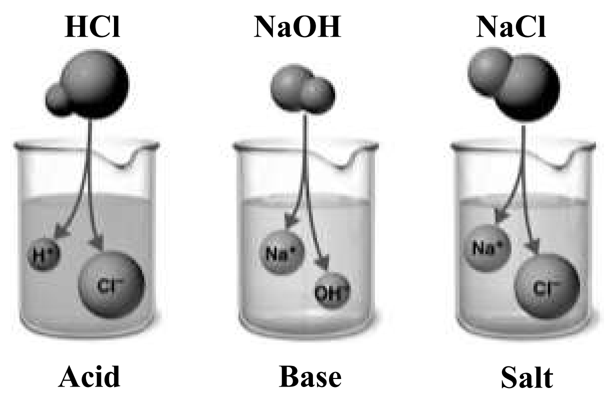
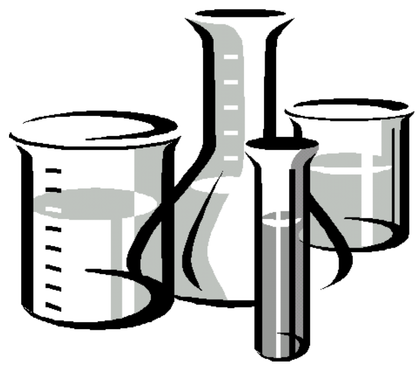
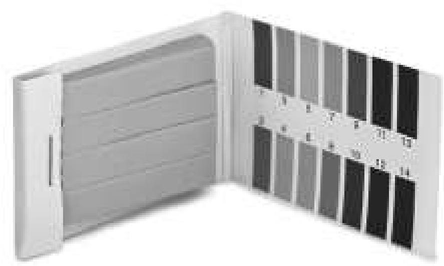
Acids, Bases & Salts

Chapter Outline







Indicator

INTRODUCTION

A wide variety of materials having, different characteristics exist around us. These materials consist essentially of elements and compounds. In the present chapter, we shall study the kinds of compounds that we come across in our day-to-day activities. Some of them are sour, some are bitter, while some are salty in taste. For example, lemon juice is sour, soap solution is bitter and sea water is salty. One of the various ways of classifying, these compounds is to group them into three categories : acids, bases and salts.

ACIDS

The term 'acid' has its origin in the Latin word 'acidus', meaning sour. In fact, anything that tastes sour contains an acid. For example, lemon juice, tomato, vinegar, etc, all taste sour. So, each of these substances must contain an acid. Some of the naturally occurring substances that contain acids are given in Table

Substance	Acid present
1. Orange, Lemon	Citric acid, ascorbic acid (Vitamin C)
2. Apple	Malic acid
3. Tamarind (imli), grape	Tartaric acid
4. Vinegar	Acetic acid
5. Curd	Lactic acid
6. Tomato	Oxalic acid
7. Gastric juice	Hydrochloric acid
8. Tea	Tannic acid
9. Red ants	Formic acid

Boost your knowledge

Interesting facts :

- Boyle in 1680 proposed that an acid is sour in taste and turns blue litmus red, reacts with active metals to liberate hydrogen and neutralizes bases to form salts.
- Rolled in 1774 proposed that a base is bitter in taste, neutralizes acids, possesses soapy touch and turns red litmus blue.

Arrhenius Concept :

An Arrhenius acid on dissolution in water, furnishes hydrogen ions [H^+ or more correctly hydronium ions H_3O^+] as the only positively charged ion.

$$\underset{\text{Hydrochloric acid}}{HCl} + H_2O \rightarrow \underset{\text{Hydronium ion}}{H_3O^+} + \underset{\text{Chloride ion}}{Cl^-}$$

$$\underset{\text{Nitric acid}}{HNO_3} + H_2O \rightarrow \underset{\text{Hydronium ion}}{H_3O^+} + \underset{\text{Nitrate ion}}{NO_3^-}$$

$$\underset{\text{Sulphuric acid}}{H_2SO_4} + H_2O \rightarrow \underset{\text{Hydronium ion}}{H_3O^+} + \underset{\text{Hydrogen sulphate ion}}{HSO_4^-}$$

$$\underset{\text{Acetic acid}}{CH_3COOH} + H_2O \rightleftharpoons \underset{\text{Hydronium ion}}{H_3O^+} + \underset{\text{Acetate ion}}{CH_3COO^-}$$

Classification of Acids :

(i) On the basis of source :

(a) Organic acids : The acids present in animals and plant materials are called organic acids. They are naturally occurring weak acids and there is no harm in eating or drinking those substances which contain naturally occurring organic acids. Citric acid is present in citrus fruits such as lemon and oranges, lactic acid is present in sour milk or curd, oxalic acid is present in tomatoes, acetic acid (ethanoic acid) is present in vinegar (sirka), tartaric acid is present in tamarind (imli) formic acid (methanoic acid) is present in ant sting and nettle leaf sting.

(b) Mineral acids : The acids obtained from minerals of the earth are called minerals acids. These are the synthetic acids and are prepared in laboratories and industries. These acids can burn our body, clothes etc. Therefore, these acids should be handled with care. Carbonic acid (H_2CO_3), Nitric acid (HNO_3), Sulphuric acid (H_2SO_4), Hydrochloric acid (HCl) etc. are important mineral acids.

(ii) On the basis of strength :

The relative strength of acids can be compared in terms of degree of dissociation denoted by 'α' (pronounced as 'alpha').

Mathematically, $$\alpha = \frac{\text{No. of molecules of acid dissociated into ions}}{\text{Total no. of molecules of acids}}$$

On the basis of strength, acids can be -

(a) Strong acids : Acids which undergo complete dissociation in aqueous solution producing a high concentration of hydrogen ions (or hydronium ions) are called strong acids. For example, hydrochloric acid (HCl), sulphuric acid (H_2SO_4), nitric acid (HNO_3) etc.

(b) Weak acids : Acids which undergo partial dissociation in aqueous solution producing a low concentration of hydrogen ions are called weak acids. For example, carbonic acid (H_2CO_3), phosphoric acid (H_3PO_4), formic acid (HCOOH), acetic acid (CH_3COOH), citric acid and tartaric acid etc.

Most organic acids are used as food ingredients as they are weak acids. However, mineral acids are strong acids. They are extremely dangerous and should be handled with care. They are corrosive in nature and cause burns on skin. The dilute solutions of weak acids are quite safe and are used in the food stuffs. For example, acetic acid (vinegar) is used as preservative in making pickles. Tartaric acid is used as a ingredient of baking powder whereas carbonic acid is used in fizzy soft drinks and soda water.

Boost your knowledge

☛ Strong acids completely ionize in solution and exists as ions in solution. The value of α is nearly one or 100 %. Weak acids consists of ions as well as undissociated molecules as they undergo partial association in aqueous solution. For weak acids α < 30 %.

(iii) On the basis of elements present :

(a) Oxy acids : Acids which contain hydrogen, Oxygen and at least one other element, an at least one hydrogen atom bound to oxygen are called oxyacids. For example, nitric acid (HNO_3), sulphuric acid (H_2SO_4) and phosphoric acid (H_3PO_4) etc are oxy acids.

(b) Hydracids : Acids which contain hydrogen and other nonmetallic element(s), except oxygen, are called hydracids. For example, hydrochloric acid (HCl) and hydrocyanic acid (HCN) etc. are hydracids.

(iv) On the basis of relative amount of acid and water :

(a) Concentrated acids : Concentrate acids are those whose acids solutions that contain a high percentage of the acid.

(b) Dilute acids : Dilute acids are those whose acids solutions that contain a low percentage of the acid.

Boost your knowledge

☛ It must be remembered that the dilution of an acid depends on the water content whereas the strength of an acid depends on the dissociation of the acid in solution. This means that :

(i) A weak acid remains a weak acid even if it is concentrated because it dissociated to a small extent and produces a low concentration of hydrogen ions.

(ii) A strong acid remains a strong acid even if it is dilute because it dissociates to a large extent and produces a high concentration of hydrogen ions.

Dilution of Acid : Dilution of a concentrated acid is always done by taking sufficient amount of water in a beaker and adding concentrated acid into it slowly with stirring. Thus, we always **dilute an acid by adding acid into water and not water into acid.**

Can you think why ?

- Water is not added to acid while dilution.

(v) On the basis of basicity of acids :

Basicity of acid : It is the number of replaceable hydrogen atoms present in an acid.

or

It is the number of hydrogen ions [H^+] produced by the ionization of one molecule of the acid when dissolved in aqueous solution.

According to basicity acids have been classified as :

(a) Monobasic acid : Acids which dissociate on dissolving in water to produce one hydrogen ion [H^+] per molecule of the acids are called monobasic acid.

Examples : HCl, HNO_3, CH_3COOH, HI, HBr, HOCl, HCOOH etc.

$HCl(aq) \rightarrow H^+(aq) + Cl^-(aq)$ Basicity = 1

(b) Dibasic acid : Acids which dissociate in water to produce two hydrogen ions [H^+] per molecule of the acid are called dibasic acids.

Examples : H_2SO_4, H_2CO_3, H_2SO_3, $(COOH)_2$, etc.

$H_2SO_4 \rightarrow H^+ + HSO_4^-$

$HSO_4^- \rightarrow H^+ + SO_4^{2-}$

$H_2SO_4(aq) \rightarrow 2H^+ (aq) + SO_4^{2-} (aq)$ Basicity = 2

(c) Tribasic acid : Acids which dissociate on dissolving in water to produce three hydrogen ions [H^+] per molecule of the acid are called tribasic acids.

Examples : H_3PO_4, $C_6H_8O_7$(Citric acid) etc.

$H_3PO_4 \rightarrow H^+ + H_2PO_4^-$

$H_2PO_4^- \rightarrow H^+ + HPO_4^{2-}$

$HPO_4^{2-} \rightarrow H^+ + PO_4^{3-}$

$H_3PO_4(aq) \rightarrow 3H^+ (aq) + PO_4^{3-} (aq)$ Basicity = 3

Basicity of an acid does not depend upon the number of hydrogen atoms present but upon the number of replaceable hydrogen atoms. For example, acetic acid (CH_3COOH) has four hydrogen atoms in its molecule but only one is ionisable or replaceable by a metal. Hence, acetic acid is a monobasic acid.

$$CH_3COOH(aq) \rightleftharpoons CH_3COO^-(aq) + H^+ (aq)$$

$$CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$$

Phosphoric acid (H_3PO_4) has three hydrogen atoms and all of them can be replaced by metal atoms. Hence, it is a tribasic acid.

General Characteristics of Acids :

1. **Taste :** Acids have a sour taste.
2. **Physical state :** Some acids are solids while other are liquids at room temperature.
   For example, oxalic acid, boric acid, etc., are solids while acetic acid, formic acid, etc., are liquids.
3. **Corrosive nature :** Most of the acids are corrosive in nature. They produce a burning sensation on the skin and holes in the clothes on which they fall.
   Due to their corrosive nature they are not stored in metal containers as they attack metals. They are always stored in glass or ceramic containers which are not attacked by acids.
   Concentrated acids should be handled with care in the laboratory as they are highly corrosive and cause painful blisters if they fall on skin. Therefore, a "danger mark" is put on containers containing concentrated acids.
4. **Action of Indicators :**
   (i) They turn blue litmus solution red.
   (ii) They change the colour of methyl orange from yellow to red.
   (iii) Phenolphthalein remains colourless in acidic solutions.
5. **Reaction with active metals :** Dilute acids like dilute HCl and dilute H_2SO_4, react with active metals like zinc, magnesium, iron etc., to evolve hydrogen gas.

$$\text{Metal} + \text{Dilute acid} \rightarrow \text{Metal salt} + \text{Hydrogen}$$

$$\underset{\text{Zinc}}{Zn(s)} + \underset{\text{Dil. sulphuric acid}}{H_2SO_4} \rightarrow \underset{\text{Zinc sulphate}}{ZnSO_4(aq)} + \underset{\text{Hydrogen}}{H_2(g)\uparrow}$$

$$\underset{\text{Magnesium}}{Mg(s)} + \underset{\text{Dil. hydrochloric acid}}{2HCl} \rightarrow \underset{\text{Magnesium Chloride}}{MgCl_2(aq)} + \underset{\text{Hydrogen}}{H_2(g)\uparrow}$$

$$\underset{\text{Iron}}{Fe(s)} + \underset{\text{Dil. sulphuric acid}}{H_2SO_4} \rightarrow \underset{\text{Ferrous sulphate}}{FeSO_4(aq)} + \underset{\text{Hydrogen}}{H_2(g)\uparrow}$$

Some metals like copper and silver are less reactive and they do not react with the dilute acids.

- **Reactivity series of Metals :**

$$\left.\begin{matrix} \text{K} \\ \text{Na} \end{matrix}\right] \text{React explosively with dilute acids, liberating hydrogen}$$

$$\text{Ca} \left|\ \text{React less vigorously with dilute acids}\right.$$

$$\left.\begin{array}{l} Mg \\ Al \\ Zn \\ Fe \\ Pb \end{array}\right] \text{React with dilute acids with decreasing vigour, liberating hydrogen}$$

$$\left.\begin{array}{l} H \\ Cu \\ Hg \end{array}\right] \text{Do not give hydrogen with dilute acid}$$

6. **Reaction with metal carbonates and metal hydrogen carbonates (Bicarbonates) :** Dilute acids react with metal carbonates and bicarbonates to liberate carbon dioxide gas with brisk effervescence and form corresponding salt and water. For example.

Metal carbonates or Metal hydrogen Carbonates + Acid $\rightarrow$ Salt + H_2O + CO_2

$$\underset{\text{Sodium carbonate}}{Na_2CO_3} + \underset{\text{Dil. sulphuric acid}}{H_2SO_4} \rightarrow \underset{\text{Sodium sulphate}}{Na_2SO_4} + \underset{\text{Water}}{H_2O} + \underset{\text{Carbon dioxide}}{CO_2\uparrow}$$

$$\underset{\substack{\text{Sodium hydrogen carbonate}\\\text{(Sodium bicarbonate)}}}{NaHCO_3} + \underset{\text{Dil. hydrochloric acid}}{HCl} \rightarrow \underset{\text{Sodium chloride}}{NaCl} + \underset{\text{Water}}{H_2O} + \underset{\text{Carbon dioxide}}{CO_2\uparrow}$$

Similarly, limestone, chalk and marble (all of different forms of calcium carbonate) react with dilute acid to liberate carbon dioxide.

$$\underset{\substack{\text{Calcium carbonate}\\\text{(Limestone/chalk/marble)}}}{CaCO_3} + \underset{\text{Dil. hydrochloric acid}}{2HCl} \rightarrow \underset{\text{Calcium chloride}}{CaCl_2} + \underset{\text{Water}}{H_2O} + \underset{\text{Carbon dioxide}}{CO_2\uparrow}$$

7. **Reaction of acids with bases :** When an acid reacts with a base, it forms salt and water. This reaction is called neutralization.

$$\text{Acid + Base} \rightarrow \text{Salt + Water}$$

During neutralization, acid and base react and neutralize each others effect. It is an exothermic process.

For example, when hydrochloric acid reacts with sodium hydroxide solution, then a neutralization reaction takes place to form sodium chloride and water.

$$\underset{\substack{\text{Sodium hydroxide}\\\text{(Base)}}}{NaOH(aq)} + \underset{\substack{\text{Hydrochloric acid}\\\text{(Acid)}}}{HCl(aq)} \rightarrow \underset{\substack{\text{Sodium chloride}\\\text{(Salt)}}}{NaCl(aq)} + \underset{\text{Water}}{H_2O(\ell)}$$

8. **Reaction of metallic oxides with acids :** Acids react with metal oxides to form salt and water.

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

Copper (II) oxide (black in colour) is a metallic oxide. It reacts with dilute hydrochloric acid to form copper (II) chloride (blue-green in colour) and water.

$$\underset{\substack{\text{Copper (II) oxide}\\\text{(Black)}}}{CuO(s)} + \underset{\text{Hydrochloric acid}}{2HCl(aq)} \rightarrow \underset{\substack{\text{Copper (II) chloride}\\\text{(Blue-green)}}}{CuCl_2(aq)} + \underset{\text{Water}}{H_2O(\ell)}$$

Role of water in the dissociation of an acid :

Substances can act as acids and bases only in the presence of water (in aqueous solution). In dry state which is also called anhydrous state, these characters cannot be shown. Actually, water helps in the ionisation of acid or base by separating the ions. This is also known as dissociation and is explained on the basis of a theory called Arrhenius theory of acids and bases.

In the dry state, hydrochloric acid is known as hydrogen chloride gas i.e. HCl(g). It is not in the position to give any H^+ ions. Therefore, the acidic character is not shown. Now, let us pass the gas through water taken in a beaker with the help of glass pipe. H_2O molecules are of polar nature which means that they have partial negative charge (d^-) on oxygen atom and partial positive charge (d^+) on hydrogen atoms. They will try to form a sort of envelope around the hydrogen atoms as well as chlorine atoms present in the acid and thus help in their separation as ions. These ions are said to be hydrated ions.

$$HCl(g) + H_2O \longrightarrow H_3O^+ + Cl^-(aq)$$
(Hydrated ions)

Chemical formulae, types and uses of some common acids

Name	Type	Chemical Formula	Where found or used
Carbonic acid	Mineral acid	H_2CO_3	In soft drinks and lends fizz.
Nitric acid	Mineral acid	HNO_3	Used in the manufacture of explosives (TNT, Nitroglycerine) and fertilizers (Ammonium nitrate, Calcium nitrate, Purification of Au, Ag)
Hydrochloric acid	Mineral acid	HCl	In purification of common salt, in textile industry as bleaching agent, to make aqua regia, in stomach as gastric juice, used in tanning industry
Sulphuric acid	Mineral acid	H_2SO_4	Commonly used in car batteries, in the manufacture of fertilizers (Ammonium sulphate, super phosphate) detergents etc, in paints, plastics, drugs, in manufacture of artificial silk, in petroleum refining.
Phosphoric acid	Mineral acid	H_3PO_4	Used in antirust paints and in fertilizers.
Formic acid	Organic acid	$HCOOH$	Found in the stings of ants and bees, used in tanning leather, in medicines for treating gout.
Acetic acid	Organic acid	CH_3COOH	Found in vinegar, used as solvent in the manufacture of dyes and perfumes.
Lactic acid	Organic acid	$CH_3CH(OH)COOH$	Responsible for souring of milk in curd.
Benzoic acid	Organic acid	C_6H_5COOH	Used as a food preservative.
Citric acid	Organic acid	$C_6H_8O_7$	Present in lemons, oranges and citrus fruits.
Tartaric acid	Organic acid	$C_4H_6O_6$	Present in tamarind.

BASES

Bases taste bitter and feel slippery or soapy to touch. A base is either a metallic hydroxide or a metallic oxide or aqueous ammonia which reacts with an acid to form salt and water only.

A base is a compound which reacts with an acid to form a salt and water only.

According to the Arrhenius concept, a base is a substance which when dissolved in water gives hydroxyl (OH^-) ions as the only negative ion in solution.

Table : Some examples of bases

Base	Molecular Formula	Common or commercial Name
Calcium oxide	CaO	Quick lime
Sodium hydroxide	$NaOH$	Caustic soda
Potassium hydroxide	KOH	Caustic potash
Calcium hydroxide	$Ca(OH)_2$	Slaked lime
Magnesium hydroxide	$Mg(OH)_2$	Milk of magnesia
Iron (II) hydroxide	$Fe(OH)_2$	Ferrous hydroxide
Iron (III) hydroxide	$Fe(OH)_3$	Ferric hydroxide
Ammonium hydroxide	NH_4OH	Aqueous ammonia

- **Alkali :**

An alkali is a base, soluble in water. An alkali is a compound which when dissolved in water yields hydroxyl ions (OH^-) as the only negatively charged ions.

Examples : $NaOH$, KOH, $Ca(OH)_2$, NH_4OH, etc.

Bases which are not soluble in water are not alkalies. For example, copper (II) oxide (CuO), lead oxide (PbO), zinc oxide (ZnO), lead hydroxide [$Pb(OH)_2$], ferric hydroxide $Fe(OH)_3$, copper hydroxide $Cu(OH)_2$ and magnesium hydroxide $Mg(OH)_2$.

Thus, all alkalies are bases but all bases are not alkalies.

Classification of Bases :

(i) On the basis of strength :

(a) Strong bases : Bases which undergo almost complete dissociation in aqueous solution and produce a high concentration of hydroxyl ions (OH^-) in solution are called strong bases.

For example, potassium hydroxide (KOH), sodium hydroxide (NaOH), barium hydroxide [$Ba(OH)_2$], etc.

(b) Weak bases : Bases which undergo partial dissociation in aqueous solution and produce a low concentration of hydroxyl ion (OH^-) in solution are called weak bases.

For example, $Mg(OH)_2$ (magnesium hydroxide), NH_4OH(ammonium hydroxide),$Cu(OH)_2$ (copper hydroxide) etc.

(ii) On the basis of concentration :

(a) Concentrated alkali : An alkali having a relatively high percentage of alkali in its aqueous solution.

(b) Dilute alkali : An alkali having a relatively low percentage of alkali in aqueous solution.

(iii) On the basis of acidity of bases :

Acidity of Base : The number of hydroxyl ions (OH^-) produced by the dissociation of one molecule of the base in its aqueous solution is called its acidity.

(a) Monoacidic base : Bases, which dissociate in aqueous solution to produce one hydroxyl ion (OH^-) per molecule of the base, are monoacidic bases.

$NaOH \rightleftharpoons Na^+ + OH^-$ Acidity = 1

Examples : NaOH, KOH, NH_4OH, etc.

(b) Diacidic base : Bases, which dissociate in aqueous solution to produce two hydroxyl ions (OH^-) per molecule of the base, are called diacidic bases.

$Ca(OH)_2 \xrightleftharpoons{\text{water}} Ca^{2+} + 2OH^-$ Acidity = 2

Examples : $Ca(OH)_2$, $Zn(OH)_2$, $Cu(OH)_2$, etc.

(c) Triacidic base : Bases, which dissociate in aqueous solution to produce three hydroxyl ions (OH^-) or contain three hydroxyl ions per molecule of the base (if water insoluble), are called triacidic bases.

Examples : $Al(OH)_3$, $Fe(OH)_3$, etc. Acidity = 3

General Characteristics of Bases :

1. **Taste and feel :** Alkalies have a bitter taste and their solutions feel slippery or 'soapy' when rubbed between fingers.
2. **Corrosive nature :** Both caustic soda and caustic potash are corrosive in nature, i.e., they have strong burning action on skin and produce blisters.
3. **Action of indicators :**

Indicators	Colour Change
Red litmus solution	Turns blue
Methyl orange	Remains yellow
Phenolphthalein	Colourless to pink

4. **Conduction of electricity :** Like acids, the solution of bases in water also conduct electricity.
5. **Reaction with acids :** Alkalis (and bases) react with acids to form salt and water only. This reaction is called neutralization. For example,

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

Activity :

To study a neutralization reaction.

Procedure :

Take some dilute hydrochloric acid solution in a conical flask. Add a drop or two of phenolphthalein to it. Take some sodium hydroxide solution in a burette. Add this solution to the hydrochloric acid in the conical flask by drop with constant stirring. A stage is reached when the solution in the conical flask just appears pink. Divide the solution in the flask into two parts. To one, add blue litmus paper and to the other, red litmus paper.

Observations :

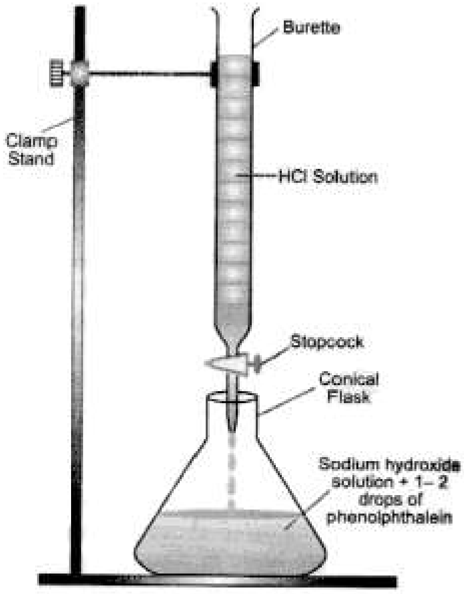
There is no change in either of the litmus papers.

Conclusion :

A neutralization reaction has taken place between the two reactants since the solution obtained is neither acidic nor basic in nature.

$$\underset{\text{Sodium hydroxide}}{NaOH(aq)} + \underset{\text{Hydrochloric Acid}}{HCl(aq)} \rightarrow \underset{\text{Sodium chloride}}{NaCl(aq)} + \underset{\text{Water}}{H_2O(aq)}$$

This is a neutralization reaction because the acid reacts with the base to form the salt, sodium chloride and water.



$$\underset{\text{Potassium hydroxide}}{KOH(aq)} + \underset{\text{Nitric acid}}{HNO_3(aq)} \rightarrow \underset{\text{Potassium nitrate}}{KNO_3(aq)} + \underset{\text{Water}}{H_2O(aq)}$$

$$\underset{\text{Ammonium hydroxide}}{NH_4OH(aq)} + \underset{\text{Hydrochloric acid}}{HCl(aq)} \rightarrow \underset{\text{Ammonium chloride}}{NH_4Cl} + \underset{\text{Water}}{H_2O}$$

6. **Alkalis liberate ammonia from ammonium salts :** Alkalis on heating with ammonium salts liberate ammonia gas.

$$\underset{\text{Ammonium Chloride}}{NH_4Cl(s)} + \underset{\text{Sodium hydroxide}}{NaOH(aq)} \xrightarrow{\Delta} \underset{\text{Sodium chloride}}{NaCl(aq)} + \underset{\text{Water}}{H_2O(\ell)} + \underset{\text{Ammonia}}{NH_3(g)}\uparrow$$

7. **Alkalis absorb carbon dioxide from air :** Alkalis absorb carbon dioxide from the air and form the corresponding metal carbonates.

$$\underset{\text{Sodium hydroxide}}{2NaOH} + \underset{\text{Carbon dioxide (From air)}}{CO_2} \rightarrow \underset{\text{Sodium Carbonate}}{Na_2CO_3} + \underset{\text{water}}{H_2O}$$

$$\underset{\text{Potassium hydroxide}}{2KOH} + \underset{\text{Carbon dioxide (From air)}}{CO_2} \rightarrow \underset{\text{Potassium carbonate}}{K_2CO_3} + \underset{\text{Water}}{H_2O}$$

8. **Reaction of alkalis with metals :** Some bases like sodium hydroxide and potassium hydroxide react with active metals like zinc and aluminum to liberate hydrogen gas.

$$\underset{\text{Zinc}}{Zn} + \underset{\text{Sodium hydroxide}}{2NaOH} \rightarrow \underset{\text{Sodium zincate}}{Na_2ZnO_2} + \underset{\text{Hydrogen}}{H_2}$$

$$\underset{\text{Aluminium}}{2Al} + \underset{\text{Sodium hydroxide}}{2NaOH} + \underset{\text{water}}{2H_2O} \rightarrow \underset{\text{Sodium aluminate}}{NaAlO_2} + \underset{\text{Hydrogen}}{3H_2}$$

INDICATORS

There are many substances which show different colours in different medium i.e., acidic and basic medium. Such substances are called indicators.

Types of indicator :

(A) Olfactory Indicators : There are some substances whose odour changes in acidic or basic media. These are called olfactory indicators. Vanilla essence, onion and clove oil can be used as olfactory indicators.

(B) Colour or Visual indicators :

An indicator, which identifies whether a given substance is an acid or a base by a sharp change in it colour change.

Indicators are basically coloured organic substances either extracted from plants or synthesized in the laboratory.

The three common acid-base indicators are litmus, phenolphthalein and methyl orange. Litmus is a natural indicator whereas phenolphthalein and methyl orange are synthetic indicators.

(1) Natural indicators :

(i) Litmus is a natural indicator. Litmus solution is a purple coloured dye which is extracted from 'lichen' a plant belonging to a variety thallophyta. There are two types of litmus solution – Blue litmus and Red litmus solution. Blue litmus solution turns red in an acidic medium and red litmus solution blue in a basic solution.

(ii) Turmeric : On adding turmeric to a basic solution its colour changes from yellow to reddish- brown. Its colour remains unchanged (i.e., yellow) if it is added to an acidic or a neutral medium.
It is observed that a yellow stain of curry on a white cloth becomes reddish-brown when soap is scrubbed on it. It shows that soap is basic in nature.

(iii) Red cabbage juice : Red cabbage juice is purple in colour. In an acidic medium, its colour changes to red and in a basic medium, its colour changes to green.

(iv) Coloured petal of some flowers such as hydrangea, petunia and geranium, also indicate the presence of acid or base in a solution. The colour of hydrangea depends on whether the soil is acidic or alkaline. Hydrangea grown in alkaline soil produce red flowers while if grown in acidic soil produce blue flowers.

(v) China rose extract : A solution of China rose turns green in a basic solution, and bright pink or magenta in an acidic solution.

(b) Synthetic Indicators : Phenolphthalein and methyl orange are synthetic indicators.

(i) Phenolphthalein : Phenolphthalein is a dye which is a weak organic acid. In neutral or acidic solution, it is colourless while in the basic solution it changes to pink colour.

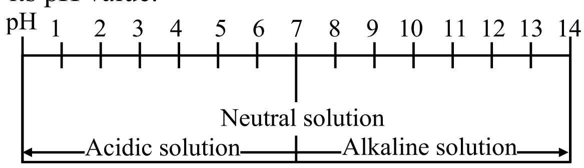
(ii) Methyl orange : Methyl orange is a dye which is a weak organic base. It is orange in colour in neutral medium. In acidic medium it changes to red colour while in basic medium it changes to yellow colour.

pH SCALE :

"The pH of a solution is the logarithm (to the base 10) of the reciprocal of its hydrogen ion concentration in moles per litre."

$$pH = \log\frac{1}{[H^+]} \quad \text{or} \quad pH = -\log[H^+]$$

The p in pH stand for 'potenz' in German meaning power and H stands for hydrogen ion concentration. On the pH scale we can measure pH from 0 (very acidic) to 14 (very alkaline). pH is simply a number which indicates acid or basic nature of the solution. Higher the hydrogen ion concentration, lower is its pH value.



For calculating the pH of a solution, we have to use its hydrogen ion concentration $[H^+]$ in moles per litre. In other words, we have to use the molar concentration (M) of the hydrogen ions. By using the above formula, we can calculate the pH of a solution from its hydrogen ion concentration. And if we know the pH value, we can find out the hydrogen ion concentration.

pH of Pure Water :

The concentration of hydrogen ions in pure water is 10^{-7} M which means $[H^+] = 10^{-7}$

$$pH = -\log[H^+] = -\log[10^{-7}]$$
$$= -[-7] \qquad (\because \log 10^{-7} = -7)$$

Or $\quad pH = 7$

Thus, pH of water is 7. Whenever the pH of a solution is 7, it will be a neutral solution. Such a solution will have no effect on any litmus solution or any other indicator.

Ex.1 Calculate the pH of a solution whose concentration is 1×10^{-4} mol/L in HCl.

Sol. $[H^+] = [HCl] = 1 \times 10^{-4}$ mol/L.

$pH = -\log_{10}[H^+] = -\log_{10}(1 \times 10^{-4}) = (-4)\log_{10} 10$

$pH = 4$

Thus, 1×10^{-4} mol/L solution of HCl has a pH of 4.

Ex.2 Calculate the pH of 10^{-5} M NaOH solution.

Sol. Conc. of $[OH^-] = 10^{-5}$ M

$[H^+][OH^-] = 10^{-14}$ M

$$[H^+] = \frac{10^{-14}}{[OH^-]} = \frac{10^{-14}}{10^{-5}} = 10^{-9}\text{ M}$$

Therefore, $pH = -\log_{10}[H^+] = -\log_{10} 10^{-9} = +9\log_{10} 10 \quad (\because \log_{10} 10 = 1)$

then, $pH = 9$

Solution	pH
1. 1M Hydrochloric acid	0
2. Battery acid	0.5
3. Dilute hydrochloric acid	1.0
4. Gastric juices (Digestive juices in stomach)	1.0 - 3.0
5. Lemon juice	2.2 - 2.4
6. Vinegar	2.4 - 3.4
7. Soft drinks	3.0
8. Wine	2.8 - 3.8
9. Oranges	3.6
10. Tomato juice	4.0 - 4.4
11. Beer	4.0 - 5.0
12. Coffee	4.5 - 5.5
13. Milk	6.5
14. Urine	5.5 - 7.5
15. Saliva	6.5 - 7.5
16. Blood	7.3 - 7.5
17. Eggs	7.8
18. Baking soda solution	8.4
19. Sea-water	8.5
20. Washing soda solution	9.0
21. Lime-water	10.5
22. Milk of magnesia [$Mg(OH)_2$ solution]	10.5
23. 1 M Ammonium hydroxide (Household ammonia)	11.6
24. Dilute sodium hydroxide	13
25. 1 M Sodium hydroxide	14

Importance of pH in Everyday Life

pH plays a very important role in our everyday life.

(A) Are plants and Animals pH sensitive ?

(i) Human Beings and Animals :

Our body works within a pH range of 7.0 to 7.8. If, due to some reason this pH range gets disturbed in the body then many ailments can occur. The pH value of urine and blood is used to diagnose various diseases. A human body is like a chemical factory in which different reactions take place in different parts of the body at a specific pH value.

Lakes and rivers can be polluted by acid rain. When pH of rain water is less than 5.6, it is called acid rain. When the acid rain flows into the rivers or lake, it lowers the pH of the water or increases the acidity of water. The survival of aquatic life in such rivers or lakes becomes difficult. The high acidity of river or lake water can even kill the aquatic animals like fish. Calcium carbonate is often added to acidic lake water to neutralise the acidity of the water.

(ii) Soil pH and Plant Growth :

Plants require a specific pH range for their healthy growth. Therefore, the pH of soil needs to be checked to ensure fast growth of crops. **For example**, citrus fruits need a slightly alkaline soil, rice crops needs an acidic soil and sugarcane needs a neutral soil.

Soils in chalk and limestone regions are usually alkaline. Sometimes its pH reaches as high as 8.3 which is quite harmful for plant growth. Soils in sandstone, clay and peat areas are usually acidic. The soil pH in such areas can reach as low as 4. The acidic effect can be neutralized by 'liming the soil' which is carried out by adding calcium hydroxide, calcium oxide, powdered chalk (calcium carbonate), etc.

(B) pH in our Digestive System :

Our stomach produces hydrochloric acid which helps in the digestion of food without harming the stomach. It also kills the harmful bacteria that may enter into the stomach along with the food that we eat. During indigestion, the stomach produces too much acid and this causes pain and irritation. The excessive acid can be neutralized with the help of antacids which are recommended by doctors. **'Milk of Magnesia'** which is magnesium hydroxide, a mild base, is often used for this purpose. Sodium bicarbonate (baking soda) can also be used for the same purpose.

(C) pH change as the cause of tooth decay :

Tooth decay starts when the pH of the mouth is lower than 5.5. Tooth enamel, made up of calcium phosphate is the hardest substance in the body. It does not dissolve in water, but is corroded when the pH in the mouth is below 5.5. Bacteria present in the mouth produce acids by degradation of sugar and food particles remaining in the mouth after eating. This acid lowers the pH in the mouth (making it acidic). The acid attacks the tooth enamel and corrode it. This sets in tooth decay.

The saliva produced in the mouth by the salivary glands is alkaline and partially neutralizes the acids produced in the mouth. However, the excess acid can be removed by cleaning the teeth with a good quality toothpaste. The best way to prevent tooth decay is to clean the mouth after eating food. Using toothpastes which are generally basic, for cleaning the teeth can neutralize the excess acid and prevent tooth decay.

(D) Self defence by Animal and Plants through Chemical Warfare :

Many animals and plants protect themselves from their enemies by injecting painful and irritating acids and bases into the skin by stinging them. Honey-bee and ant sting leaves an acid (formic acid) which causes pain and irritation. Use of a mild base like baking soda on the sting area gives relief. This is because being a base, baking soda neutralizes the acid of the bee sting. When a wasp stings, it injects an alkaline liquid into the skin. Use of a mild acid like vinegar on the sting area gives relief. This is because, being acidic, vinegar neutralizes the alkaline liquid injected by the wasp sting and cancels its effect.

Boost your knowledge

☛ **Nature provides neutralization options :** Nettle is a herbaceous plants which grows in the wild. Its leaves have stinging hair, which cause painful stings when touched accidentally. This is due to methanoic acid and secreted by them. So, a traditional remedy for the nettle leaf sting is to rub the stung area of the skin of the person with the leaf of dock plants, which often grows beside the nettle in the wild. The leaves of dock plant contain some basic chemical which neutralizes the acidic sting of the nettle plant leaves and gives relief.

SALTS

A substance formed by neutralization of an acid with a base is called a salt.

e.g. $Ca(OH)_2\,(aq) + H_2SO_4\,(aq) \rightarrow CaSO_4\,(aq) + 2H_2O(\ell)$

$Cu(OH)_2\,(aq) + 2HNO_3\,(aq) \rightarrow Cu(NO_3)_2\,(aq) + 2H_2O(\ell)$

$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(\ell)$

Neutralisation reactions involving the complete or partial neutralization of an acid by a base give rise to the formation of salt.

A salt is an electrovalent or ionic compound formed by the partial or complete replacement of the replaceable (ionisable) hydrogen atoms (i.e., H^+ ions) of an acid by a metallic ion or ammonium ion. All salts are ionic in nature and strong electrolytes i.e. they ionize completely on dissolution in water e.g., NH_4Cl, KCl, Na_2SO_4, $Na_2C_2O_4$ etc.

Salts are regarded as compounds made up of positive and negative ions. The positive part comes from a base while negative part comes from a acid. Salts may taste salty, sour, bitter, astringent, sweet or tasteless. Solutions of salts may be acidic, basic or neutral.

pH OF SALT SOLUTIONS:

The aqueous solutions of some salts are either acidic or alkaline or neutral. When a salt is dissolved in water, it undergoes salt hydrolysis. The hydrolysis of salt makes the solution either acidic or alkaline. The behaviour of different types of salts in aqueous solution is given below :

(i) Salts of strong acids and strong bases : Sodium chloride (NaCl), potassium sulphate (K_2SO_4), sodium sulphate (Na_2SO_4), sodium nitrate ($NaNO_3$) etc. are the salts formed by strong acids and strong bases. The aqueous solutions of such type of salts are neutral having pH equal to 7. These do not undergo hydrolysis.

(ii) Salts of strong acids and weak bases : Ammonium chloride (NH_4Cl), copper sulphate ($CuSO_4$), ammonium sulphate [$(NH_4)_2SO_4$], ammonium nitrate (NH_4NO_3), ferrous sulphate ($FeSO_4$) etc. are formed by strong acids and weak bases. The aqueous solutions of such salts are acidic with pH less than 7 due to the hydrolysis of salt.

$$NH_4Cl + H_2O \rightleftharpoons \underset{\text{Strong acid}}{HCl} + \underset{\text{Weak base}}{NH_4OH}$$

(iii) Salts of weak acids and strong bases : Sodium carbonate (Na_2CO_3), sodium acetate (CH_3COONa), sodium cyanide (NaCN) etc. are the salts made up of weak acid and strong base. Their aqueous solutions are basic in nature with pH more than 7 due to hydrolysis of salt.

$$CH_3COONa + H_2O \rightleftharpoons \underset{\text{Weak acid}}{CH_3COOH} + \underset{\text{Strong base}}{NaOH}$$

CH_3COONa and NaOH being completely ionized and thus we can write

$$CH_3COO^- + Na^+ + H_2O \rightleftharpoons CH_3COOH + Na^+ + OH^-$$

HYDRATED SALT:

Sometimes salts are associated with water molecules, in which salt is in loose chemical combination with water molecules associated. This water is referred as water of crystallization and such a salt is termed as a hydrated salt e.g., Blue vitriol ($CuSO_4 . 5H_2O$), Green vitriol ($FeSO_4 . 7H_2O$), White vitriol ($ZnSO_4.7H_2O$), hydrated calcium chloride ($CaCl_2 . 2H_2O$) etc.

During the crystallization of the salt from its aqueous solution, water of crystallization gets associated with the molecules of a salt. The water of crystallization associated with the molecules of the salt can easily be removed by heating the crystals of the salt to a definite temperature.

$$\underset{\text{decahydrate}}{Na_2CO_3.10H_2O} \xrightarrow{\text{below 373 K}} \underset{\text{monohydrate}}{Na_2CO_3.H_2O} + 9H_2O$$

$$Na_2CO_3 . H_2O \xrightarrow{\text{above 373 K}} \underset{\text{soda ash}}{Na_2CO_3} + H_2O$$

Some Hydrated salts

Hydrated salt	Chemical Name	Common Name
1. $Na_2CO_3. 10H_2O$	Sodium carbonate decahydrate	Washing soda
2. $Na_2SO_4.10H_2O$	Sodium sulphate decahydrate	Glauber's salt
3. $MgSO_4. 7H_2O$	Magnesium sulphate heptahydrate	Epsom salt
4. $CaSO_4 . 2H_2O$	Calcium sulphate dihydrate	Gypsum
5. $CaSO_4.½H_2O$	Calcium sulphate hemihydrate	Plaster of Paris
6. $CuSO_4.5H_2O$	Copper (II) Sulphate pentahydrate	Blue vitriol
7. $ZnSO_4.7H_2O$	Zinc sulphae heptahydrate	White vitriol
8. $FeSO_4.7H_2O$	Iron (II) sulphate heptahydrate	Green vitriol
9. $FeSO_4.(NH_4)_2SO_4.6H_2O$	Iron (II) ammonium sulphate hexahydrate	Mohr's salt

Are the crystals of salts really dry?

The presence of water of crystallization in a hydrated salt like hydrated copper (II) sulphate ($CuSO_4.5H_2O$) can be demonstrated by the following experiment :

Experiment : Copper sulphate crystals (blue in colour) on strongly heating in a dry boiling tube over the flame of a burner, loses water of crystallization and turns to a white powdery substance anhydrous copper sulphate. The tiny water droplets appear on the inner wall of the boiling tube due to liberation of water molecules on heating which were associated as water of crystallisation in hydrated copper sulphate.

$$\underset{\substack{\text{Hydrated copper sulphate}\\ \text{(Blue)}}}{CuSO_4.5H_2O(s)} \xrightarrow{\text{Heat}} \underset{\substack{\text{Anhyrdous copper sulphate}\\ \text{(white)}}}{CuSO_4(s)} + \underset{\text{Water}}{5H_2O(\ell)}$$

On cooling the boiling tube the white powder is taken out on a glass. Now on adding few drops of water on this white powder, the original blue colour of hydrated copper sulphate is restored due to the conversion of anhydrous copper sulphate to hydrated copper sulphate.

$$\underset{\substack{\text{Anhydrous copper sulphate}\\ \text{(white)}}}{CuSO_4(s)} + \underset{\text{Water}}{5H_2O(\ell)} \rightarrow \underset{\substack{\text{Hydrated copper sulphate}\\ \text{(Blue)}}}{CuSO_4.5H_2O(s)}$$

Can you think why ?
- Both hygroscopic and deliquescent substances absorb moisture.

Boost your knowledge

Moistening of Table salt on Exposure to Atmosphere :

Table salt (or common salt, NaCl) usually gets moistened when exposed to the atmosphere, particularly in the rainy season. Sodium chloride, NaCl is not at all hydroscopic in nature. It gets moistened on exposure to atmosphere due to the presence of impurities of some deliquescent salts such as magnesium chloride which are usually present in the commercial varieties of the table salt. These impurities absorb moisture from the atmosphere and make the table salt moistened to show deliquescent nature.

SOME COMMON COMPOUNDS

(A) Common Salt (Sodium chloride, NaCl) :

- Common salt is a mixture however, its main component is NaCl.
- Formula-NaCl
- Chemical name-Sodium chloride.
- Other names-table salt or kitchen salt or rock salt.

Introduction :

It is one of the most important constituent of table salt. It is not only an important constituent of our food but also an important chemical and is a starting material for the preparation of several other important compounds.

1. **Occurrence :**
Common salt occurs naturally in sea water and as rock salt. Sea water contains several salts along with sodium chloride. Therefore, deposits of solid common salt are found in several parts of the world as a result of solar evaporation of water.

2. **Isolation of NaCl from sea water :** Sea water is the most abundant source of sodium chloride (about 2.7 % to 2.9 % by mass). Many of the lakes such as Sambhar lake (Rajasthan in India) has sufficient quantity of NaCl dissolved in its water. Common salt is mainly obtained by solar evaporation of saline water either from sea or from lakes. The common salt so obtained is crude NaCl. It contains Na_2SO_4, $CaSO_4$, $CaCl_2$ and $MgCl_2$ etc. as impurities. Pure NaCl is obtained by dissolving crude NaCl in minimum amount of water and the insoluble impurities are filtered off. Now $HCl_{(g)}$ is passed through nearly saturated solution to obtain crystals of pure NaCl. $CaCl_2$ and $MgCl_2$ being more soluble, remain in soluble form.

3. **Uses :**
(i) Sodium chloride is an essential constituent of our food. It is used in food materials. It is used in food materials to develop taste and as essential gradient required for body. Table salt used for domestic purposes contains mainly NaCl along with little $CaCl_2$, $MgCl_2$, KI etc.
(ii) It is used in freezing mixture (i.e., NaCl + ice mixture) to attain less than 0ºC temperature.
(iii) It is used for the salting out action of soap.
(iv) As preservatives for pickles, meat and fish.
(v) It is used in the manufacture of so many chemicals such as sodium, sodium hydroxide, baking soda, washing soda, hydrogen chloride, chlorine, bleaching powder etc.

(B) Caustic Soda (Sodium hydroxide, NaOH)

Sodium hydroxide (NaOH) is commonly known as caustic soda.

1. Industrial Preparation of Sodium Hydroxide :

(chlor-alkali process)

Sodium hydroxide is prepared by the electrolysis of a concentrated aqueous solution of sodium chloride (a conc. Solution of NaCl 28 % by mass is called brine). The process is also known as chlor-alkali process.

On passing an electric current through a concentrated aqueous solution of sodium chloride either in following Nelson cell or Castner-Kellner cell, H_2 gas is obtained at anode and Cl_2 gas is at cathode. The solution becomes rich in NaOH.

$$\underset{\text{Sodium chloride}}{2NaCl(aq.)} + 2H_2O(\ell) \xrightarrow[\text{current}]{\text{Electric}} \underset{\substack{\text{Sodium hydride}\\ \text{(caustic soda)}}}{2NaOH(aq.)} + \underset{\text{Chlorine}}{Cl_2(g)} + \underset{\text{Hydrogen}}{H_2(g)}$$

Sodium hydroxide so obtained in aqueous solution is evaporated to dryness to get flakes of solid sodium hydroxide. All the three products, formed during the electrolysis (sodium hydroxide, chlorine and hydrogen) are very useful materials.

2. Uses of Sodium Hydroxide :

(i) In the manufacture of soap, paper, artificial fibers, dyes, drugs and many of chemicals such as several sodium salts.

(ii) In the refining of petroleum and vegetable oils.

(iii) As a laboratory reagent.

(iv) In purification of bauxite ore ($Al_2O_3.2H_2O$)

(C) Baking Soda (Sodium hydrogencarbonate, ($NaHCO_3$)

Baking soda commonly used in kitchen is sodium hydrogencarbonate ($NaHCO_3$).

1. Industrial Preparation of Baking Soda :

(Solvay process)

Carbon dioxide and ammonia are passed through a cold and concentrated solution of sodium chloride to give sodium hydrogencarbonate as :

$$\underset{\text{Sod. chloride}}{NaCl} + H_2O + \underset{\substack{\text{Carbon}\\ \text{dioxide}}}{CO_2} + \underset{\text{Ammonia}}{NH_3} \rightarrow \underset{\substack{\text{Sodium}\\ \text{hydrogencarbonate}\\ \text{(Baking soda)}}}{NaHCO_3} + \underset{\substack{\text{Ammonium}\\ \text{chloride}}}{NH_4Cl}$$

The solution obtained contains sodium hydrogencarbonate as a fine suspension, which is filtered by a vacuum filter and dried.

2. Properties of Baking Soda :

(i) It is a white crystalline solid, sparingly soluble in water.

(ii) Its aqueous solution is mildly alkaline due to hydrolysis of hydrogencarbonate ion.

$HCO_3^- + H_2O \rightarrow H_2O + CO_2 + OH^-$

(iii) On heating to 373 K, it decomposes to give Na_2CO_3 with evolution of CO_2.

$2NaHCO_3 \xrightarrow{373K} Na_2CO_3 + CO_2\uparrow + H_2O$

Due to this property, it is used as one of the constituent of baking powder (potassium sodium tartarate and sodium hydrogen carbonate) for baking cakes and pastries. The carbon dioxide evolved during the decomposition in baking cakes leaves holes in cakes and pastries and make them light and fluffy.

3. Uses of Baking Soda :

(i) It is used as a component of baking powder. Baking powder is mixture of baking soda and a mild edible salt like sodium potassium tartarate.

(ii) In medicines as a mild antiseptic for skin infections.

(iii) In fire extinguishers Fire extinguishers contains sodium hydrogen carbonate solution in one container and H_2SO_4 in other container. As soon as the knob of fire extinguisher is pressed, the glass containers are broken up and the two components come in contact to give off CO_2.

$NaHCO_3 + H_2SO_4 \rightarrow NaHSO_4 + H_2O + CO_2\uparrow$

The CO_2 so formed comes out from the nozzle and covers the burning substance. Thus supply of oxygen is ceased up and fire extinguishes.

(iv) It is an important ingredient of antacids due to alkaline in nature and neutralizes the excess acid produced in stomach and prevents acidity.

(v) In making effervescent drinks such as beer, coke etc.

(vi) As a reagent in the laboratory such as to test the presence of acidic nature.

(D) Washing Soda (sodium carbonate decahydrate, $Na_2CO_3.10H_2O$) :

It is chemically known as sodium carbonate, a hydrated salt and its correct chemical name is sodium carbonate decahydrate (e.g., $Na_2CO_3.10H_2O$). It is available in various forms such as

(i) Anhydrous sodium carbonate of Na_2CO_3 or soda ash.

(ii) Monohydrate sodium carbonate $Na_2CO_3.H_2O$ or crystal carbonate.

(iii) Heptahydrate sodium carbonate or $Na_2CO_3.7H_2O$

(iv) Decahydrate sodium carbonate of $Na_2CO_3.10H_2O$

1. Industrial Preparation of Washing Soda :

Baking soda ($NaHCO_3$) on heating liberates CO_2 and gives sodium carbonate.

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

Sodium carbonate so obtained is recrystallised from its saturated solution to obtain the crystals of sodium carbonate.

$$\underset{\text{Sodium carbonate}}{Na_2CO_3} + 10H_2O \longrightarrow \underset{\text{Washing Soda}}{Na_2CO_3.10H_2O}$$

2. Properties of Washing Soda :

(i) Sodium carbonate decahydrate is a white crystalline solid.

(ii) It is an efflorescent substance and loses its water of crystallization to form a monohydrate on putting open in air.

$$Na_2CO_3.10H_2O \xrightarrow{\text{On standing}} Na_2CO_3.H_2O + 9H_2O$$

(iii) It is readily soluble in water and its solution is alkaline due to hydrolysis of carbonate ion.

$$CO_3^{2-} + H_2O \rightarrow HCO_3^- + OH^-$$

(iv) **Action of heat :** On heating it forms a monohydrate at 373 K and above 373 K, it crumbles to amorphous powder known as soda ash.

$$\underset{\text{(Decahydrate)}}{Na_2CO_3.10H_2O} \xrightarrow[-9H_2O]{373K} \underset{\text{(Monohydrate)}}{Na_2CO_3.H_2O} \xrightarrow[-H_2O]{\text{above } 373\text{ K}} \underset{\substack{\text{(Anhydrous sodium carbonate)} \\ \text{(soda ash)}}}{Na_2CO_3}$$

(v) **Action of acids :** It is readily decomposed by acids with the evolution of CO_2. The reaction takes place in the following two steps :

$$Na_2CO_3 + HCl \rightarrow NaHCO_3 + NaCl$$

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

3. Uses of Washing Soda :

(i) In the manufacture of glass, borax, soap, caustic soda etc.

(ii) For washing purposes in laundry.

(iii) For removing temporary and permanent hardness of water.

(iv) A mixture of sodium carbonate and potassium carbonate is used as a fusion mixture.

(v) In paper, textile and paint industries and petroleum refineries.

(vi) As a laboratory reagent.

(E) Bleaching Powder, $CaOCl_2$:

Bleaching powder's exact chemical composition is quite complex. Chemically it is $CaOCl_2$ and is called calcium oxychloride. It is a mixed salt having Cl^- and ClO^- ions derived from hydrochloric acid (HCl) and hypochlorous acid (HOCl). Therefore it is also called calcium chlorohypochlorite.

1. Industrial Preparation of Bleaching Powder :

Bleaching powder is manufactured by passing chlorine gas in dry slaked time.

$$\underset{\substack{\text{Calcium hydroxide} \\ \text{(slaked lime)}}}{Ca(OH)_2} + \underset{\text{Chlorine gas}}{Cl_2} \xrightarrow{313\text{ K}} \underset{\text{Bleaching powder}}{CaOCl_2} + H_2O$$

Boost your knowledge

- The chlorine obtained as byproduct in the manufacture of sodium hydroxide during the electrolysis of an aqueous solution of brine can be used for the large scale production of bleaching powder.

2. Properties of Bleaching Powder :

(i) Bleaching powder is pale yellow or yellowish-white powder with a strong smell of chlorine.

(ii) It is soluble in cold water but the solution has turbidity due to presence of free lime as impurity. A clear solution may be obtained by filtering off the impurity of lime.

(iii) **Bleaching properties :** Bleaching powder gives nascent oxygen in the presence of small amounts of dilute acids and therefore it also acts as bleaching agent. It changes coloured matter to colourless due to oxidation and its bleaching action is permanent.

$$\text{Coloured matter} + [O] \rightarrow \text{Colourless}$$

3. Uses of Bleaching Powder :

(i) As a bleaching agent for cotton, linen, wood and paper pulp.

(ii) As a disinfectant and germicide, particularly in the sterilization of municipal water supply.

(iii) In the manufacture of chloroform.

(iv) For making unshrinkable wool.

(v) As oxidising agent in the laboratory and in industries.

(F) Plaster of Paris :

It is a hemihydrate of calcium sulphate with formula $CaSO_4 . \frac{1}{2}H_2O$ or better to write $(CaSO_4)_2 . H_2O$. The name plaster of paris (or POP) was given on account of the fact that it was first time obtained by heating gypsum, mainly found in Paris.

1. Industrial Preparation of Plaster of Paris :

Plaster of Paris is prepared by the partial dehydration of gypsum ($CaSO_4 . 2H_2O$) on heating it in a kiln to 373 K.

$$\underset{\substack{\text{Calcium sulphate dihydrate}\\ \text{(Gypsum)}}}{2CaSO_4.2H_2O} \xrightarrow[373K]{\text{Heat}} \underset{\substack{\text{Calcium sulphate hemihydrate}\\ \text{(Plaster of Paris)}}}{CaSO_4 . \frac{1}{2}H_2O} + 1\frac{1}{2}H_2O$$

The heating of gypsum should be done carefully with agitation and the temperature should not rise above 373 K, otherwise all the water of crystallization will be eliminated and anhydrous calcium sulphate or dead burnt plaster will be formed.

2. Properties of Plaster of Paris :

(i) It is a white powder.

(ii) When Plaster of Paris is mixed with sufficient water and the paste is allowed to stand for sometime, it sets into a hard mass with expansion showing a slight increase in volume. Some heat is also evolved and the dihydrate is formed.

$$\underset{\substack{\text{Calcium sulphate dihydrate}\\ \text{(Plaster of Paris)}}}{2CaSO_4.\frac{1}{2}H_2O} \xrightarrow{\text{Settling}} \underset{\substack{\text{Gypsum}\\ \text{(orthorhombic)}}}{CaSO_4.2H_2O} \xrightarrow{\text{Hardening}} \underset{\substack{\text{Gypsum}\\ \text{(monoclinic)}}}{CaSO_4.2H_2O}$$

Boost your knowledge

The setting of Plaster of Paris is accelerated by sodium chloride and is retarded by borax or alum. Addition of alum to plaster of Paris gives hard setting. The mixture is known as Keene's cement.

(iii) Plaster of Paris when heated at 200ºC forms anhydrous calcium sulphate which is known as dead-burnt plaster. It has no setting property.

$$(2CaSO_4) . H_2O \xrightarrow{200^\circ C} 2CaSO_4 + H_2O$$

3. Uses of Plaster of Paris :

(i) Plaster of Paris is extensively used for making moulds for casting. It expands on setting and is very useful for casting purposes e.g., in making casts for statues, toys, surgical instruments etc, in making casts in dentistry.

(ii) In the building industry.

(iii) In making blackboard chalks.

(iv) For setting broken or dislocated bones (in surgical bandages).

(v) For making designs in ceilings & walls.

(vi) Sealing gaps in lab apparatus.