Acid, Bases and Salt

Chemistry – X CBSE

Introduction
All of us irrespective of our age group and occupation are quite familiar with three names. These are acids, bases and salts. substances with sour taste are regarded as acids. Lemon Juice, vinegar, grape fruit juice and spoilt milk etc. taste sour since they are acidic. Similarly, substances with bitter taste and soapy touch are regarded as bases. Familiar examples of the bases are of caustic soda, caustic potash, slaked lime etc. It may not be possible to identify all the salts by their taste as in case of acids and bases. However, they have their own characteristics which help in their identification. The most common is table salt or sodium chloride which is essential part of our diet. Washing soda. baking soda, copper sulphate (blue vitriol) etc. are some of the well known salts which we come across quite often. In general, salts are formed by the chemical combination of acids and bases. In the present chapter, we shall look into the chemical composition of acids, bases and salts and shall try to probe into their characteristics in the light of development and researches that have taken place over the years.

What is an Acid?
As pointed above, originally the word acid was applied to the substances with 'sour taste'. Many substances can be identified as acids based on their taste. But this cannot be the sole criteria for the acidic character. Some of the acids like sulphuric acid ; nitric acid etc. have very strong action on the skin and they form severe bums. In such cases, it would be rather dangerous to taste them. Now let us analyse an acid from the angle of a chemist. For that. the chemical formulae and the structures of different acids have to be examined. All of them have been found to have at least one or more hydrogen atoms in their formulae. For example, the formula of hydrochloric acid is HCl and that of sulphuric acid is H_2SO_4. Further, when these acids are dissolved in water, these release hydrogen atoms as ions (protons). The protons get converted to H atoms and finally to H_2 gas by taking part in chemical reactions.

An acid may be defined as a substance which releases one or more H^+ ions in aqueous solution.
Acids are mostly obtained from natural sources. Those obtained from rocks and minerals are called mineral acids while the acids present in animal and plant materials are known as organic acids. A list of commonly used acids along with their chemical formulae and typical uses is given.

Some common acids

Name	**Type**	**Chemical Formula**	**Where found or used**
Carbonic acid	Mineral acid	H_2CO_3	In soft drinks and lends fizz.
Hydrochloric acid	Mineral acid	HCl	In stomach as gastric juice, used in cleaning metal acid surfaces and in tanning industry.
Nitric acid	Mineral acid	HNO_3	Used in the manufacture of explosives and fertilizers.
Sulphuric acid	Mineral acid	H_2SO_4	Commonly used in car batteries, in the manufacture of fertilizers, detergents etc.

Phosphoric acid	Mineral acid	H_3PO_4	Used in ant-rust paints and in fertilizers.
Formic acid	Organic acid	$HCOOH(CH_2O_2)$	Found in the string of ants, nettle and bees, used in tanning leather and in medicines for treating gout.
Acetic acid	Organic acid	$CH_3COOH(C_2H_4O_2)$	Foud 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 and in curd
Benzoic acid	Organic acid	C_6H_5COOH	Used as food preservative.
Citric acid	Organic acid	$C_6H_8O_7$	Present in lemons, oranges and other citric fruits Present in tamrind.

What is a Base?

Like acids, bases are also the well known substances. They can identified by their bitter taste and soapy touch. We quite often feel the same If the soap enters our mouth per chance while taking bath. Soaps particularly the washing soaps have strong or corrosive Both caustic soda and caustic action on the skin. They contain in them large percentage of sodium potash are caustic in nature hydroxide (caustic soda) and potassium hydroxide (caustic potash). It is quite obvious that just like acids, taste and touch cannot be the criteria to identify a base.

A base may be defined as a substance capable of releasing one or more OH^- ions in aqueous solution.

A list of a few typical bases along with their chemical formula and uses is given.

Both caustic soda and caustic potash are caustic in nature i.e. they have strong action on skin and produce blisters. Some bases like sodium hydroxide and potassium hydroxide are water soluble. All water soluble bases are called

Some common bases

Name	**Commercial name**	**Chemical formula**	**Uses**
Sodium hydroxide	Caustic soda	NaOH	In manufacture of soap, refining of petroleum, paper, pulp etc.
Potassium hydroxide	Caustic potash	KOH	In alkaline storage battery, manufacture of soap
Calcium hydroxide	Slaked lime	$Ca\left(OH\right)_2$	In naufacture of bleaching powder, softening of hard water, for white wash etc.
Aluminium hydroxide	-	$Mg\left(OH\right)_2$	As an antacid to remove acidity from stomach.
Aluminium hydroxide	-	$Al(OH)_3$	As foaming agent in fire extinguishers
Ammonium hydroxide	-	NH_4OH	In removing greases stains from clothes, and in cleaning window panes.

Indicators

The acids and bases can be Identified with the help of their chemical formulae. But it may not be possible to know the same unless mentioned on the samples of acids or bases to be identified. Chemists have developed substances called Indicators to know the presence of acids and bases present in solutions. Indicator as the name suggests, indicates the nature of particular solution whether acidic, basic or neutral. Apart from this. Indicator also represents the change in nature of the solution from acidic to basic and vice versa. Indicators are basically coloured organic substances extracted from different plants. They can also be prepared in the laboratory. A few common acid base Indicators are:

Indicators

Litmus. Litmus is a purple dye which is extracted from 'lichen' a plant belonging to a variety Thallophyta. It can also be applied on paper in the form of strips and is available as blue and red strips. A blue litmus strip when dipped in an acid solution acquires red colour. Similarly, a red litmus strip when dipped in a base solution becomes blue.

Phenolphthalein

It is also an organic dye. In neutral or acidic solution, it is colourless while in the basic solution, the colour of Indicator changes to pink.

•Methyl orange. Methyl orange is an orange coloured dye and keeps this colour in the neutral medium. In the acidic medium, the colour of Indicator becomes red and in the basic medium. it changes to yellow.

An indicator has a certain colour in the acidic medium which undergoes a change when the medium becomes basic or alkaline. The indicators listed above and their characteristic colours in different media are given in a tabular form.

Both phenolphthalein and methyl orange are synthesized in laboratory by carrying certain chemical reactions. These are synthetic indicators. Litmus is a nature indicator extracted from plants.

Some common indicators with characteristic colours

Indicator	**Colour in acid solution**	**Colour in neutral solution**	**Colour in base solution**
Litmus	Red	Purple	Blue
Phenolphthalein	Colourless	Colourless	Pink
Methy orange	Red	Orange	Yellow

Sample	**Blue litmus solution**	**Red litmus solution**	**Phenolphthalein**	**Methyl orange**
HCl	Changes to red	No colour change	Colourless	Changes to red
HNO_3	Change to red	No colour change	Colourless	Changes to red
NaOH	No colour change	Changes to blue	Changes to light pink	Changes to yellow
KOH	No colour change	Change to blue	Changes to light pink	Change to yellow

Some other Indicators

The acid base Indicators mentioned above are very commonly used in the laboratory. Apart from these, red cabbage juice and turmeric juice can also act as acid base indicators.

Red cabbage Juice. It is purple in colour in neutral medium and turns red or pink in the acidic medium. In the basic or alkaline medium, its colour changes to green

Turmeric juice. It is yellow in colour and remains as such both in the neutral and acidic medium. In the basic medium, its colour becomes reddish or deep brown.

Apart from these, coloured petals of some flowers like petunias, hydrangea and geranium can also be used to identify the presence of acid or base in a solution.

There are certain substances which give different smell in acidic and basic solutions. These are known as **Olfactory indicators**. For example, onion, vanilla and clove oil etc. All of them have characteristic odours and we are all quite familiar with them. These change when some acid or base solution is brought in their contact and can be identified. However, the results in this case are not quite satisfactory.
Only some guess can be made about the nature of the substance whether acid or base.
Acids are identified by their sour taste.

•Souring of milk is due to the presence of lactic acid.
•The acid present in the stomach is hydrochloric acid and causes acidity.
•Acids obtained from rocks and minerals are called mineral acids.
•Acids obtained from plants and animals are known as organic acids
•Bases are identified by their bitter taste and soapy touch.
•Sodium hydroxide (NaOH) and potassium hydroxide (KOH) have strong corrosive action on skin. These are called caustic alkalies.
•In aqueous solution, an acid gives H^+ ions while a base releases OH^- ions.
•The main acid-base indicators are litmus solution, phenolphthalein and methyl orange.
•The acid-base indicators are mostly organic dyes with characteristic colours.
•Litmus is the extract of the plant lichen. Phenolphthalein and methyl orange are synthesised in the laboratory.
•The indicators impart different colours to the acid/base solutions and help in their identification-

Chemical Properties of Acids

We have studied that all acids contain one or more hydrogen atoms in their molecules which they release as H^+ ions when dissolved in water. The important chemical characteristics of acids are briefly discussed.

Action with Metals

Dilute acids like dilute HCl and dilute H_2SO_4 react with certain active metals to evolve hydrogen gas

$$Metal + Dilute\ acid \longrightarrow Metal\ \ salt + Hydrogen$$

$$Zn(s) + H_2SO_4(dilute) \longrightarrow ZnSO_4(aq) + H_2(g)$$

$$Mg(s) + 2HCl(dilute) \longrightarrow MgCl_2(aq) + H_2(g)$$

$$Fe(s) + H_2SO_4(dilute) \longrightarrow FeSO_4(aq) + H_2(g)$$

BOOST YOUR KNOWLEDGE

- Metals which ran displace hydrogen from dilute adds are known as active, metals e.g. Na, K, Zn, Fe, Ca, Mg etc. The active metals which lie above hydrogen in the activity series are **electropositive** In nature. Their atoms lose electrons to form positive Ions and these are accepted by H^+ Ions of the acid. As a result. H_2 (g) is evolved. For example
- $Zn(s) \longrightarrow Zn^{2+}(aq) + 2e^-$
- $2H^+(aq) + SO_4^{2-}(aq) + 2e^- \longrightarrow H_2(g) + SO_4^{2-}(aq)$
- $Zn(s) + 2H^+(aq) \longrightarrow Zn^{2+}(aq) + H_2(g)$
- (Acid)
- This reaction is a redox reaction in which Zn(s) has been oxidised to Zn^{2+}(aq) ions by losing electrons while $H^+(aq)$ ions have been reduced to $H_2(g)$ by accepting them.
- Action with Metal oxides
- Acids react with metal oxides to form salt and water. These reactions are mostly carried upon heating. For example.
- Metal oxide + Acid $\longrightarrow$ Salt + Water
- $ZnO(s) + 2HCl(aq) \longrightarrow ZnCl_2(aq) + H_2O(l)$

- $MgO(s)+H_2SO_4(aq)\longrightarrow MgSO_4(aq)+H_2O(l)$

Action with metal carbonates and Metal hydrogen carbonates

Both metal carbonates and hydrogen carbonates react with acids to evolve $CO_2(g)$ and form salts. For example.

$CaCO_3(s)+2HCl(aq)\longrightarrow CaCl_2(aq)+H_2O(aq)+CO_2(g)$

$2NaHCO_3(s)+H_2SO_4(aq)\longrightarrow Na_2SO_4(aq)+H_2O(aq)+CO_2(g)$

A metal hydrogen carbonate is also called metal bi-carbonate

Strong and Weak Acids

We have studied in our earlier discussion that acids give H^+ ions when dissolved in water. For example, (water)

$HCl\,(l)\xrightarrow{(water)}H^+(aq)+Cl^-(aq)$

$H_2SO_4\xrightarrow{Water}2H^+(aq)+SO_4^{2-}(aq)$

Since tons are formed, this is known as ionisation. Now all acids are not equally ionised in water. The acids which are ionised to large extent are known as strong acids. For example, both HCl and H_2SO_4 are strong acids. However, some of them are ionised to small extent. These are regarded as weak acids. For example, carbonic acid (H_2CO_3). phosphoric acid (H_3PO_4), formic acid (HCOOH), acetic acid (CH_3COOH) are weak acids.

$CH_3COOH(l)\xrightarrow{Water}CH_3COO^-(aq)+H^+(aq)$

$H_3PO_4(l)\xrightarrow{water}3H^+(aq)+PO_4^{3-}(aq)$

BOOST YOUR KNOWLEDGE

- The relative strengths of acids can be compared in terms of degree of ionisation also called degree
- of dissociation. It is denoted as 'a' (pronounced as alpha). Mathematically,
- $\alpha=\dfrac{No.\ of\ molecules\ of\ acid\ existing\ as\ ions}{Total\ no.of\ molecules\ of\ acid}$
- If acid is strong, this means that almost all the molecules are existing as ions. The value of a is nearly one. If the acid is weak, this means that only a fraction of it exists as ions. In this case, the value of a is less than one.
- In the dry state also called anhydrous state, the acids donot release any H^+ ions i.e. they donot show any acidic nature.
- •Concentration of an acid is quite different from its strength. Whereas the concentration means the amount of water present in a particular add. the strength is related to the number of H^+ ions which an acid releases in solution. For example. HCl will always remain a strong acid even if it is dilute because it is almost completely ionised in water and a is nearly one. Similarly. CH_3COOH will remain weak even if it is highly concentrated since it is ionised to small extent. The value of an this case is less than one.

Basicity of Acids

We quite often use the term basicity in case of acids. It may be defined as:

the number of replaceable hydrogen atoms present in an acid which it can release when dissolved in water or in aqueous solution.

Acids have been classified as monobasic, dibasic, tribasic etc. depending upon the number of replaceable hydrogen atoms present. Please note the hydrogen atoms are replaced when acid is reacted with a base in aqueous solution,

For example,

$$HCl(aq) + NaOH(aq) \longrightarrow NaCl(aq) + H_2O(l)$$

(Monobasic)

$$CH_3COOH(aq) + NaOH(aq) \longrightarrow CH_3COONa(aq) + H_2O(l)$$

(Monobasic)

$$H_2SO_4(aq) + 2NaOH(aq) \longrightarrow Na_2SO_4(aq) + 2H_2O(l)$$

(Dibasic)

$$H_3PO_4(aq) + 3KOH(aq) \longrightarrow K_2PO_4(aq) + 3H_2O(l)$$

(Tribasic)

Chemical properties of Bases

We have discussed the important chemical characteristics of the acids which are mainly due to the participation of H atoms present in them. Bases as we all know, contain hydroxyl groups (OH) which they release in solution as OH^- ions. Their chemical properties are mainly because of these OH^- ions and are briefly discussed.

Action with Metals

Metal like zinc, tin and aluminium react with strong alkalies like NaOH (caustic soda) and KOH (caustic potash) to evolve hydrogen gas.

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

$$Sn(s) + 2NaOH(aq) \longrightarrow \underset{\text{Sodium stannite}}{Na_2SnO_2(aq)} + H_2(g)$$

$$2Al(s) + 2NaOH(aq.) + 2H_2O(l) \longrightarrow \underset{\substack{\text{Sodium}\\ \text{metaaluminate}}}{2NaAlO_2(aq)} + 3H_2(g)$$

Basicity of an acid does not depend upon the number of H atoms present but upon number of replaceable H atoms. For example, acetic acid (CH_3COOH) has four H atoms. But only one is replaced. It is monobasic in nature. Phosphoric acid (H_3PO_4) has three H atoms and all of them can be replaced. It is a tribasic acid

Strong and Weak Bases

Just like acids, bases have also been classified as strong and weak. But in their cases, the ions released in water are not H^+ ions but OH^- ions also called hydroxyl ions. Bases which are almost completely ionized in water, are known as strong bases. For example, sodium hydroxide (NaOH), potassium hydroxide (KOH), barium hydroxide $Ba(OH)_2$ are all strong bases.

$$NaOH(s) \xrightarrow{(water)} Na^+(aq) + OH^-(g)$$

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

Bases which are ionised to small extent in water are known as weak bases. For example, magnesium hydroxide $Mg(OH)_2$, hydroxide NH_4OH, copper hydroxide $Cu(OH)_2$ are all weak bases.

$$NH_4OH(l) \xrightarrow{water} NH_4^+(aq) + OH^-(aq)$$

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

Just like acids, relative strengths of bases can also be compared in terms of degree of ionisation also called degree of dissociation. It is denoted as α . Mathematically,

$$\alpha = \frac{No.\ of\ \ molecules\ of\ \ base\ existing\ \ as\ ions}{Total\ \ no.of\ \ molecules\ of\ \ base}$$

For strong bases, a is close to one while for weak bases, it has small value.

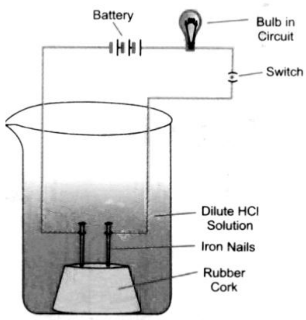
Acidity of Bases

For acids, we use the learn basicity because H^+ ions of the acid can be replaced only when it react with a base. Similarly, the term acidity is used for bases because OH^- ions of the base can be replaced only when it reacts with an acid.

Acidity of a base may be defined as:
the number of replaceable hydroxyl groups present in a base which it can release when dissolved in water or in aqueous solution as ions.
Bases like NaOH and KOH have acidity equal to one. These are called mono acid bases. Similarly, bases like $Ca\left(OH\right)_2$ and $Mg(OH)_2$ are diacid bases because they have acidity equal to two.

What do all Acids and all Bases have in common?

We have learnt that acids are the substances which contain one or more hydrogen atoms in their molecules which they can release in water as H^+ ions. Similarly, bases are the substances which contain one or more hydroxyl groups in their molecules and can release them in water as OH^- ions. Since the ions are the carriers of charge therefore, the aqueous solutions of both acids and bases are conducting in nature.



Tendency to conduct electric current is the common characteristic of all acids and bases when dissolved in water.

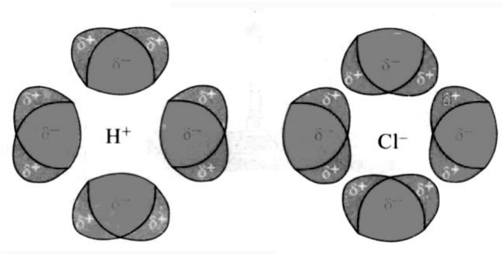
What happens to an Acid and Base in water solution?

We have learnt that the acidic nature of certain substances is due to the presence of H$^+$ ions and the basic character of some other substances is due to the presence of OH^- ions. It is Interesting to note that

Bulb will not glow it glucose $(C_6H_{12}O_6)$ or ethyl alcohol (C_2H_6O) solution is kept in the beaker. This means that both of them will not give any ions in solution.

Substances can act as acids and bases not due to the presence of H atoms and OH groups respectively but due to their release as H^+ and OH^- ions in aqueous solution.

Thus. substances act as acids or bases only in water. In dry state also called anhydrous state or in solvent other than water (e.g.. benzene, toluene etc.), their acidic and basic characters can not be shown or exhibited.



Actually water has a specific role to play. It helps in separating an acid into H^+ ions and anions. Similarly, it helps in separating OH^- ions and cations from a base. The separation of ions from a substance is known as dissociation. It is explained on the basis **of Arrhenius** Theory and is briefly discussed:

Let us consider a compound HCl. This is formed as a result of sharing an electron pair between the two atoms H and Cl and the bond is known as covalent bond (H—Cl). It exists as a gas at room temperature and is called hydrogen chloride gas i.e.. HCl (g). If we try to pass any electric current through the gas. It will not conduct. This means that hydrogen chloride gas is non-conducting. Now, let us pass the gas into water taken in a beaker with the help of a pipe. It will readily dissolve and the solution will conduct electricity. Actually water (H_2O) is made up of two hydrogen (H) and one oxygen (0) atoms. The hydrogen atoms have some partial positive charge (δ^+) while the oxygen atoms some partial negative charge (δ^-). Due to the presence of charge, H_2O is called polar molecule (polarity means charge). When hydrogen chloride (HCl) is dissolved in water, its H atoms will be attracted towards oxygen atoms of H_2O molecules while its Cl atoms will be attracted towards hydrogen atoms of H_2O molecules. These molecules will form a sort of envelope around these atoms. They will no longer be in contact with each other and get separated as ions. i.e.. H^+ and Cl^- ions. Since the H_2O molecules are still associated with them, the ions are called hydrated ions and are represented as H^+ (aq) and Cl^- (aq) ions. Thus, we conclude that H_2O molecules have helped in separating HCl (g) into ions. This is known as dissociation of acid.

$$HCl(g) \xrightarrow{Water} H^+(aq) + Cl^-(aq)$$

Similarly, water also helps in separating ions from a base. This is known as dissociation of base. For example, sodium hydroxide (NaOH) dissociates into $Na^+(aq)$ and OH^- (aq) ions in water.

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

In the gaseous state, HCl is called hydrogen chloride gas. It is not an acid and does not conduct electric current. In aqueous solution, it
Dissociates into $H^+(aq)$ and Cl^- (aq) which are hydrated ions. It is called hydrochloric acid, HCl (aq) and conduct electric current.

Boost your knowledge

Syante August Arrhenius, a Sweedlsh chemist has given a very important theory for acids and bases known as Arrhenius theory. According to the theory: •

• An acid or base when dissolved in water, splits into ions. This is known as ionisation.

• Upon dilution, the ions get separated from each other. This is known as dissociation of ions.

• The fraction of the acid or base which dissociates into ions is called its degree of dissociation and is denoted as a.

• The degree of dissociation depends upon the nature of the acid and base. Strong acids and bases are highly dissociated while weak acids and bases are dissociated to lesser extent.

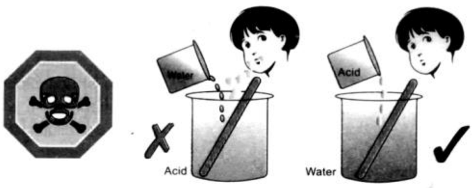
• The electric current is carried by the movement of ions. Greater the ionic mobility, more will be the conductivity of the acid or base.

• The H^+ ions do not exist as such and exist in combination with a molecules of H_2O as H_3O^+ ions (known as hydronium ion). For example.

$$H^+ + H_2O \longrightarrow [H_3O]^+ \text{ or } HCl + H_2O \longrightarrow [H_3O]^+ + Cl^-$$

What happens in the dilution of Acid and Base with Water ?

Acids and bases are mostly water soluble and can be diluted by adding water. In fact, with the addition of water, the amount of acid or base per unit volume decreases and dilution occurs. The process is generally exothermic in nature. In some cases, so much heat is evolved that the acid or base Immediately changes into vapour state. The vapours spread in air or atmosphere and appear like a fog. Since these are poisonous, they pollute the atmosphere. This is known as pollution.



DILUTING CONCENTRATED H_2SO_4 ACID WITH WATER

Precaution needed for dilution

Whenever a concentrated acid like sulphuric acid or nitirc acid is to be diluted with water, care must be taken that acid should be added dropwise to water taken in the container with constant stirring. Heat evolved in this case will be quite slow. If water is added to the acid. it will have affinity for the entire quantity of the acid present. So much heat will be evolved that the glass container in which dilution is carried will crack. Moreover, the vapours released in the atmosphere as fog, will cause pollution problem.

You must have come across containers with labels depicting 'danger sign'. They contain either strong acids or strong bases and must be handled with care. These have strong and corrosive action on the skin and can result in severe bums and blisters.

How do Acids and Bases mutually react —Neutralisation

We have seen that the acids and bases differ in characteristics. Whenever a solution of acid dissolved in water is treated with a solution of base also dissolved in water, salt and water are formed as the products. The reaction is known as **neutralisation reaction.**

$$Acid + Base \longrightarrow Salt + Water$$

$$HCl(aq) + NaOH(aq) \longrightarrow NaCl(aq) + H_2O(l)$$

The reaction is called neutralisation because the salt (NaCI) which is formed in this case is neutral towards litmus. It means that the colour of the litmus paper (blue or red) if dipped in the salt solution does not change. Thus, neutralisation may be defined as:

the reaction between acid and base present in aqueous solution to form salt and water.

H^+ ions of the acid neutralize the effect OH^- ions of the base in solution and vice versa. The solution formed is neutral and does not change the colour of litmus paper whether blue or red.

Explanation: According to Arrhenius theory, an acid when dissolved in water gives H^+ ions. Similarly, a base when dissolved in water gives OH^- ions. Neutralisation is the combination between H^+ ions of the acid with OH^- ions of the base to form H_2O. For example,

$$\underbrace{H^+(aq) + Cl^-(aq)}_{HCl(aq)} + \underbrace{Na^+(aq) + OH^-(aq)}_{NaOH(aq)} \longrightarrow \underbrace{Na^+(aq) + Cl^-(aq)}_{NaCl(aq)} + H_2O$$

(Common Na^+ and Cl^- ions cancel on both sides of the equation).

The complete neutralisation of an acid solution by a base and vice versa is indicated by the sudden change in the colour of the indicator present. This is called end point. It implies that H^+ ions of the acid have completely reacted with OH^- ions of the base to form H_2O which is neutral,

Boost Your Knowledge

Neutralisation reaction involving an acid and base is of exothermic nature. Heat is evolved in all neutralisation reactions. If both acid and base are strong, the value of heat energy evolved remains same irrespective of their nature. For example

$$HCl(aq) + NaOH(aq) \longrightarrow NaCl(aq) + H_2O(l) + 57.1kJ$$

(strong) (strong)

$$HNO_3(aq) + KOH(aq) \longrightarrow KNO_3(aq) + H_2O(l) + H_2O(l) + 57.1kJ$$

(strong) (strong)

Strong acid and strong base are completely ionised of their own to solution. No energy is needed for their ionisation. Since the cations of base and anions of acid on both sides of the equation cancel out completely, the heat evolved is given by the following reaction:

$$H^+(aq) + OH^-(aq) \longrightarrow H_2O(l) + 57.1kJ$$

If either the acid or base is weak, some energy is needed for Its ionisation. As a result, heat evolved is comparatively less. For example

$$HCl(aq) + NH_4OH(aq) \longrightarrow NH_4Cl(aq) + H_2O(l) + 51.5\ kJ$$

(strong) (weak)

In this case, heat energy needed for the ionisation per mole of NH_4OH is (57.1 – 51.5) = 5-6 kJ

$$NH_4OH(aq) \longrightarrow NH_4^+(aq) + OH^-(aq) - 5.6kJ$$

Practical Applications of Neutralisation

1. People particularly of old age suffer from acidity problems in the stomach which is caused mainly due to release of excessive gastric juices containing HCl. The acidity is neutralised by antacid tablets which contain sodium hydrogen carbonate (baking soda), magnesium hydroxide, aluminium hydroxide etc.

2. The stings of bees and ants contain formic acid. Their corrosive and poisonous effect can be neutralized by rubbing soap which contains NaOH (an alkali).

3. The stings of wasps contain an alkali and their poisonous effect can be neutralized by an acid like acetic acid (present in vinegar).

4. Farmers generally neutralize the effect of acidity in the soil caused by acid rain by adding slaked lime (calcium hydro) to the soil

How strong are Acid and Base solutions?

We have studied that acids and bases may be either strong or weak and have compared their relative strengths on the basis of the Arrhenius theory. According to the theory, more the number of H^+ ions released by acid in water, stronger is the acid. Similarly, more the number of OH^- ions released by a base in water, stronger is the base. Now let us discusss some ways or means to compare the relative strengths of the acids and bases.

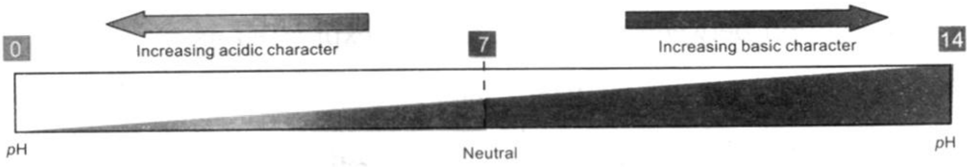
The pH Scale

An easier way to measure the strength of an acid or base sodium was worked out by the Dannish biochemist S. Sorensen. He was interested in checking the acidity of beer and introduced a scale known as pH scale (In German ‘p’ stands for ‘potenz’ meaning power).

The scale runs from 0 to 14 and the characteristics of scale are:

- Acids have pH less than 7.
- The more acidic is a solution, lesser will be its pH
- Neutral solutions (e.g. water) have pH of 7.
- Alkalies have pH more than 7.
- The more alkaline is a solution, higher will be its pH….

The pH scale may be shown as follows:



pH SCALE FOR EXPRESSING CONCENTRATION OF SOLUTIONS

Universal indicator papers for pH values

Plain Paper strips are also available in small packets. One such strip is dipped in particular solution whose pH is to be determined. It will develop a specific colour. By comparing the same with the colour chart available on the Universal indicator paper, the pH of the solution can be predicted. However, it is only approximate. The exact pH of the solution ca be measured with the help of pH metre which gives instant reading and it can be relied upon. The pH values of a few common solutions are given for reference.

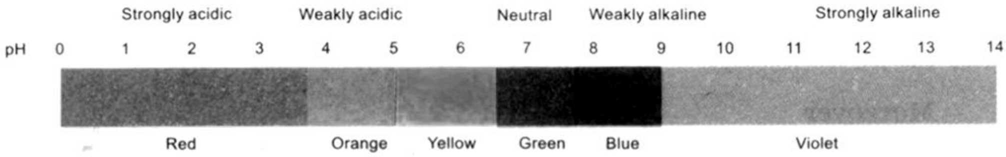


FIGURE 2.10. UNIVERSAL INDICATOR PAPER FOR pH VALUES

Increase in pH decreases the acidic strength and increases the basic strength. Decrease in pH increases the acidic strength and decreases the basic strength.

Approximate pH value of some common solutions

Solution	**Approximate pH**	**Solution**	**Approximate pH**
1M HCl	**0**	**Human saliva**	**6.5 to 7.5**
Gastric juices	**1.0 to 3.0**	**Pure water**	**7.0**
Lemon juice	**2.2 to 2.4**	**Human blood**	**7.36 to 7.42**
Vinegar	**3.0**	**Baking soda solution**	**8.4**
Beer	**4.0 to 5.0**	**Sea water**	**8.5**
Tomato juice	**4.1**	**Washing soda solution**	**9.0**
Coffee	**4.5 to 5.5**	**Lime water**	**10.5**
Acid rain	**5.6**	**House hold ammonia**	**12.0**
Milk	**6.5**	**1M NaOH**	**14.0**

Relation between pH value and hydrogen ion concentration

According to Arrhenius theory. An acid releases H^+ ions in aqueous solution. The concentration of these ions is expressed by enclosing H^+ in square bracket i.e., as $\left[H^+\right]$ ions, stronger will be the acid. However, according to pH scale, lesser the pH value, stronger will be the acid. From the above discussion, we can conclude that:

pH value and H^+ ion concentration $\left[H^+\right]$ are inversely proportional to each other.

Relative strengths of different defferent acid and base solution are generally compared in terms of their pH values. The pOH values are usually not used for this purpose.

The relation between them can also be expressed as:

$$pH = -\log\left[H^+\right] = \log\left[\frac{1}{H^+}\right]$$

For example, let the $\left[H^{+}\right]$ of an acid solution be 10^{-3} M. Its pH can be calculated as:

$$pH = -\log\left[H^{+}\right] = -\log\left[10^{-3}\right] = (-)(-3)\log 10 = 3.$$

(Please remember that log 10 = 1).

For neutral solution : pH = 7, and $\left[H^{+}\right] = 10^{-7}$

For acidic solution : $pH < 7$ and $\left[H^{+}\right] > 10^{-7}$

For basic solution : $pH > 7$ and $\left[H^{+}\right] < 10^{-7}$

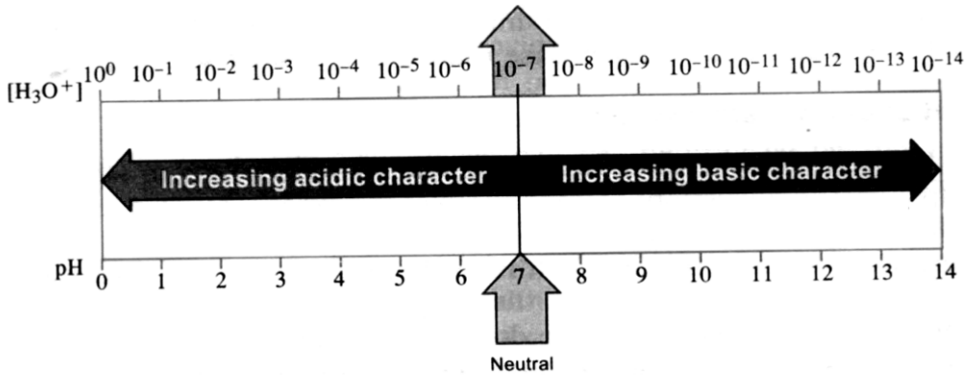
Just as the $\left[H^{+}\right]$ of a solution can be expressed in terms of pH value, the $\left[OH^{-}\right]$ can be expressed as pOH.

Mathematically, $pOH = -\log\left[OH^{-}\right] = \log\frac{1}{\left[OH^{-}\right]}$

Moreover $pH + pOH = 14$

Thus, if pH value of solution is known, its pOH value can be calculated.

The relation between $\left[H^{+}\right]$ and pH scale of expressing the nature of a solution is shown in the Figure.



Example 2.1 Calculate the pH of (i) 0.0001 M HCl (ii) 0.001 M NaOH solution.
Solution. (i) pH value of 0.0001M HCl solution.

As HCl is a strong acid, it is completely dissociated and $\left[H^{+}\right]$ is the same a that of acid i.e., 0.001M.

$$\left[H^{+}\right] = 0.0001M = 10^{-4}M$$

$$pH = -\log\left[H^{+}\right] = -\log\left[10^{-4}\right] = (-)(-4)\log 10 = 4$$

(ii) pH value of 0.001M NaOH solution.

As NaOH is a strong base, it is completely dissociated and $\left[OH^{-}\right]$ is the same as that of base i.e., 0.001 M

$$\left[OH^{-}\right] = 0.001M$$

$$pOH = -\log\left[OH^{-}\right] = -\log\left[10^{-3}\right] = (-)(-3)\log 10 = 3$$

$$pH = 14 - pOH = 14 - 3 = 11$$

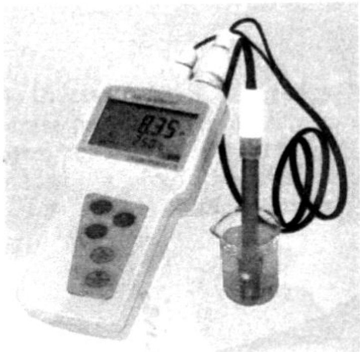
Example 2.2 An aqueous solution has hydrogen ion concentration $\left[H^{+}\right]$ = $1.0\times10^{-7}\ mol\ L^{-1}$. Calculate its pH value.

Solution. $\left[H^{+}\right] = 10^{-7}\ mol\ L^{-1} = 10^{-7}\ M$

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

Importance of pH in Daily Life

We have studied in detail the pH of a solution. In general pH ranges between 0 to 14. The pH of a neutral solution is 7. If it falls below 7, the solution becomes acidic. Similarly, if it increases above this value, the solution is regarded as basic. The pH scale is quite useful in comparing the relative acidic and basic strengths of solutions. Apart from that pH is quite useful to us in a number of ways in daily life. These applications are based on the neutralisation reactions which we have studied.



Comparision of relative acidic and basic strengths of acids and bases

The main utility of pH is to know about the acidict and basic strength of solutions and also to compare these
In general, lesser the pH of a solution, more will be its acidic strength. Similarly, higher the pH of a solution, more will be its basic strength.

For example. pH of vinegar is about 3.0 while that of coffee is nearly 4.5. This means that vinegar is a stronger acid than coffee. Similarly, pH of washing soda solution (Na_2CO_3 solution) is nearly 9.0 and that of lime water containing $Ca(OH)_2$ is 10.5. This indicates that lime water is a stronger base than washing soda solution.

The ph of human blood varies between 7.36 to 7.42. It is maintained by the soluble bicarbonates and carbonic acid present in the blood. These are known as 'buffers'. In general, the role of different buffers is to help in controlling the pH of solutions. It is not possible to discuss mechanism of the buffer action at this level of the students

pH of our digestive system

We all know that dilute hydrochloric acid produced in our stomach helps in the digestion of food. However, excess of acid causes indigestion and leads to pain as well as irritation. The pH of the digestive system in the stomach is likely to decrease. The excessive acid can be neutralised with the help of antacids (or anti-acids) which are recommended by the doctors. Actually, these are group of compounds (basic in nature) and have hardly any side effects. A very popular antacid is 'Milk of Magnesia' which is insoluble magnesium hydroxide. Aluminium hydroxide and sodium hydrogen carbonate can also be used for the same purpose. These antacids bring the pH of the system back to its normal value.

•pH change leads to tooth decay

The white enamel coating on our teeth is of insoluble calcium phosphate which is quite hard. It is not affected by water. However, when the pH in the mouth falls below 5.5, the enamel gets corroded. Water will have a direct access to the roots and decay of teeth will occur. In fact, the bacterias present in the mouth break down the sugar that we eat in one form or the other to acids. Lactic acid is one of these. The formation of these acids causes decrease in pH. It is therefore, advisable to avoid eating sugary foods and also to keep the mouth clean so that sugar and food particles may not be present. The tooth pastes contain in them some basic ingredients and they help in neutralising the effect of the acids and also in increasing the pH In the mouth.

Self- defence by animals and plants through Chemical Warfare

We have studied earlier that the stings of bees and ants contain methanoic acid (or formic acid). When stung, they cause lot of pain and irritation. The cure is in rubbing the affected area with soap. Sodium hydroxide (NaOH) present in the soap neutralises acid injected In the body and thus brings the pH back to its original level bringing relief to the person who has been stung. Similarly, the effect of stings by wasps containing alkali is neutralised by the application of vinegar which is ethanoic acid (or acetic acid).

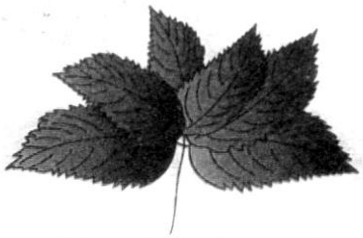


FIGURE 2.12. NETTLE PLANTS GROW IN WILD AREA.

Nettle plants are herbaceous in nature and grow in the wild. These have sharp hair which contain in them methanoic acid. If they happen to touch the body by accident, their stings are very painful because methanoic acid present gets injected in the body. These are commonly known as stinging nettles. You will be surprised to note that the remedy for the same is provided by the nature itself. The stung area is rubbed by the leaves of 'dock plants' which often grow beside nettle plants. Most probably, these plants Inject some base or alkali which neutralises the effect of acid and has soothing effect.

Soil pH and Plant Growth

The growth of plants in a particular soil is also related to its pH. Actually, different plants prefer different pH range for their growth. It is therefore, quite important to provide the soil with proper pH for their healthy growth. Soils with high peat content or iron minerals or with rotting vegetation tend to become acidic. The soil pH can reach as low as 4. The acidic effect can be neutralised by 'liming the soil' which is carried by adding calcium hydroxide, calcium oxide or powdered chalk (calcium carbonate). These are all basic in nature and have neutralising effect. Similarly, the soil with excess of lime stone or chalk is usually alkaline. Sometimes, its pH reaches as high as 8.3 and is quite harmful for the plant growth. In order to reduce the alkaline effect, it is better to add some decaying organic matter which is acidic in nature (compost or manure) or dig in some peat.

Please note that the soil pH is also affected by the acid rain and the use of fertilizers. Therefore, soil treatment is quite essential.

Plants	**Preferred pH range**
Potatoes	**4.5-6.0**
Carrot, Sweet potato	**5.5-6.5**
Cauliflower, Garlic,tomato	**5.5-7.5**
Onion, cabbage	**6.0-7.5**

Do you know?
Some flowering plants carry their own 'built-in pH indicators'. For example, the flowers of a hydrangea bush are bule in colour when grown in an acid soil. If it is alkaline in nature, the flowers become pink.

Boost Your knowledge

All the discussion that we have made so far about the acids and bases is based upon Arrhenius theory. According to this, an acid releases hydrogen ions (H^+) in water while base gives hydroxide ions (OH^-) when dissolved in water. The theory has limited applications only because according to it, in the absence of water, the acidic and basic characters of the substances cannot be shown or exhibited. In addition to this theory, there are two more important theories for the acids and bases.

Bronsted-Lowry Theory

Bronsted (a Dannish Chemist) and Lowry (an English Chemist) gave this theory in 1923. According to it. an acid is a substance (molecule or ion) which has a tendency to donate proton and similarly abase has a tendency to accept the same. The theory is quite often known as proton donor and proton acceptor theory Moreover, according to the theory, an acid after losing a proton becomes a base (called conjugate base) while the base by accepting a proton changes to add (called conjugate acid). Let us consider the example,

$$\underset{Acid}{CH_3COOH} + \underset{Base}{H_2O} \rightleftarrows \underset{\substack{Base \\ (Conjugate)}}{CH_3COO^-} + \underset{\substack{Acid \\ (conjugate)}}{H_3O^+}$$

• CH_3COO^- ion is conjugate base of CH_3COOH

• H_3O^+ ion is conjugate acid of H_2O

Lewis Theory

G.N. Lewis has given yet another theory in 1923 for the acids and bases. According to it, an acid is a substance (molecule or ion) which can accept a pair of electrons while the base Is one which can donate the same. This theory is also known electron pair donor and electron pair acceptor theory. For example,

• $FeCl_3$ and $AlCl_3$ are Lewis acids because the central atoms have only six electrons after sharing and need two more electrons.

• $\ddot{N}H_3$ is a Lewis base as it has a pair of electrons which can be easily donated.

It is not possible to discuss more details about these theories in the present class. We shall study the same in the higher classes.

Example 2.3. A first aid manual suggests that vinegar should be used to treat wasp stings and baking soda for bee stings.

(i) What does this information tell you about the chemical nature of the wasp stings?

(ii) If there were no baking soda in the house, what other household substance could you use to treat bee stings?

Solution, (i) Since vinegar (acetic acid) is used to heal or neutralise the effect of wasp stings, this means that the chemical present in the stings must be some base.

(ii) Since bee stings are treated by baking soda which is a base, this means they must contain in them some acid. If baking soda is not available in the house, solution of ammonium hydroxide. NH_4OH can be used for the same purpose.

Example 2.4. 'A' is a soluble acidic oxide and 'B' is a soluble base. Compared to pH of pure water, what will be the pH of (a) solution of A (b) solution of B?

Solution. 'A' being an acidic oxide, will dissolve in water to form an acid solution. Since the pH of water (neutral in nature) is 7. the pH of the acid solution will be less than 7.

'B' is already a water soluble base. Its solution will have pH more than 7.

Example 2.5 A road tanker carrying an acid was involved in an accident and its contents spilled on the road. At the side of the road, iron drain covers began melting and fizzing as the acid ran over them. A specialist was called to see if the acid actually leaked into the nearby river.

(a) Explain how the specialist could carry out a simple test to see if the river water contains some acid or not. [

(b) The word 'melting' is incorrectly used in the report. Suggest a better name that should have been used for the same purpose.

(c) Explain why the drain covers began fizzing as the acid ran over them.

Solution, (a) This can be done by adding a strip of blue litmus paper into the tube containing a small amount of the sample water. If the colour changes to red, this means that some acid has gone into the river.

(b) The acid has reacted chemically with the drain cover which is usually made of iron. The correct word for the reaction is 'corrosion' and not 'melting'.
(c) Iron reacts with an acid (H_2SO_4 or HCl etc.) to evolve hydrogen gas. Since the gas is released immediately accompanied by large number of bubbles, fizzing of drain covers is expected.

BOOST YOUR KNOWLEDGE

- Active metals lie above hydrogen in the activity series and liberate hydrogen gas on reacting with dilute acids.
- •Oxides of metals are basic in nature while those of non metals are of acidic nature.
- •For strong acids and strong bases, degree of dissociation (α) is nearly 1 (i.e., they are almost completely dissociated). For weak acids and weak bases, it is comparatively less.
- •In dry or anhydrous state, neither acids nor bases show any acidic or basic character.
- •A strong acid or base remains strong even if it is diluted with water. A weak acid or base remains weak even if the solution is highly concentrated.
- •Basicity of acid does not depend upon the number of hydrogen atoms present but upon the number of replaceable hydrogen atoms.
- •Acidity of base does not depend upon the number of OH groups present but upon the number of replaceable OH groups.
- •Water helps in separating ions from add and base and thus helps in their dissociation.
- •The acids and bases are not conducting in the dry or gaseous state and are conducting either in molten state or when dissolved in water.
- •An acid solution in water always contains some OH^- ions. Similarly, a base solution in water always contains some H^+ ions.
- •Reaction between acid and base to form salt and water is called neutralisation reaction.
- •Neutralisation reactions are always exothermic and are accompanied by evolution of heat.
- •pH value and $\left[H^+\right]$ of a solution are inversely proportional to each other.
- •Higher the pH value, weaker is the acid and stronger is the base.
- •pH of a neutral solution is 7 and of human blood ranges between 7.36 to 7.42.

More About Salts

We have learnt in the chemical characteristics of acids and bases that an acid dissolved in water reacts with a base also dissolved in water to form salt and water as the product. Since the salt formed is generally neutral in nature, the reaction is called neutralisation reaction, For example,

$$Acid + Base \longrightarrow Salt + Water$$

$$HCl(aq) + NaOH(aq) \longrightarrow NaCl(aq) + H_2O(l)$$

$$HNO_3(aq) + KOH(aq) \longrightarrow KCl(aq) + H_2O(l)$$

Salts are basically ionic compounds made up of positively charged ions (cations) and negatively charged ions. (anions). In the solid state, these ions are held together by electrostatic force of attraction. When the salt is dissolved in water, these ions readily get separated. A list of some commonly used salts along with their chemical formulae is given.

Some commonly used salts and their chemical formulae

Salt	**Formula**	**Positive ion (cation)**	**Negative ion (Anion)**
Sodium nitrate	$NaNO_3$	Na^+	NO_3^-
Sodium chloride	$NaCl$	Na^+	Cl^-

Copper sulphate	$CuSO_4$	Cu^{2+}	SO_4^{2-}
Zinc carbonate	$ZnCO_3$	Zn^{2+}	CO_3^{2-}
Calcium chloride	$CaCl_2$	Ca^{2+}	$2Cl^-$
Magnesium carbonate	$MgCO_3$	Mg^{2+}	CO_3^{2-}
Sodium sulphate	Na_2SO_4	$2Na^+$	SO_4^{2-}
Aluminium chloride	$AlCl_3$	Al^{3+}	$3Cl^-$
Aluminium sulphate	$Al_2(SO_4)_3$	$2Al^{3+}$	$3SO_4^{2-}$
Barium nitrate	$Ba(NO_3)_2$	Ba^{2+}	$2NO_3^-$
Lead sulphate	$PbSO_4$	Pb^{2+}	SO_4^{2-}

Classification of Salts

The salts have been classified in a number of ways. These are briefly discussed.

• Classification based on chemical formulae

On the basis of chemical formulae, salts are classified into three type.

Normal salts. A normal salt is the one which does not contain any ionisable hydrogen atom or hydroxyl group. This means that It has been formed by the complete neutralisation of an acid by a base. For example, NaCl, KCl. $NaNO_3, K_2SO_4$ etc. are normal salts.

Acidic salts. An acidic salt still contains some replaceable hydrogen atoms. This means that the neutralisation of acid by the base is not complete. For example, sodium hydrogen sulphate ($NaHSO_4$) sodium hydrogen carbonate ($NaHCO_3$).

Basic salts. A basic salt still contains some replaceable hydroxyl groups. This means that the neutralisation of base by the acid is not complete. For example, basic lead nitrate $Pb(OH)NO_3$. basic lead chloride, $Pb(OH)Cl$

Classification based on pH values

Salts as we know, are formed by the reaction between acids and bases. Depending upon the nature of the acids and bases or upon the pH values, the salt solutions are of three types.

Neutral salt solutions. Salt solutions of strong acids and strong bases are neutral and have pH = 7. They donot change the colour of litmus solution. For example, NaCl, KCl, $Na_2SO_4 . Na_2SO_4$ etc.

Acidic salt solutions. Salt solutions of strong acids and weak bases are of acidic nature and have pH less than 7. They change the colour of blue litmus solution/paper to red. For example. $\left(NH_4\right)_2 SO_4, NH_4Cl$ etc. In both these salts, the base NH_4OH is weak while the acids H_2SO_4 and HCl are strong.

Basic salt solutions. Salt solutions of strong bases and weak acids are of basic nature and have pH more than 7. They change the colour of red litmus solution/paper to blue. For example. Na_2CO_3, K_3PO_4 etc. In both the salts, bases NaOH and KOH are strong while the acids H_2CO_3 and H_3PO_4 are weak.

• Classification based on common ion.

The salts have also been classified into different families based on the common ion present. For example, salts such as NaCl, $NaNO_3, Na_2SO_4$ belong to sodium family known as sodium salts because all of them have common Na^+ ion. Similarly, salts like $NH_4Cl, KCl, MgCl_2$ belong to chloride family known as chloride salts since they have common Cl^- ion.

- **A neutral salt solution has pH = 7**
- **An acidic salt solution has pH<7**
- **A basic salt solution has pH>7**

Preparation of Sate

Many salts are found to be present in rocks and minerals which may be regarded as natural sources. For example, washing soda ($Na_2CO_3.10H_2O$) blue vitriol ($CuSO_4.5H_2O$). marble ($CaCO_3$) etc. Sea water is the major source of the salts like sodium chloride (NaCI), potassium chloride (KCl). magnesium sulphate ($MgSO_4$) etc.

However, most of the salts are prepared in the laboratory by chemical reactions. These are briefly described:

By the neutralisation of an acid by a base. As pointed earlier, acids and bases react to form salt and water. For example,

$$NaOH(aq) + HCl(aq) \longrightarrow NaCl(aq) + H_2O(aq)$$

$$NH_4OH(aq) + HNO_3(aq) \longrightarrow NH_4NO_3(aq) + H_2O(aq)$$

$$2KOH(aq) + H_2SO_4(aq) \longrightarrow K_2SO_4(aq) + H_2O(aq)$$

By the action of acids on metals. Some active metals react with dilute acids to form salts and liberate hydrogen gas. For example.

$$Zn(s) + H_2SO_4(aq) \longrightarrow ZnSO_4(aq) + H_2(g)$$

$$Fe(s) + 2HCl(aq) \longrightarrow FeCl_2(aq) + H_2(g)$$

By the action of acids on certain metal carbonates and metal hydrogen carbonates. A few examples are given:

$$Na_2CO_3(aq) + 2HCl(aq) \longrightarrow 2NaCl(aq) + H_2O(aq) + CO_2(g)$$

$$NaHCO_3(aq) + H_2SO_4(aq) \longrightarrow NaHSO_4(aq) + H_2O(aq) + CO_2(g)$$

By the combination of oxides of certain metals and non- metals. Salts can also formed by the chemical combination of the oxides of certain metals (known as basic oxides) with those of non- metals (known as acidic oxides). For example,

$$Na_2O(aq) + SO_3(aq) \longrightarrow Na_2SO_4(aq)$$

$$MgO(aq) + CO_2(g) \longrightarrow MgCO_3(aq)$$

Sodium chloride - Common salt (Table salt)

Sodium chloride (NaCl) also called common salt or table salt is the most essential part of our diet. Chemically it is formed by the reaction between solutions of sodium hydroxide and hydrochloric acid. Sea water is the major source of sodium chloride where it is present in the dissolved form along with other soluble salts such as chlorides and sulphates of calcium and magnesium. It is separated by some suitable method. Deposits of the salt are found in different parts of the world and is known as rock salt. When pure, it is a white crystalline solid.

However, it is often brown due to the presence of impurities.

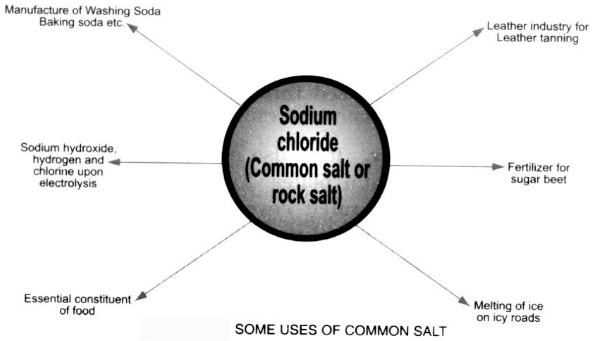
• Sodium Chloride- Essential for Life

Sodium chloride is quite essential for life. Biologically, it has a number of functions to perform such as in muscle contraction, in conduction of nerve impulses in the nervous system and is also converted into hydrochloric acid which helps in the digestion of food in the stomach. When we sweat, there is loss of sodium chloride along with water. It leads to muscle cramps. Its loss has to be compensated suitably by giving certain salt preparations to the patient. Electral powder is an important substitute of common salt.

• Chemicals form Common Salt

Sodium chloride is also a very useful raw material for different chemicals. A few out of these are: hydrochloric acid (HCl). Washing soda ($Na_2CO_3.10H_2O$). baking soda ($NaHCO_3$) etc. Upon electrolysis. a strong solution of the salt (brine), sodium hydroxide, chlorine and hydrogen are obtained.

Apart from these, it is used to leather Industry for the leather tanning. In severe cold, rock salt is spread on icy roads to melt ice. It is also a fertilizer for sugar beet.



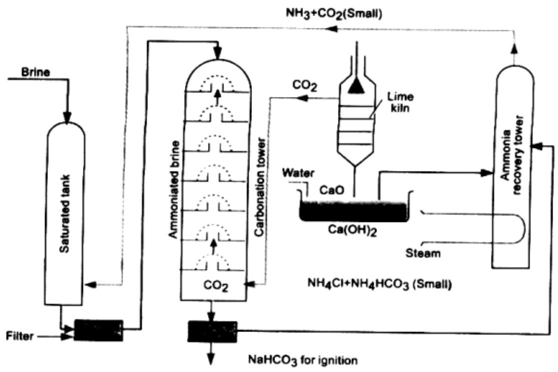
SOME USES OF COMMON SALT

Washing Soda ($Na_2CO_3.10\,H_2O$)

Washing soda has been known since very early times. In India, it was called 'sajji' and 'reh'. It is primarily used for washing of clothes. Chemically, washing soda is sodium carbonate decahydrate ($Na_2CO_3.10\,H_2O$). In the anhydrous form (Na_2CO_3). it is called soda ash and has been found to be present in the ashes of certain marine plants. In the crude form, it is found in the dry lakes of East Africa, Egypt, U.S.A. etc. In India, deposits of the salts are located mainly in Dehradun, Mathura. Jaunpur and a few other places.

Manufacture of Washing Soda. Washing soda is manufactured by Solvay Process, also called mmonia-soda process. In addition to this. Le Blanc process and Electrolytic process are also available but are less popular. Solvay process is being described.

The plant used for the manufacturing process is shown in the Figure



SOLVAY AMMONIA PROCESS FOR THE MANUFACTURE OF NA_2CO_3.

1. Saturation tank. A strong solution of brine (30% NaCI solution) is introduced from the top of the tank made up of iron. A mixture of ammonia and carbon dioxide which are formed in the ammonia recovery tower is led from a side into the tower. As a result, brine gets saturated with ammonia. Soluble impurities of some calcium and magnesium salts like $CaCl_2$ and $MgCl_2$ associated with sodium chloride are precipitated as carbonates by ammonium carbonate which is formed in the reaction.

$$2NH_3 + CO_2 + H_2O \longrightarrow (NH_4)_2CO_3$$

$$CaCl_2 + (NH_4)_2CO_3 \longrightarrow \underset{(ppt.)}{CaCO_3} + 2NH_4Cl$$

$$MgCl_2 + (NH_4)_2CO_3 \longrightarrow \underset{(ppt.)}{MgCO_3} + 2NH_4Cl$$

The solution is then passed through filters in order to remove these precipitates.

2. Carbonation tower. It is also made up of iron and is fitted with a number of horizontal plates. Each plate has a hole in the centre covered by a perforated cover. The brine saturated with ammonia (or ammoniated brine) is introduced from the top and ie55vapours of carbon dioxide from the lime kiln are introduced from the side. As the vapours rise, they come in contact with the ammoniated brine and the following reactions take place:

$$CO_2 + H_2O + NH_3 \longrightarrow NH_4HCO_3$$

$$NaCl + NH_4HCO_3 \longrightarrow NaHCO_3 + NH_4Cl$$

The temperature in the carbonation tower is between 300 – 310K (very low) and crystals of sodium hydrogen carbonate are formed.

Carbon dioxide needed is for the reaction is obtained by heating lime stone $(CaCO_3)$ in a lime kiln.

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

(Quick lime)

Quick lime formed is dissolved in water to form $Ca(OH)_2$ which is led into the ammonia recovery tower as shown in the figure.

3. Filtration. The solution coming out of the carbonation tower is passed through filters when the precipitated sodium hydrogen carbonate gest separated. The solution containing NH_4CI and small amount of NH_4HCO_3 is taken to the ammonia recovery tower where it meets calcium hydrogen. Sodium hydrogen carbonate formed above is heated strongly in the absence of air (calcined) in a furnace to give sodium carbonate.

$$2NaHCO_3 \xrightarrow{heat} Na_2CO_3 + H_2O + CO_2\text{ s}$$

4. Ammonia recovery tower. In this tower, ammonia is formed by the reaction between NH_4Cl and $Ca(OH)_2$ and the reaction mixture is heated with the help of steam coil.

$$2NH_4Cl + Ca(OH)_2 \xrightarrow{heat} CaCl_2 + 2NH_3 + 2H_2O$$

Ammonium hydrogen carbonate present in the tower also decomposes to evolve NH_3 and CO_2.

$$NH_3CO_3 \xrightarrow{heat} NH_3 + CO_2 + H_2O$$

Both these gases are pumped into the saturated tank where they take part in the reaction.

Solvay process gives anhydrous sodium carbonate (soda ash) which is completely pure. When crystallised from water, it gives crystals of washing soda.

The process is called Chloralkali process because the products formed are chlorine (forchlor) and alkali (for sodium hydroxide).

Uses of Washing Soda

Washing soda or sodium carbonate is one of the most useful chemicals in industry. It is used

1. in the manufacture of glass, soap. paper and also chemicals like caustic soda (NaOH), borax ($Na_2B_4O_7$) etc.

2. in the laundry for washing clothes and is a constituent of a number of dry soaps
3. as a cleansing agent for domestic purposes
4. for removing permanent hardness from water
5. as a useful reagent in the laboratory.

Caustic Soda (NaOH)

Caustic soda is prepared commercially by the electrolysis of a strong solution of sodium chloride (NaCI) also called brine. Following reactions take place during electrolysis

$$NaCl(s) + water \longrightarrow \underset{(cathode)}{Na^+(aq)} + \underset{(anode)}{Cl^-(aq)}$$

$$H_2O(l) \longrightarrow \underset{(cathode)}{H^+(aq)} + \underset{(anode)}{OH^-(aq)}$$

At cathode H^+(aq) ions are oxidised by accepting electrons to hydrogen gas in preference to Na^+ ions. which remain in solution. Similarly, at anode, Cl^-(aq) ions are reduced by losing electrons to chlorine gas in preference to OH^- ions which remain in solution.

$$H^+(aq) + e^- \longrightarrow H \text{ or } 1/2H_2(g);\ Cl^-(aq) - e^- \longrightarrow Cl \text{ or } 1/2Cl_2(g)$$

Thus as result of electrolysis, hydrogen is evolved at cathode and chlorine at anode. The solution contains sodium hydroxide (NaOH). It can be recovered from it.
Chlorine evolved at anode Is expected to react with sodium hydroxide. Care should be taken so that they may not come in contact with each other. Process of electrolysis is carried in a special cell known as Nelson's cell.

Uses of Caustic Soda

Sodium hydroxide or caustic soda is used**:**

1. in the manufacture of soap, paper, rayon (artificial silk) and a large number of chemicals.
2. in cotton industry for mercerizing (or making unshrinkable) cotton fabrics.
3. in the refining of petroleum and also of vegetable oils.
4. in the preparation of soda lime (a mixture of NaOH and (CaO).
5. as a cleansing aent for machines and metal sheets.

Baking Soda ($NaHCO_3$)

Baking soda. as the name suggests is the major constituent of baking powder. Chemically it is sodium hydrogen carbonate, also called sodium bicarbonate.

Do you know?
During summer, the milkmen usually add a very small amount of baking soda to fresh milk. It acts as a preservative. Actually, in hot weather milk is expected to decompose and release lactic acid which is likely to make milk sour. Baking soda ($NaHCO_3$) reacts with acid to form salt and water. In this way, it neutralizes the acid and the milk does not become sour.

Preparation of Baking Soda

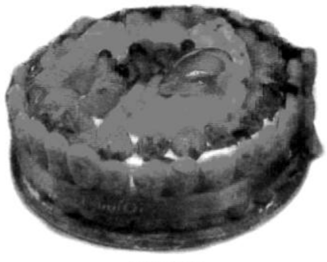
In the laboratory, baking soda can be prepared by passing excess of carbon dioxide gas through the saturated solution of sodium carbonate. As a result, sodium hydrogen carbonate is formed. Being sparingly soluble in water, it gets precipitated. The precipitate is separated, washed and dried without heating.

$$Na_2CO_3 + CO_2 + H_2O \longrightarrow \underset{(ppt.)}{2NaHCO_3}$$

On commercial scale, sodium hydrogen carbonate is formed as an intermediate product in the carbonation tower when sodium carbonate or washing soda is prepared by Solvay process. For details, please refer to the process discussed earlier in the study of washing soda.

Baking Soda in Baking Powder

Baking soda, as the name suggests, is used In baking powder along with tartaric acid ($C_4H_6O_6$). Baking powder is normally added to the dough to be used for making cake or bread. When the dough is baked or heated, sodium hydrogen carbonate releases carbon dioxide gas.



Fruit Cake

$$2NaHCO_3 \xrightarrow{heat} Na_2CO_3 + H_2O + CO_2$$

The bubbles of the gas that are escaping leaving behind pores which Increase the size of the cake or bread and make it fluffy. Tartaric acid present in the baking powder neutralises sodium carbonate. In case it is not done, then the cake will taste bitter. Moreover, sodium carbonate has also injurious side effects.

Baking Soda as Antacid

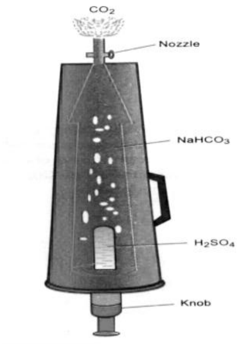
The acidity in the stomach is caused due to the formation of excess of hydrochloric acid (HCl). Sodium hydrogen carbonate (baking soda) reacts with the acid because of its alkaline nature and neutralizes this effect.

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

It therefore, acts as an antacid and is the major constituent of antacid medicines.

Baking Soda in Fire Extinguishers

Sodium hydrogen carbonate or baking soda is used to soda acid fire extinguishers which is shown in



SODA ACID FIRE EXTINGUISHER

It is in the form of a conical metallic vessel. A strong solution of is taken in a container. A glass ampoule containing H_2SO_4 and provided with a knob is placed inside the container. When required, the ampoule can be broken by hitting the knob. As a result, the acid will come in contact with sodium bicarbonate. The two will react to evolve CO_2 gas. When enough pressure gets generated inside the container, the gas escapes through the nozzle with force. It forms a cover or blanket around the flame and the contact flame with air Is cut off. The fire Is extinguished.

Bleaching Powder ($CaCl_2$)

Bleaching powder is one of the most useful bleaching agent particularly for textile and paper. Chemically bleaching powder is $CaOCl_2$. It has been given different chemical names such as calcium oxychloride. calcium hypochlorite or chloride of lime.

Manufacture of Bleaching Powder

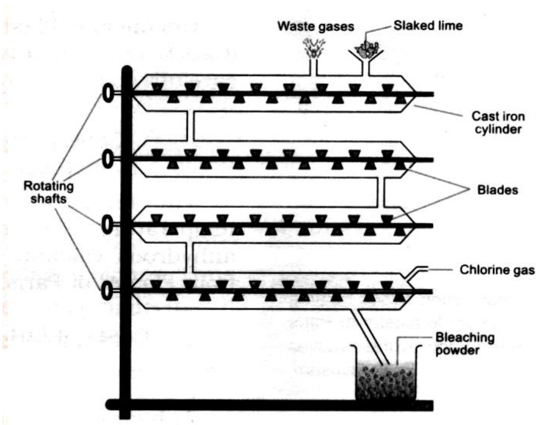
The raw materials for the manufacture of bleaching powder are slaked lime and chlorine (which is obtained from the electrolysis of (brine). The two react as follows:

$$\underset{Slaked\ lime}{Ca(OH)_2} + Cl_2 \longrightarrow \underset{Bleaching\ powder}{CaOCl_2\left(Ca\langle^{Cl}_{OCl}\right)} + H_2O$$

Two plants have been employed for the manufacture. These are Hasenclever's plant and Bachmann's plant. A brief description of the first plant is given.

Hasenclever's Plant. The plant consists of a number of horizontal cylinders made up of cast iron as shown in the Figure. Each cylinder has a rotating shaft fitted with blades.

A fresh and dry sample of slaked lime or calcium hydroxide is introduced through the hopper at the top. As the shaft rotates, the blades attached push the slaked lime from one cylinder to the next. A current of dry chlorine is slowly introduced from the bottom. As it rises up, it comes in contact with slaked lime to form bleaching powder, which can be taken out from an outlet in the lower most



HASENCLEVER'S PLANT FOR THE MANUFACTURE OF BLEACHING POWDER

Uses of Bleaching Power

Bleaching powder is used:

1. for bleaching cotton, linen, wool pulp etc.
2. for sterilisation of drinking water
3. in rendering wool unshrinkable
4. in the manufacture of chloroform
5. as an oxidising agent in the laboratory.

•**Bleaching of Cloth by Bleaching Powder**

The cloth to be bleached is initially treated with a very dilute solution of sodium hydroxide which removes any greasy matter sticking to it. It is then dipped in bleaching powder solution followed by dilute hydrochloric solution taken in a separate tank. The acid also reacts with bleaching powder to evolve chlorine which bleaches the cloth. In order to remove the unreacted chlorine, it is then dipped in a dilute solution of sodium thiosulphate called antichlor $\underset{\text{Sodium thiosulphate}}{Na_2S_2O_3} + Cl_2 + H_2O \longrightarrow Na_2SO_4 + 2HCl + S$

An antichlor is a substance which removes the unreacted chlorine. The cloth s thoroughly washed with water and Is then dried.

Plaster of Paris ($CaSO_4.1/2\,H_2O$)

Plaster of Paris as the name suggests, has something to do with Paris. Actually it was initially prepared by heating gypsum which was found In Montmatre in Paris. To start with, it was mainly usedhghguin the construction industry but now a days a number of substitutes are available and Plaster of Paris is used for plastering fracture bones, making statues and moulds. It also finds application in covering the roofs and walls. It is known as P.O.P.

Preparation of Plaster of Paris

Chemically Plaster of Paris is calcium sulphate hemihydrate ($CaSO_4.1/2\,H_2O$). It can be obtained by heating gypsum ($CaSO_4.2H_2O$) carefully to a temperature of 373 K in a kiln.

$$\underset{\text{Gypsum}}{CaSO_4.2H_2O} \xrightarrow{373K} \underset{\text{Plaster of Paris}}{CaSO_4.1/2\,H_2O} + 3/2\,H_2O$$

The temperature must be carefully controlled. At higher temperature, Plaster of Paris gets completely dehydrated to form anhydrous calcium sulphate. It has properties altogether different from Plaster of Paris.

$$CaSO_4.1/2\,H_2O \xrightarrow{heat} \underset{\text{Calcium sulphate}}{CaSO_4} + 1/2\,H_2O$$

Anhydrous calcium sulphate is called dead burnt plaster or anhydrite.

Gypsum upon strong heating changes to plaster of Paris which upon hydration gives back Gypsum.

Uses of Plaster of Paris

Plaster of Paris is used

1. for making moulds or casts for toys, pottery, ceramics etc.
2. for covering the walls and roofs and for making designs on them. It is called P.O.P.
3. In surgical bandages for setting fractured bones
4. In the laboratory for making air tight apparatus by sealing the gaps
5. for making fire-proofing materials.

Setting of Fractured Bones

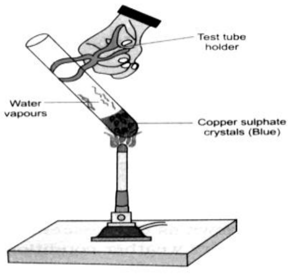
Plaster of Paris is the major constituent of surgical bandages that are used for setting fractured bones. Before applying on fractured bone, it is made wet with water. The bandage is then immediately spread on the broken part. As a result of hydration, it changes into Gypsum which keeps the bones in position that have been made straight by the doctor before applying plaster. Slow calcification takes place on the broken part and the gap is slowly filled. In this way, broken bones once again unite to form a single piece.

$$\underset{Plaster\ of\ Paris}{CaSO_4.1/2\,H_2O} + 3/2H_2O \longrightarrow \underset{Gypsum}{CaSO_4.2H_2O}$$

Hydrated salts - Salts containing water of crystallisation

Certain salts contain definite amount of some H_2O molecules loosely attached to their own molecules. These are known as hydrated salts and are of crystalline nature. The molecules of H_2O present are known as 'water of crystallisation'. A few examples of hydrated salts are**:**

Salt	**Commercial name**	**Chemical formula**	**Colour**
Sodium carbonate	Washing soda	$Na_2CO_3.10\,H_2O$	White
Magnesium sulphate	Epsom salt	$MgSO_4.7H_2O$	White
Calcium sulphate	Gypsum	$CaSO_4.2H_2O$	White
Copper sulphate	Blue vitriol	$CuSO_4.5H_2O$	Blue
Ferrous sulphate	Green vitriol	$FeSO_4.7H_2O$	Gren



HEATING BLUE VITRIOL
($CuSO_4.5H_2O$) IN A DRY TUBE

In coloured crystalline and hydrated salts, the molecules of water of crystallization also account for their characteristic colours. Thus, upon heating a hydrated salt. its colour changes since molecules of water of crystallisation are removed and the salt becomes anhydrous. For example, take a few crystals of blue vitriol i.e. hydrated copper sulphate in a dry test tube or boiling tube. Heat the tube from below. The salt will change to a white anhydrous powder and water droplet will appear on the walls of the tube. Cool the tube and add a few drops of water to It. The white anhydrous powder will again acquire blue colour.

$$\underset{(Blue)}{CuSO_4.5H_2O} \xrightarrow{Heat} \underset{(White)}{CuSO_4} + 5H_2O$$

$$\underset{(White)}{CuSO_4} + 5H_2O \longrightarrow \underset{(Blue)}{CuSO_4.5H_2O}$$

It is interesting to note that the crystalline salts containing molecules of water of crystallization are actually not wet. The H_2O molecules are the part of the crystals. Upon heating, these are released and the salt becomes anhydrous

Example 2.6. Choosing only the substances from the list given in the box below, write equations for the reactions which you would use in the laboratory to obtain:
(i) Sodium sulphate (ii) Copper sulphate
(iii) Iron (II) sulphate (iv) Zinc carbonate

Dilute sulphuric acid	**Copper**	**Copper carbonate**
	Iron	**Sodium carbonate**
	Sodium	
	Zinc	

Solution.
(i) $Na_2CO_3(s) + H_2SO_4(aq) \longrightarrow Na_2SO_4(s) + H_2O(l) + CO_2(g)$
(ii) $CuCO_3(s) + H_2SO_4(aq) \longrightarrow CuSO_4(aq) + H_2O(l) + CO_2(g)$
(iii) $Fe(s) + H_2SO_4(aq) \longrightarrow FeSO_4(aq) + H_2(g)$
(iv) $Zn(s) + CuCO_3(aq) \longrightarrow ZnCO_3(aq) + Cu(s)$

Boost Your Knowledge

Efflorescence
Certain hydrated crystalline salts when exposed to the atmosphere at ordinary temperature, lose their water of crystallisation molecules either partially or completely and become anhydrous. These are known as efflorescent substances/salts and this property is known as efflorescence It increases under dry weather conditions and in summer when the ordinary temperature is quite high.

Example. Washing soda, epsom salt and blue vitriol listed above are the examples of efflorescent substances.

•Deliquescence
Certain substances have the property to absorb moisture when exposed to atmosphere at ordinary temperature. They Initially become wet. lose their crystalline forms and ultimately dissolve in absorbed water to form a solution. Such substances are known as deliquescent substances and this property is called deliquescence.

Example. Sodium hydroxide (NaOH). potassium hydroxide (KOH), ferric chloride ($FeCl_3$), hydrated calcium chloride ($CaCl_2.6H_2O$) etc.

•Hygroscopy
Certain substances also absorb moisture from atmosphere at ordinary temperature but do not dissolve in it. These are called hygroscopic substances and this property is known as hygroscopy.

Examples. Anhydrous calcium chloride ($CaCl_2$), conc. sulphuric acid (H_2SO_4), phosphorus pentoxide (P_2O_5), Quick lime (CaO), silica get etc.

Hygroscopic substances are mostly used as drying agents particularly for gases.

BOOST YOUR KNOWLEDGE

- Salts are generally formed as a result of neutralisation reactions between acids and bases,
- •On the basis of the chemical formulae, salts are classified as normal, acidic and basic salts.
- •Salts with pH equal to 7 are neutral. Those with pH less than 7 are acidic while the salts with pH more than this value are basic in nature.
- •Rock salt is chemically sodium chloride (NaCI).
- •NaCI is useful in muscle contraction and also helps in conduction of nerve impulses.
- •A strong solution of sodium chloride in water (about 30%) is called brine.
- •Baking powder is a mixture of baking soda and tartaric acid
- •Antacid is a substance which can neutralise acidity in the stomach.
- •The constituents of soda-acid fire extinguisher are sodium hydrogen carbonate and sulphuric acid
- •Bleaching powder ($CaOCl_2$) is prepared commercially by reacting chlorine with slaked lime.
- •Gypsum is chemically $CaSO_4.2H_2O$. Upon heating, it changes to Plaster of Paris $CaSO_4.1/2H_2O$
- •Plaster of Paris is used for making casts or moulds of different types and also for setting fractured bones.
- •Hydrated copper sulphate ($CuSO_4.5H_2O$) is blue in colour while anhydrous salt ($CuSO_4$) is colourless.