightarrow{\text{Heat}} \underset{\text{Sodium carbonate}}{Na_2CO_3} + H_2O + CO_2\uparrow$$

Uses of Baking Soda

(*i*) For making baking powder, which is a mixture of baking soda (sodium hydrogen carbonate) and a mild edible acid such as tartaric acid. When baking powder is heated or mixed in water, the following reaction takes place:

$$\underset{\text{Sodium hydrogen carbonate}}{NaHCO_3} + \underset{\text{(From any acid)}}{H^+} \longrightarrow \underset{\text{Carbon dioxide}}{CO_2} + \underset{\text{Water}}{H_2O} + \text{Sodium salt of acid}$$

Carbon dioxide produced during the reaction causes bread or cake to rise making them soft and spongy.

(*ii*) Sodium hydrogen carbonate is also an ingredient of antacids. Being alkaline, it neutralises excess acid in the stomach and provides relief.

$$\underset{\text{Sodium hydrogen carbonate}}{NaHCO_3\,(s)} + \underset{\text{Hydrochloric acid}}{HCl\,(l)} \longrightarrow \underset{\text{Sodium chloride}}{NaCl\,(aq)} + \underset{\text{Water}}{H_2O\,(l)} + \underset{\text{Carbon dioxide}}{CO_2\,(g)}$$

(*iii*) It is also used in soda-acid fire extinguishers.

Note Baking soda is also acts as a preservative for milk. In summer, it is added to the milk, as milk decompose and release lactic acid which makes milk sour. Added $NaHCO_3$ reacts with acid to form salt and water. It neutralises the acidic effect and milk does not become sour.

4. Washing Soda
[Sodium Carbonate ($Na_2CO_3 \cdot 10H_2O$)]

Sodium carbonate is a white crystalline solid. Its solution in water is alkaline in nature (turns red litmus blue).

It has the property to remove dirt and grease from dirty clothes, thus it is called washing soda.

Sodium carbonate can be obtained by heating baking soda. The recrystallisation of sodium carbonate gives washing soda. It is also a **basic salt.**

$$Na_2CO_3\,(s) + 10H_2O\,(l) \longrightarrow Na_2CO_3 \cdot 10H_2O\,(s)$$

Uses of Washing Soda

(*i*) It is used in glass, soap and paper industries.

(*ii*) It is used for the manufacture of sodium compounds like borax.

(*iii*) It also removes permanent hardness of water.

(*iv*) It is used as a cleansing agent (detergent) in houses and laundries.

5. Plaster of Paris [Calcium Sulphate Hemihydrate ($CaSO_4 \cdot 1/2H_2O$)]

It is obtained by heating gypsum ($CaSO_4 \cdot 2H_2O$) at 373 K. At this temperature, gypsum loses water molecules and forms plaster of Paris.

$$\underset{\text{Gypsum}}{CaSO_4 \cdot 2H_2O} \xrightarrow[\text{Heat}]{373\ K} \underset{\text{Plaster of Paris}}{CaSO_4 \cdot \frac{1}{2}H_2O} + 1\frac{1}{2}H_2O$$

When gypsum is heated above 400 K, dead burnt plaster (anhydrous $CaSO_4$) is obtained which does not have the property of hardening.

Plaster of Paris is a white powder and on mixing with water, it changes to gypsum giving a hard solid mass.

$$\underset{\text{Plaster of Paris}}{CaSO_4 \cdot \tfrac{1}{2}H_2O} + 1\frac{1}{2}H_2O \longrightarrow \underset{\text{Gypsum}}{CaSO_4 \cdot 2H_2O}$$

Uses of Plaster of Paris

(*i*) It is used by doctors for joining the fractured bones at right position, i.e. for making plaster to support fractured bones.

(*ii*) It is also used for making decorative pieces and for making designs on ceilings.

Water of Crystallisation

Crystals of some compounds seem to be dry (or anhydrous) but actually contain some water molecules attached to them. This water is called water of crystallisation and such salts are called **hydrated salts.**

Water of crystallisation is the fixed number of water molecules present in one formula unit of a salt. Five water molecules are present in one formula unit of copper sulphate (blue vitriol; $CuSO_4 \cdot 5H_2O$). Other salt which possesses water of crystallisation is gypsum ($CaSO_4 \cdot 2H_2O$). It has two water molecules as water of crystallisation. This water is removed by heating the crystals of the hydrated salt. Plaster of Paris possesses 1/2 molecule of water of crystallisation.

Check Point 03

1 Fill in the blank:
The salt that we used in food is a ..... salt.

2 State True or False for the following statement:
Sodium hydrogen carbonate is used in fire extinguisher.

3 Name the chemical compound which is used as a disinfectant for water.

4 When a sodium compound X which is also used in soda-fire extinguisher is heated, gives a sodium compound Y alongwith water and carbon dioxide. Y on crystallisation forms compound Z. Identify X, Y and Z.

5 Write the chemical formula of blue vitriol.