ACIDS, BASES AND SALTS

CONTENTS

INTRODUCTION

A chemical substance is a kind of matter that cannot be separated into any other kind of matter by physical method. Pure substances have uniform composition and always have some properties like taste, smell, texture, etc.

We use several materials in our daily life for various purposes. Some of them are sweet in taste, some are salty, some are sour and some are bitter.

The sweet taste of a substance is due to sugar present in it. Why are certain food materials sour in taste like curd, vinegar, tamarind, lemon juice, green mango, tomatoes, orange, unripened grapes, others are sweet in taste whereas some are salty and some are bitter in taste ? What substance are present in which make them sour, bitter or salty ?

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

Aqueous solutions of acids are generally sour in taste. Acids turn blue litmus red, conduct electricity and react with bases to form salts and water. [Bases and salts are discussed a little later.]

An acid may be defined in various ways. Here, we shall study the definition given by Liebig in 1838. According to Liebig, an acid is a compound which contains hydrogen that can be replaced partially or wholly by a metal or a group of elements acting like a metal, to produce a salt.

For example, sulphuric acid (H_2SO_4) is an acid because of the following reasons.

(i) It contains hydrogen atoms in its molecule.

(ii) The two hydrogen atoms present in its molecule can be replaced partially or wholly by a metal like sodium (Na) to produce sodium hydrogensulphate or sodium sulphate.

$$H_2SO_4 \xrightarrow[+Na^+]{-1\,H^+} \underset{\text{sodium hydrogensulphate}}{NaHSO_4} \quad \text{(partial replacement)}$$

$$H_2SO_4 \xrightarrow[+2Na^+]{-2H^+} \underset{\text{sodium sulphate}}{Na_2SO_4} \quad \text{(complete replacement)}$$

The hydrogen atoms in H_2SO_4 can also be partially or wholly replaced by a group of elements, like an ammonium ion (NH_4^+) to form ammonium hydrogensulphate (NH_4HSO_4) or ammonium sulphate ($(NH_4)_2SO_4$) respectively.

$$H_2SO_4 \xrightarrow[+\,NH_4^+]{-1\,H^+} \underset{\text{ammonium hydrogensulphate}}{NH_4HSO_4} \quad \text{(partial replacement)}$$

$$H_2SO_4 \xrightarrow[+2\,NH_4^+]{-2H^+} \underset{\text{ammonium sulphate}}{(NH_4)SO_4} \quad \text{(complete replacement)}$$

The substances $NaHSO_4$, Na_2SO_4, NH_4HSO_4 and $(NH_4)_2SO_4$ are all salts.

(iii) The acid dissolves in water to make a solution that turns blue litmus red.

(iv) It is sour in taste.

(v) It reacts vigorously with a base to produce a salt.

The hydrogen atoms present in an acid that can be replaced by a metal or a group of elements are called replaceable hydrogen or acidic hydrogen.

◈ Classification of Acids :

Depending upon the elements present, acids may be classified as follows.

(i) Oxyacid : Acids that contain both hydrogen and oxygen are called oxyacids. For example, nitric acid (HNO_3), sulphuric acid (H_2SO_4) and phosphoric acid (H_3PO_4) are oxyacids.

(ii) Hydracid : Acids that contain hydrogen and other nonmetallic element(s), except oxygen, are called hydracids. For example, hydrochloric acid (HCl) and hydrocyanic acid (HCN) are hydracids.

Acids may also be classified as follows.

1. **Organic and inorganic acids :** All sour things that we use in our daily food contain acids. These acids are organic acids. Some of the common acids that are generally used in the laboratory are hydrochloric acid (HCl), sulphuric acid (H_2SO_4) and nitric acid (HNO_3). These are inorganic acids, also called mineral acids. Hydrochloric acid is also present in the gastric juice in our stomach.

2. **Concentrated and dilute acids :** An acid solution may be concentrated or dilute depending upon the amount of the acid present in the solution. Concentrated and dilute solutions of acids are generally used in laboratories. Let us see what these acids are.

   An acid is generally used as solution in water. When the solution contains a larger amount of the acid, it is said to be concentrated, whereas a dilute solution contains smaller amount of the acid.

   Thus, concentrated and dilute solutions of an acid differ from each other only in the proportions of the acid and water in them.

3. **Strong and weak acids :** The strength of an acid is determined by the amount of hydrogen ions (H^+) that the acid provides when dissolved in water.

   Some of the acids, when dissolved in water, get almost completely dissociated to provide hydrogen ions. These acids are called strong acids. For example, hydrochloric acid (HCl), nitric acid (HNO_3) and sulphuric acid (H_2SO_4) are strong acids.

   On the other hand, there are some acids which when dissolved in water, are only incompletely dissociated to give hydrogen ions. These are called weak acids. For example, carbonic acid (H_2CO_3) and acetic acid (CH_3COOH) are weak acids.

◈ Basicity of an acid :

The basicity of an acid is the number of replaceable hydrogen atoms present in a molecule of the acid.

The acid which contains one replaceable hydrogen atom in its molecule is called a monobasic acid and its basicity is 1. The acids containing two or three replaceable hydrogen atoms in their molecules are called dibasic acids or tribasic acids and their basicities are 2 or 3.

Examples of a few acids with their basicities are given in the table below.

Acid	Basicity
HCl	1
HNO_3	1
H_2SO_4	2
H_3PO_4	3

◈ Preparation of Acids :

There are several methods for preparing acids. Some of them are discussed here.

1. **Synthetic method :** In the synthetic method, acids are prepared by direct combination of elements. For example, hydrogen and chlorine react together under the action of an electric spark to produce hydrogen chloride gas which is absorbed in water to give hydrochloric acid.

$$H_2 + Cl_2 \xrightarrow{\text{electric spark}} 2HCl$$

Similarly, sulphuric acid may be obtained from its elements as follows.

$$\underset{\text{sulphur}}{S} + \underset{\text{oxygen}}{O_2} \longrightarrow \underset{\text{sulphur dioxide}}{SO_2}$$

$$2SO_2 + O_2 \longrightarrow \underset{\text{sulphur trioxide}}{2SO_3}$$

$$SO_3 + H_2O \longrightarrow \underset{\text{sulphuric acid}}{H_2SO_4}$$

2. **By dissolving acidic oxides in water :** Some oxides dissolve in water to give acids. These oxides are called acidic oxides. For example, sulphur trioxide (SO_3) dissolves in water to give H_2SO_4.

$$SO_3 + H_2O \longrightarrow H_2SO_4$$

Silimlarly, carbon dioxide (CO_2) dissolves in water to produce carbonic acid (H_2CO_3).

$$CO_2 + H_2O \longrightarrow H_2CO_3$$

3. **By the action of an acid on the salt of another acid :** An acid having higher boiling point can react with the salt of an acid of lower boiling point to produce an acid. For example, NaCl is a salt of HCl. The boiling point of HCI is lower than that of H_2SO_4, When NaCl (salt of HCl) reacts with H_2SO_4, HCl is formed.

$$H_2SO_4 + NaCl \longrightarrow NaHSO_4 + HCl$$

◈ General Properties of Acids :

1. They are sour in taste.
2. They turn blue litmus paper red.
3. Acids show acidic properties only in the presence of water. This can be demonstrated by the following activity.

   Dry hydrogen chloride gas does not produce H^+ ions in the absence of moisture/water. It produces H^+ ions only in the presence of moisture/water.

$$HCl + H_2O \rightarrow H_3O^+ + Cl^-$$

4. Their aqueous solutions conduct electricity.
5. They react with certain metals with the evolution of hydrogen gas.

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Metals like potassium, sodium, calcium, magnesium, aluminium, zinc and iron can react with the aqueous solution of an acid to evolve hydrogen gas.

$$2Na + 2HCl \rightarrow \underset{\text{sodium chloride}}{2NaCl} + \underset{\text{hydrogen}}{H_2\uparrow}$$

$$Fe + 2HCl \rightarrow \underset{\text{ferrous chloride}}{FeCl_2} + H_2\uparrow$$

$$Mg + H_2SO_4 \rightarrow \underset{\text{magnesium sulphate}}{MgSO_4} + H_2\uparrow$$

$$2Al + 3H_2SO_4 \rightarrow \underset{\text{aluminium sulphate}}{Al_2(SO_4)_3} + 3H_2\uparrow$$

These reactions show certain metals can displace hydrogen from acids to form salts.

Nitric acid reacts only with magnesium and manganese. In both the reactions hydrogen gas is evolved.

$$\underset{}{Mg} + 2HNO_3 \rightarrow \underset{\text{magnesium nitrate}}{Mg(NO_3)_2} + H_2\uparrow$$

$$Mn + 2HNO_3 \rightarrow \underset{\text{magnesium nitrate}}{Mn(NO_3)_2} + H_2\uparrow$$

Nitric acid does not behave like this with any other metal.

6. They can react with bases to produce salts and water. [We will study these reactions when we deal with the bases.]

7. They react with carbonates and hydrogencarbonates to form carbon dioxide and a salt.

$$\underset{\text{sodium carbonate}}{Na_2CO_3} + 2HCl$$
$$\rightarrow \underset{\text{sodium carbonate}}{2NaCl} + \underset{\text{water}}{H_2O} + \underset{\text{carbon dioxide}}{CO_2}\uparrow$$

$$Na_2CO_3 + H_2SO_4 \rightarrow$$
$$\underset{\text{sodium sulphate}}{Na_2SO_4} + H_2O + CO_2\uparrow$$

$$\underset{\text{calcium carbonate}}{CaCO_3} + 2HCl$$
$$\rightarrow \underset{\text{calcium chloride}}{CaCl_2} + H_2O + CO_2\uparrow$$

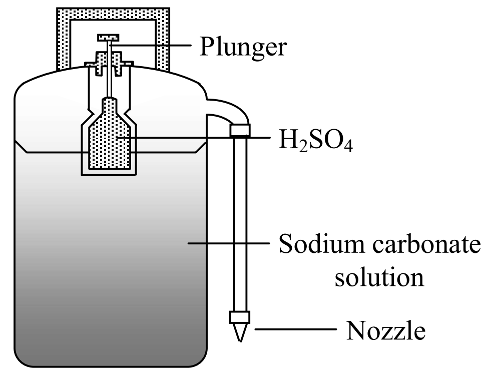
$$\underset{\text{sodium hydrogencarbonate}}{NaHCO_3} + HCl \rightarrow NaCl + H_2O + CO_2\uparrow$$

$$2NaHCO_3 + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O + CO_2\uparrow$$

This activity may be used as a method of determining if a given substance is an acid or not.

◈ Fire extinguisher :

The reaction between sulphuric acid and sodium carbonate or sodium hydrogencarbonate is utilized in the making of fire extinguisher as shown in Figure. A sealed glass bottle filled with dilute sulphuric acid is kept inside a container filled with an aqueous solution of sodium carbonate. In case of fire, the plunger is struck against a hard surface to break the bottle. As a result, sulphuric acid comes in contact with the sodium carbonate. The carbon dioxide gas which comes out is directed towards the fire.



7. Acids react with the oxides of metals to form salts and water.

$$\underset{\text{sodium oxide}}{Na_2O} + 2HCl \rightarrow 2NaCl + H_2O$$

$$\underset{\text{cuprix oxide}}{CuO} + H_2SO_4 \rightarrow \underset{\text{cupric sulphate}}{CuSO_4} + \underset{\text{water}}{H_2O}$$

$$\underset{\text{calcium oxide}}{CaO} + 2HCl \rightarrow \underset{\text{calcium chloride}}{CaCl_2} + \underset{\text{water}}{H_2O}$$

◈ All acids contain hydrogen :

All acids have similar chemical properties. This indicates that all acids must have something in common. You know, all acids react with metal to produce hydrogen gas. Thus, hydrogen is the common substance present in all acids. But all compounds containing hydrogen are not acids. For example, hydrochloric acid and sulphuric acid contain hydrogen and these are acids. On the other hand, alcohol and glucose also contain hydrogen but they are not acids.

The acidic properties of acids are due to the fact that they produce H^+ ions in aqueous solution.

◈ Uses of Acids :

The following table shows the uses of some organic and inorganic acids.

Acid	Uses
Organic acids	
Citric acid	1. As a preservative for food 2. As a flavouring agent
Ascorbic acid (also called vitamin C)	In the treatment of bone marrow and scurvy diseases
Acetic acid	Added to pickles to make them sour
Tartaric acid	A component of baking power (baking powder is a mixture of sodium hydrogencarbonate and tartaric acid)
Inorganic acids	
Hydrochloric acid	1. Its presence in the gastric juice helps digestion of food we eat. 2. As a bathroom cleaner 3. In the manufacture of polyvinyl chloride (PVC)
Nitric acid	1. Nitric acid present in rainwater forms nitrates in the soil which are then used by plants to obtain nitrogen. 2. In the manufacture of fertilizers like ammonium nitrate 3. In making explosives like TNT and dynamite
Sulphuric acid	1. In storage batteries 2. In the manufacture of fertilizers, paints and pigments, detergents and artificial fibre 3. In the manufacture of hydrochloric acid and alum
Phosphric acid	In fertilizer and detergent industries
Boric acid	1. In the manufacture of glass, glazes and enamels, leather, paper, adhesives and explosives 2. Widely used in detergents 3. As a grain preservative

BASES

Bases are substances that are soapy to touch and bitter in taste.

A base is a substance, usually the oxide or the hydroxide of a metal, which can react with an acid to produce salt and water.

For example, sodium oxide (Na_2O), calcium oxide (CaO), cupric oxide (CuO), iron oxides (FeO, Fe_2O_3 etc.), sodium hydroxide ($NaOH$) and calcium hydroxide ($Ca(OH)_2$ are all bases.

Certain substances are also called bases, though they do not fit into the above definition. For example, ammonia (NH_3). It forms salt with an acid without giving water. So, it should not be treated as a base. But ammonium hydroxide (NH_4OH), the aqueous solution of NH_3, is a base as it reacts with an acid to give salt and water

$$NH_4OH + HCl \rightarrow NH_4Cl + H_2O$$

Alkalis :

Bases that are soluble in water are called alkalis. For example, sodium hydroxide, potassium hydroxide, calcium hydroxide are soluble in water. Therefore, they are alkalis. But bases like copper hydroxide ($Cu(OH)_2$ ferric hydroxide ($Fe(OH)_3$), aluminium hydroxide ($Al(OH)_3$ do not dissolve in water. They are, therefore, not alkalis.

Hence, all alkalis are bases, but all bases are not alkalis. Some of the bases are listed here in Table.

Oxides	Soluble hydroxides	Insoluble hydroxides
Sodium monoxide (Na_2O)	Sodium hydroxide ($NaOH$)	Ferric hydroxide ($Fe(OH)_3$).
Calcium oxide (CaO)	Potassium hydroxide (KOH)	Aluminium hydroxide ($Al(OH)_3$)
Cupric oxide (CuO) ZnO	Calcium hydroxide ($Ca(OH)_2$) Ammonium hydroxide NH_4OH	

Lime water, baking soda and washing soda are all bases

◈ Preparation of Bases :

Bases can be prepared by the following methods.

1. By the direct union of a metal with oxygen Some metals when heated in air or oxygen form the oxides of the metals.

$$4Na + O_2 \rightarrow \underset{\text{sodium oxide}}{2Na_2O}$$

$$4K + O_2 \rightarrow \underset{\text{potassium oxide}}{2K_2O}$$

$$2Ca + O_2 \rightarrow \underset{\text{calcium oxide}}{2CaO}$$

These oxides when dissolves in water make the hydroxides of metals.

$$Na_2O + H_2O \rightarrow 2NaOH$$

$$K_2O + H_2O \rightarrow 2KOH$$

$$CaO + H_2O \rightarrow Ca(OH)_2$$

2. By the action of water or steam on some active metals Some active metals like sodium and potassium react with cold water to form hydroxides with the evolution of hydrogen gas.

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

Magnesium reacts with steam to form magnesium oxide with the evolution of hydrogen gas.

$$Mg + H_2O \rightarrow \underset{\text{magnesium oxide}}{MgO} + H_2\uparrow$$

On passing superheated steam over red-hot iron, ferrosoferric oxide is formed and hydrogen gas is evolved.

$$\underset{\substack{\text{iron}\\ \text{(red-hot)}}}{3Fe} + \underset{\substack{\text{steam}\\ \text{(superheated)}}}{4H_2O} \rightarrow \underset{\substack{\text{ferrosoferric}\\ \text{oxide}}}{Fe_3O_4} + \underset{\text{hydrogen}}{4H_2}\uparrow$$

3. By heating carbonates of some metals When calcium carbonate is heated, calcium oxide and carbon dioxide are formed.

$$CaCO_3 \rightarrow CaO + CO_2\uparrow$$

Similarly, when zinc carbonate is heated, zinc oxide and carbon dioxide are formed

$$ZnCO_3 \rightarrow ZnO + CO_2\uparrow$$

4. By the action of an alkali on a salt solution For example, when an aqueous solution of sodium hydroxide is added to an aqueous solution of magnesium sulphate, magnesium hydroxide gets precipitated and sodium sulphate remains in the solution.

$$MgSO_4 + 2NaOH \rightarrow \underset{\substack{\text{magnesium}\\ \text{hydroxide}}}{Mg(OH)_2}\downarrow + \underset{\substack{\text{sodium}\\ \text{sulphat}}}{Na_2SO_4}$$

◈ General Properties of Bases

1. The solutions of bases in water give a soapy touch. When dissolved in water they produce hydroxide ions (OH^-) in solution.

$$NaOH \xrightarrow{H_2O} Na^+ + OH^-$$

$$Ca(OH)_2 \xrightarrow{H_2O} Ca^{2+} + 2OH^-$$

$$Mg(OH)_2 \xrightarrow{H_2O} Mg^{2+} + 2OH^-$$

2. They turn red litmus paper blue.

   Take some soap solution in a test tube. Dip the tip of a red litmus paper into it. You will see that red litmus paper turns blue. This indicates that the soap solution contains a base.

3. They react with acids to produce salt and water.

$$NaOH + HCl \rightarrow NaCl + H_2O$$

$$2KOH + H_2SO_4 \rightarrow CuSO_4 + 2H_2O$$

$$Cu(OH)_2 + H_2SO_4 \rightarrow CuSO_4 + 2H_2O$$

In these reactions, the acid and the base neutralize each other. Therefore, these reactions are called neutralization reactions.

Thus, a neutralization reaction may be defined as a reaction between an acid and a base, producing salt and water.

This neutralization reaction may be explained as follows. You know, all acids provide H^+ ions and all bases provide OH^- ions in aqueous solution. Let us see what happens when HCl and NaOH react together.

$$HCl + NaOH \rightarrow NaCl + H_2O$$

or $H^+ + Cl^- + Na^+ + OH^-$

$$\rightarrow Na^+ + Cl^- + H_2O$$

or $H^+ + OH^- \rightarrow H_2O$

Thus, during neutralization of an acid with a base or vice versa H^+ ions (from acid) and OH^- ions (from base) combine to produce H_2O molecules.

4. The oxides which produce acids in aqueous solutions are called acidic oxides which are usually the oxides of nonmetals. Acidic oxides react with bases to give salts and water.

$$2NaOH + \underset{\text{Carbon dioxide}}{CO_2} \rightarrow \underset{\text{sodium carbonate}}{Na_2CO_3} + \underset{\text{water}}{H_2O}$$

$$Ca(OH)_2 + \underset{\text{Carbon dioxide}}{CO_2} \rightarrow \underset{\text{calcium carbonate}}{CaCO_3} + \underset{\text{water}}{H_2O}$$

5. When a base is heated with an ammonium salt, ammonia gas, another salt and water are produced. For example, when sodium hydroxide is heated with ammonium chloride, the products formed are sodium chloride, water and ammonia gas.

$$NaOH + \underset{\text{ammonium chloride}}{NH_4Cl}$$

$$\rightarrow \underset{\text{sodium chloride}}{NaCl} + H_2O + \underset{\text{ammonia}}{NH_3} \uparrow$$

Ammonia gas is recognized by its pungent smell.

6. Bases react with certain salts to produce another salt and another base. For example, when NH_4OH is added to a solution of $Al_2(SO_4)_3$, $(NH_4)_2SO_4$ and $Al(OH)_3$ are produced.

$$\underset{\text{ammonium hydroxide}}{6NH_4OH} + \underset{\text{aluminium sulphate}}{Al_2(SO_4)} \rightarrow$$

$$\underset{\text{aluminium hydroxide}}{2Al(OH)_3} + \underset{\text{aluminimum sulphate (salt)}}{3(NH_4)_2SO_4}$$

◈ Strong Bases and Weak Bases :

The strength of a base is determined by the amount of hydroxide ions (OH^-) that the base provides when dissolved in water.

Some of the bases, when dissolved in water, get almost completely dissociated to provide hydroxide ions. These bases are called strong bases. (Bases soluble in water are also called alkalis.) For example, sodium hydroxide and potassium hydroxide are strong bases.

But there are bases which, when dissolved in water, get only partially dissociated to give hydroxide ions. These are weak bases. For example, magnesium hydroxide and ammonium hydroxide are weak bases.

◈ Acidity of a Base :

The acidity of a base is defined as the number of hydroxyl (OH) groups present in a molecule of the base.

In each molecule of NaOH, KOH and NH_4OH only one hydroxyl group is present. Therefore, the acidity of all these bases is 1.

In $Ca(OH)_2$ and $Ba(OH)_2$ there are two hydroxyl groups present in each molecule. Hence, their acidity is 2.

Similarly, the acidity of $Fe(OH)_3$ and $Al(OH)_3$ is 3.

The base containing one hydroxyl group in a molecule is said to be mono acidic base, that containing two hydroxyl groups is called diacidic base, and that containing three hydroxyl groups is called triacidic base. Thus, NaOH, $Ca(OH)_2$ and $Fe(OH)_3$ are monoacidic, diacidic and triacidic bases respectively.

◈ Common bases and their uses :

Table lists some of the common bases and their uses.

Bases	Uses
Sodium hydroxide	1. In the manuacture of soaps, textile, paper, medicines 2. In the refining of petroleum
Ammonium hydroxide	1. As a reagent in the laboratory

	2. In making fertilizers, rayon, plastics and dyes
Calcium hydroxide	1. In making cement and mortar 2. In making bleaching powder 3. In whitewashing 4. In removing acidity of soils

➢ INDICATOR

An indicator may be defined as follows.

An acid-base indicator is defined as a substance that assumes different colours in acidic, basic and neutral solutions.

Litmus, methyl orange and phenolphthalein are some of the most commonly used acid-base indicators that change colour as follows.

Indicator	Acid solution	Basic solution	Neutral solution
Blue litmus solution	Red	No change in colour	No change in colour
Red litmus solution	No change in colour	Blue	No change in colour
Methyl orange	Red	Yellow	Orange
Phenolphthalein	Colourless	Red	Colourless

Litmus : It is a natural dye made from small plants called lichens. Blue and red litmus solutions are prepared from two different varieties of lichens.

Litmus paper : Blue or red litmus paper is prepared by dipping a strip of filter paper in blue or red litmus solutions. The paper is then removed from the solution and dried.

Blue litmus paper turns red in an acidic solution and red litmus paper blue in a basic solution.

Phenolphthalein : It is a colourless compound. An alcoholic solution of phenolphthalein is used as an indicator. It is colourless in an acidic solution, but becomes pink (red) in basic solution:

Methyl orange : A very small amount of solid methyl orange is dissolved in hot water and filtered. The filtrate is used as an indicator. It turns red in acid solutions and yellow in basic solutions.

❖ Household indicators :

Some useful household indicators are discussed below.

(i) Turmeric juice It is yellow in colour. It remains yellow in acidic or neutral solutions but turns deep brown in a basic solution.

(ii) Red-cabbage juice Itself purple in colour, it turns red in an acid solution, but green in a basic solution.

The household indicators may be used to test whether some of the substances of daily use as listed below are acidic or basic.

Acidic substances	Basic substance
Vitamine C tablets (ascorbic acid)	Antacids
	Toothpaste
Lemon juice	Soap solution
Orange juice	Washing soda solutions
Tomato juice	
Vinegar	

❖ Olfactory indicators :

There are substances like onion juice, vanilla essence and clove oil which by change of their smell indicate whether the sample solution is acidic or basic. These are called olfactory indicators.

You have learnt that in neutralization reactions an acid and a base react to produce salt and water. For example, the neutralization reaction between NaOH and HCl gives the salt NaCl and water.

$$NaOH + HCl \rightarrow NaCl + H_2O$$

Thus, a salt may be defined as follows.

A salt is a compound formed by the reaction of an acid with a base in which the hydrogen of the acid is replaced by the metal.

In polybasic acids, more than one hydrogen atoms are present in a molecule. These hydrogen atoms can be replaced partially or completely. So, two kinds of salts are possible.

(i) $H_2SO_4 + NaOH \rightarrow \underset{\text{sodium water hydrogensulphate}}{NaHSO_4} + \underset{\text{water}}{H_2O}$

Here, partial replacement of hydrogen atoms from H_2SO_4 has resulted in the formation of sodium hydrogensulphate.

(ii) $H_2SO_4 + 2NaOH \rightarrow \underset{\text{sodiumsulphate}}{Na_2SO_4} + \underset{\text{water}}{2H_2O}$

Here, complete replacement of hydrogen atoms from H_2SO_4 has resulted in the formation of sodium sulphate. $NaHSO_4$ and Na_2SO_4 represent two kinds of salts.

❖ Types of Salts :

The different types of salts are: normal salt, acid salt, basic salt and double salt.

1. Normal salt : A salt that does not contain any replaceable hydrogen atoms or hydroxyl groups is

EXAMPLES

Na_2SO_4 obtained in the reaction between H_2SO_4 and NaOH is a normal salt because it is formed by the complete replacement of both the H atoms of H_2SO_4,

Similarly, calcium su1phate ($CaSO_4$), sodium phosphate (Na_3PO_4) and potassium phosphate (K_3PO_4) are also normal salts.

2. Acid salt : When a polybasic acid is not completely neutralized by a base, the salt produced will contain replaceable hydrogen atoms. Hence, it may further take part in the reaction with the base as an acid. Such a salt is called an acid salt. For example, the salt $NaHSO_4$ produced in the reaction between NaOH and H_2SO_4 is an acid salt because it is capable of further reaction with the base NaOH to produce the normal salt Na_2SO_4.

$$H_2SO_4 + NaOH \rightarrow NaHSO_4 + H_2O$$

$$NaHSO_4 + NaOH \rightarrow Na_2SO_4 + H_2O$$

Thus, an acid salt may be defined as follows.

A salt that contains replaceable hydrogen atoms is called an acid salt.

EXAMPLES :

$NaHSO_4$, NaH_2PO_4 and Na_2HPO_4 are examples of acid salts.

3. Basic salt : When a polyacidic base reacts with lesser amount of acid than is necessary for complete neutralization, the salt produced contain hydroxyl group(s) (OH) also. Such a salt is called a basic salt.

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1 mole of $Pb(OH)_2$ requires 2 moles of HCl for complete neutralization. But when 1 mole of $Pb(OH)_2$ is made to react with 1 mole of HCl, some $Pb(OH)_2$ is left unreacted. The salt produced is not $PbCl_2$, but Pb(OH)Cl.

$$Pb(OH)_2 + HCl \rightarrow \underset{\text{lead oxychloride}}{Pb(OH)Cl} + H_2O$$

Similarly, when one mole of $Bi(OH)_3$ is reacted with 1 mole of HNO_3, the salt $Bi(OH)_2NO_3$ is formed.

$$Bi(OH)_3 + HNO_3 \rightarrow Bi(OH)_2NO_3 + H_2O$$

Salts like $Pb(OH)Cl$ and $Bi(OH)_2NO_3$ contain the OH group. These salts are called basic salts, because they can further react with the acids to form H_2O and the corresponding normal salts.

$$Pb(OH)Cl + HCl \rightarrow PbCl_2 + H_2O$$

$$Bi(OH)_2NO_3 + HNO_3 + Bi(OH)(NO_3)_2 + H_2O$$

$$Bi(OH)(NO_3)_2 + HNO_3 \rightarrow Bi(NO_3)_3 + H_2O$$

Thus, a basic salt is formed when a poly acidic base reacts with a lesser amount of an acid than is necessary for the formation of a normal salt.

4. Double salt : In a double salt, there are two different negative ions and/or positive ions. For example, the mineral dolomite, $CaCO_3 \cdot MgCO_3$, contains both Ca^{2+} and Mg^{2+} ions. Hence, it is a double salt. Potash alum, $K_2SO_4 \cdot Al_2(SO_4)_3 \cdot 24H_2O$, also is a double salt.

Double salts exist only in the solid state. When dissolved in water, they break up into a mixture of two separate salts. For example, when potash alum is dissolved in water, it breaks up as follows.

$$K_2SO_4 \rightleftharpoons 2K^+ + SO_4^{2-}$$

$$Al_2(SO_4)_3 \rightleftharpoons 2Al^{3+} + 3SO_4^{2-}$$

◈ Preparation of Salts :

1. **By the reaction between metal and acid** Certain metals (for example, Zn and Mg) react with HCl or H_2SO_4 to form salt and hydrogen.

$$Zn + 2HCl \rightarrow ZnCl_2 + H_2\uparrow$$

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

2. **By the reaction between an acid and a base :** All acid-base reactions (neutralization reactions) produce salts.

$$NaOH + HCl \rightarrow NaCl + H_2O$$

$$CuO + 2HCl \rightarrow CuCl_2 + H_2O$$

3. **By direct union of a metal and a nonmetal** : Sodium and chlorine combine directly to form sodium chloride.

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

Similarly, when sulphur is heated with iron filings, ferrous sulphide (FeS) is formed.

4. **By the union between an acidic oxide and a basic :**

$$\underset{\text{carbon dioxide}}{CO_2} + \underset{\text{calcium oxide}}{CaO} \rightarrow \underset{\text{calcium carbonate}}{CaCO_3}$$

$$\underset{\text{sulphur trioxide}}{SO_3} + \underset{\text{sodium oxide}}{Na_2O} \rightarrow \underset{\text{sodium sulphate}}{Na_2SO_4}$$

5. **By the reaction between a metal and a base** : When zinc is heated with an aqueous solution of NaOH, sodium zincate (salt) is formed with the evolution of hydrogen gas.

◈ General Properties of Salts :

1. **Reaction with an acid :** When a salt reacts with an acid, another salt and acid are formed. For example, when sodium chloride is heated with sulphuric acid, sodium hydrogensulphate (at low temperature) and then sodium sulphate (at high temperature) are produced and hydrogen chloride gas is evolved.

$$NaCl + H_2SO_4 \rightarrow NaHSO_4 + HCl$$

(at low temperature)

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

(at high temperature)

2. **Reaction with a base :** A salt reacts with a base to produce another salt and base.

$$(NH_4)_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2NH_4OH$$

3. **Reaction with a metal :** Sometimes, a salt solution may react with a metal. For example, when an iron nail is dipped into

an aqueous solution of copper sulphate, copper gets deposited on the surface of the nail and the ferrous sulphate formed remains in the solution.

$$CuSO_4 + Fe \rightarrow FeSO_4 + Cu$$

This reaction shows that iron is more reactive than copper.

Thus, more reactive metal can displace a less reactive metal from a solution of its salt.

4. Behaviour of salts towards water :

When a salt is dissolved in water, the solution may be neutral, acidic or alkaline. This depends upon the nature of the salt used.

(i) A normal salt derived from a strong acid and a strong base gives a neutral solution. For example, the aqueous solutions of NaCl and K_2SO_4 are neutral to litmus.

(ii) A normal salt derived from a weak acid and a strong base gives an alkaline solution. For example, the aqueous solutions of both sodium carbonate (Na_2CO_3) and sodium acetate (CH_3COONa) are alkaline.

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

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

(iii) A salt derived from a strong acid and a weak base gives an acidic solution. For example, both aluminium chloride ($AlCl_3$) and ammonium chloride (NH_4Cl) make acidic aqueous solutions.

$$AlCl_3 + 3H_2O \rightarrow Al(OH)_3 + 3HCl$$

$$NH_4Cl + H_2O \rightarrow NH_4OH + HCl$$

(iv) Solutions of acidic salts are acidic to litmus, i.e., these solutions turn blue litmus paper red. For example, a solution of sodium hydrogensulphate ($NaHSO_4$) turns blue litmus paper red.

Sodium hydrogencarbonate ($NaHCO_3$) solution, however, is slightly alkaline.

❖ **Uses of Salts :**

The following table lists uses of some salts.

Salts	**Uses**
Sodium chloride	1. An essential requirement of our food 2. In the preservation of food 3. In curing fish and meat 4. In making a freezing mixture which is used by icecream vendors 5. In the manufacture of soaps
Sodium carbonate	1. As washing soda for cleaning clothes 2. Used in the manufacture of glass, paper, textiles, caustic soda, etc. 3. In the refining of petroleum 4. In fire extinguishers
Sodium bicarbonate	1. Used as baking soda 2. In fire extinguishers 3. As an antacid in medicine
Potassium nitrate	1. To make gunpowder, fireworks and glass 2. As a fertilizer in agriculture
Copper sulphate	1. Commonly called 'blue vitriol', used as a fungicide to kill certain germs 2. In electroplating 3. In dyeing
Potash alum	1. Used to purify water; makes suspended particles in water settle down 2. As an antiseptic 3. In dyeing

◈ The pH Scale :

A litmus solution or litmus paper can be used to determine whether a given solution is acidic or basic. But suppose you have two acidic solutions containing different amounts of acids in them. How can you say which solution is more acidic? Similar is the case with the basic solutions. This problem is solved by using a scale known as the pH scale introduced by S P Sorensen in 1909. pH of a solution indicates which solution is more acidic or more basic than the other.

The acidity or basicity (alkalinity) of a solution is usually expressed in terms of a function of the H^+ ion concentration. This function is called the pH of a solution.

The pH of an aqueous solution is the negative logarithm of its H+ ion concentration. That is,

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

$$pOH = -\log [OH^-].$$

Note: $[H^+]$ and $[OH^-]$ denote the concentrations of H^+ and OH^- ions respectively.

The concentrations of H^+ and OH^- ions in aqueous solutions are usually very small numbers and therefore difficult to work with. Since pH is the negative logarithm of $[H^+]$, we get positive' numbers and the inconvenience of dealing with small numbers is eliminated.

It should be noted here that pH is only a number, because we can take the logarithm of a number and not of a unit. Therefore, pH of a solution is a dimensionless quantity.

In a neutral solution, $[H^+] = 1.0 \text{ x } 10^{-7}$ M.

$\therefore \quad pH = -\log (1.0 \times 10^{-7}) = 7.$

We can say that the pH of a neutral solution is 7. In an acidic solution, $[H^+] > 1.0 \times 10^{-7}$ M.

Let us assume, $[H^+] = 1.0 \times 10^{-5}$ M.

$\therefore \quad pH = -\log (1.0 \times 10^{-5}) = 5.$

Here, we find that the pH of an acidic solution is less than 7.

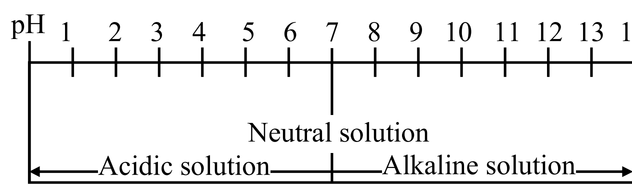
In an alkaline solution, $[H^+] < 1.0 \times 10^{-7}$ M. Let

as assume, $[H^+] = 1.0 \times 10^{-9}$ M.

$\therefore \quad pH = -\log (1.0 \times 10^{-9}) = 9.$

In other words, the pH of an alkaline solution is more than 7.

The pH of different solutions at 298 K can now be expressed on the pH scale as shown below.



◈ Rules for pH scale (at 298 K)

1. Acidic solutions have pH less than 7.
2. The lower the pH, the more acidic is the solution.
3. Neutral solutions or pure water has pH equal to 7.
4. Basic solutions have pH greater than 7.
5. The higher the pH, the more basic is the solution.

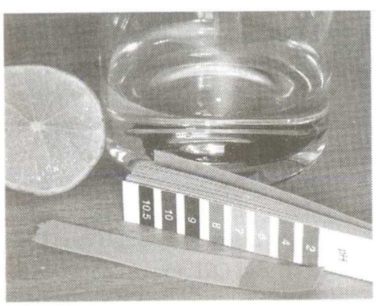
◈ The pH values of some common solutions

Substance	pH
Gastric juice	1.0
Lemon juice	2.5
Vinegar	3.0
Wine	3.5
Tomato juice	4.1

Acid rain	5.6
Urine	6.0
Milk	6.5
Pure water	7
Blood	7.4
Lime water	11.0

How is pH measured?

The pH of a solution is generally determined with the help of a pH paper, or universal indicator. The pH paper gives a particular colour with a solution of particular pH. The colour is compared with a chart which has different colours at different pH values.



Role of pH in everyday life :

pH plays a very important role in our everyday life.

1. **In our digestive system :** Hydrochloric acid produced in our stomach helps the digestion of food without causing any harm to the stomach. But when the amount of the acid goes beyond a certain limit due to indigestion, pain and irritation are created in the stomach. So, in order to neutralize the effect of excess acid, a mild base called antacid is usually taken. Magnesium hydroxide (milk of magnesia) is a mild base which is usually used as an antacid.

2. **Acids cause tooth decay :** When we eat sugary food, it gets degraded by bacteria present in the mouth and an acid is formed. When the pH becomes lower than 5.5, tooth enamel gets corroded. Saliva, which is slightly alkaline, produced in the mouth neutralizes some acid, but excess acid remains unaffected. The excess acid can be removed only by the use of toothpaste which is alkaline. Neem stick contains alkaline juice. So, the cleaning of tooth by Neem stick also helps to reduce tooth decay.

3. **Acid is produced in fatigued muscle :** As a result of physical exercise, stiffness and pain in the muscle starts due to the formation of lactic acid. The supply of oxygen in the muscle is reduced. This causes difficulty in the release of energy leading to increase in the rate of anaerobic metabolism. As a result, lactic acid gets accumulated in the muscles.

4. **Some animals and plants contain acids :** Honey-bee injects an acid through its stings which causes pain and irritation. Hence, a mild base like baking soda is applied to treat the wound. Similarly, nettle leaves, which have stinging hairs, when touched inject formic acid in our body. This causes a burning pain.

   Note : Nettle is a stinging plant. When one accidentally touches its hairs, a painful effect is produced. As a remedy, the affected area is rubbed with the dock plant. The dock plant is alkaline which neutralizes the effect of the acid.

5. **The brilliance of a tarnished copper vessel can be restored by using acid :** You know, lemon juice contains an acid. In order to clean a copper vessel, we rub it with the piece of a lemon. The tarnish on the vessel is caused by the formation of a layer of basic copper oxide. Since lemon juice contains citric acid, it reacts with the copper oxide to form copper citrate and is washed away. The vessel then regains its shining appearance.

6. **pH of soil :** Soils are generally acidic. Plants require definite pH range for their proper growth. They do not grow in alkaline soil. Many plants do not grow properly in highly acidic or highly alkaline soil. So, highly acidic soil is treated by spreading quicklime, slaked lime or calcium carbonate to lower its acidity.

pH of Salts :

The aqueous solutions of all kinds of salts do not have the same pH value.

(i) Salts of strong acids and strong bases : Sodium chloride (NaCl), potassium nitrate (KNO_3), sodium sulphate (Na_2SO_4), etc., are salts of this category. The aqueous solutions of these salts are neutral with pH value of 7.

(ii) Salts of strong acids and weak bases : Aluminium chloride ($AlCl_3$), copper sulphate ($CuSO_4$), zinc sulphate ($ZnSO_4$), etc., are salts of this category. The aqueous solutions of these salts are acidic with pH value less than 7.

(iii) Salts of weak acids and strong bases : Sodium acetate (CH_3COONa), sodium carbonate (Na_2CO_3) and sodium hydrogencarbonate ($NaHCO_3$) are examples of this category of salts. The aqueous solutions of these salts are basic in nature with pH value more than 7

➢ POINT TO REMEMBER

- Everything that tastes sour contains an acid.
- Acetic acid, citric acid, tartaric acid are a few organic acids. Sulphuric acid, nitric acid and hydrochloric acid are examples of inorganic acids.
- Acids turn blue litmus red, whereas bases turn red litmus blue.
- When a solution of an acid contains larger amount of the acid, it is said to be concentrated, while that containing smaller amount of the acid, is said to be dilute.
- Metals like sodium, potassium and calcium react with an acid to liberate hydrogen gas.
- Acids react with bases to produce salts and water.
- Acids react with the carbonates and the hydrogencarbonates to give carbon dioxide gas.
- The hydrogen atoms of an acid which can be partially or completely replaced by an atom or a group of atoms are called replaceable hydrogen atoms. They are also called acidic hydrogen.
- The number of replaceable hydrogen atoms present in a molecule of the acid is known as the basicity of the acid.
- A compound that reacts with an acid to form a salt and water is called a base.
- Bases that are soluble in water are called alkalis. All alkalis are bases, but all bases are not alkalis.
- The reaction between an acid and a base is called neutralization reaction. In such a reaction, the acid and the base destroy the properties of each other.
- The number of hydroxyl groups (OH) present in a molecule of the base is called the acidity of the base.
- A salt is a compound formed by the reaction of an acid with a base.
- Na_2SO_4, $CaSO_4$ and Na_3PO_4 are normal salts, whereas $NaHSO_4$, $NaHCO_3$, Na_2HPO_4 are acid salts.

- A strong acid is one which gets almost completely dissociated when dissolved in water to give hydrogen ions, whereas a weak acid gets only partially dissociated in water to give hydrogen ions.
- A strong base gets almost completely dissociated when dissolved in water to give hydroxide ions (OH^-), whereas a weak base, when treated as such, gets only partially dissociated to provide hydroxide ions.

Exercise-I

A. Very Short Answer Type Questions

Q.1 What is the nature of the solution which turns blue litmus to red ?

Q.2 Conjugate acid-base pair differ by

Q.3 A substance gives H_3O^+ ions in aqueous solution. What is that substance ?

Q.4 The conjugate base of a strong acid

Q.5 In a reaction H^+ ions combine with OH^- ions to form water. What is the type of reaction ?

Q.6 Arrhenius theory of acids-bases is not applicable to

Q.7 What is the conjugate base of CH_3OH ?

Q.8 What is the conjugate acid of CH_3COOH ?

Q.9 Write conjugate base of HCN

Q.10 Write conjugate base of HN_3

Q.11 In the Bronsted-Lowry system a base is defined as.

Q.12 In the following system
$CN^- + H_2O \rightleftharpoons HCN + OH^-$ the conjugate acid-base pairs are.

Q.13 What is the nature of the solution which turns red litmus to blue ?

Q.14 Give one example of Bronsted-Lowry acid.

Q.15 Give one example of Amphoteric compound

B. Short Answer Type Questions

Q.16 Find the pH value of the solution when its H^+ ion concentration is
(a) 10^{-4} mol L^{-1}
(b) 10^{-7} mol L^{-1}

Q.17 Discuss Arrhenius theory of acids and bases taking the example of NaOH and NH_4OH.

Q.18 What is the pH of a solution when the hydrogen ion concentration is 1×10^{-10} ?

Q.19 Calculate the pH of solution containing concentration of hydroxyl ions as 1×10^{-11}.

Q.20 (i) Find out the pH of 0.05 M H_2SO_4.
(ii) Find out the pH of H^+ ion concentration $= 3\times 10^{-3}$.

Q.21 What is the pH range ?

Q.22 If pH is equal to 7, what kind of solution is indicated ?

Q.23 Define and give one example of Bronsted–Lowry base ?

Q.24 Define the term of Neutralisation.

Q.25 What is the Arrhenius theory of acids and bases ? Give its two important limitations.

Q.26 Describe the Bronsted-Lowry concept of acids and bases. What are the conjugate acid base pairs according to the concept ?

Q.27 Explain giving reasons.
(i) Water behaves as an acid and also like a base on the basis of protonic concept ?

Q.28 Find the conjugate acid/base for the following species:
HNO_2, $HClO_4$, OH^-, CO_3^{-2}, S^{-2}

C. Long Answer Type Questions

Q.29 Define the term acid and base on the basis of Arrhenius concept.

Q.30 What are strong and weak electrolytes ? Explain with suitable examples.

Q.31 Define pH. What is pH-scale ?

Exercise-II

A. Fill in the Blanks

Q.1 According to Arrhenius acid-base theory, in neutralisation reaction....... molecule is formed.

Q.2 The conjugate acid of HPO_3^{2-} is.......

Q.3 The conjugate base of NH_3 is.......

Q.4 A conjugate acid forms a conjugate base by....... of a proton.

Q.5 A strong base would have a....... Conjugate acid.

Q.6 The conjugate acid of O^{2-} ion is.......

Q.7 .... acid-base theory cannot define that NH_3 is a base.

Q.8 HSO_4^- is a conjugate acid of.......

Q.9 In the reaction I, HCO_3^- behaves as....... and in the reaction II HCO_3^- behaves as .... hence, HCO_3^- is said to be.......

$$HCO_3^- + H_2O \rightleftharpoons CO_3^{2-} + H_3O^+ \quad \text{(I)}$$
$$HCO_3^- + H_2O \rightleftharpoons H_2CO_3 + OH^- \quad \text{(II)}$$

Q.10 In the following reaction

$$[Al(H_2O)_6]^{3+} + H_2O \rightleftharpoons [Al(H_2O)_5OH]^{2+} + H_3O^+$$

$[Al(H_2O)_6]^{3+}$ is.......

Q.11 The pH of an acidic solution is....... than 7

Q.12 An acid produce....... ions when dissolved in water.

Q.13 A Base produce....... ions when dissolved in water.

Q.14 The pH of a basic solution is....... than 7

Q.15 The hydrogen ion concentration in pure water is.......

Q.16 pOH for a solution can be calculated by subtracting....... from 14.

B. True /False Type Questions

Q.17 A base turns blue litmus red.

Q.18 NH_4OH is a strong base.

Q.19 In pure water $[H_3O^+] = [OH^-]$.

Q.20 pH of acidic solutions ranges from 7 to 14.

Q.21 Arrhenius concept of acids and bases is based on theory of ionization.

Q.22 An acid turns blue litmus red

Q.23 pH of pure water is always 7

Q.24 NH_4^+ ion is Bronsted acid

Q.25 pH + pOH = 14 is valid at all temperatures

Q.26 pH of water increases with increase in temperature