3 Acids, Bases and Salts

Acids, bases and salts are important classes of compounds. Most compounds that we come across belong to one of these classes. For example, lemon contains an acid, toothpaste contains a base and table salt is a salt. Let us see what these compounds are and how they are important.

Acids

The term acid is derived from the Latin word *acidus*, meaning sour. In fact, everything that tastes sour, e.g., a lemon, an orange, curd or vinegar, contains an acid.

Table 3.1 Acids in common foodstuff

Foodstuff	Acid
Lemon	Citric acid + ascorbic acid (vitamin C)
Orange	Citric acid + ascorbic acid (vitamin C)
Grapes	Tartaric acid
Apple	Malic acid
Tamarind (*imli* in Hindi)	Tartaric acid
Tomato	Oxalic acid
Curd	Lactic acid
Vinegar	Acetic acid

Sour things we eat contain organic acids. It is interesting to know that vitamin C is ascorbic acid. Taste a tablet of vitamin C—it is sour.

Some inorganic acids are mentioned in Table 3.2. Hydrochloric, nitric and sulphuric acids—the common inorganic acids—are known as mineral acids. Inorganic acids have biological as well as industrial importance. Make sure you do not touch any of these acids (except carbonic acid) by mistake. They can cause what are known as acid burns.

Fig. 3.1 Things containing acids—bathroom acid, vinegar and citrus fruit

Table 3.2 Common inorganic acids

Name	Formula	Source/Use
Hydrochloric acid	HCl	1. Present in gastric juices, which are responsible for the digestion of food 2. Used as a bathroom cleaner
Nitric acid	HNO_3	Found in rainwater, especially in the first shower It forms nitrates in the soil, from which the plants derive nitrogen.

Name	Formula	Source/Use
Sulphuric acid	H_2SO_4	The acid used in lead storage batteries
Carbonic acid	H_2CO_3	The sour component of fizzy drinks
Phosphoric acid	H_3PO_4	1. Its calcium salt makes up our bones. 2. Its calcium salt forms a part of phosphatic fertilisers. 3. Its phosphate radical (PO_4^{3-}) is involved in providing energy for chemical reactions in our body.

How are Acids Prepared?

Acids are generally prepared by the following methods.

1. By the direct combination of elements

$$H_2 + Cl_2 \xrightarrow{\text{sunlight}} \underset{\text{hydrogen chloride}}{2HCl}$$

2. By dissolving the oxide of a nonmetal in water

$$\underset{\text{sulphur dioxide}}{SO_2} + H_2O \longrightarrow \underset{\text{sulphurous acid}}{H_2SO_3}$$

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

3. By heating a salt like sodium chloride or sodium nitrate with concentrated sulphuric acid

$$2NaCl + H_2SO_4 \xrightarrow{\text{heat}} Na_2SO_4 + \underset{\text{hydrogen chloride}}{2HCl}$$

$$2NaNO_3 + H_2SO_4 \xrightarrow{\text{heat}} Na_2SO_4 + \underset{\text{nitric acid}}{2HNO_3}$$

What are Concentrated and Dilute Acids?

An acid is generally used as a solution in the laboratory. For example, a solution of hydrogen chloride (HCl) in water is called hydrochloric acid. If the solution is saturated or contains a large amount of the acid, it is called a concentrated acid. When the solution contains a small amount of the acid, it is said to be dilute.

Diluting a concentrated acid

A lot of heat is released when an acid is mixed with water. So the following precautions should be taken while diluting a concentrated acid.

1. *The acid should be added to water and not the other way round.* Water absorbs the heat produced.
2. *A very small quantity of the acid should be added to the water at a time.*
3. *The solution must be stirred and cooled after each mix.*

   If you are not careful, there may be an accident.

General Characteristics of Acids

Acids have the following general characteristics.

1. They have a sour taste.
2. They turn blue litmus red. Litmus is a natural dye obtained from certain lichens, which are very small plants.
3. They corrode most metals.
4. They liberate carbon dioxide from carbonates and hydrogencarbonates (i.e., bicarbonates).
5. They lose their acidic property when they react with what are known as bases (i.e., metal oxides and hydroxides and also ammonium hydroxide). These reactions are called neutralisation reactions, which we will study soon.
6. Aqueous solutions of acids allow the passage of electricity through them.

Activity You can easily test for an acid at home too. Take some baking soda (sodium bicarbonate) and put a drop or two of the test liquid on it. Acids will cause release of carbon dioxide with effervescence, i.e., gas bubbles will be produced with a hissing sound. You will find that lemon juice and vinegar will cause effervescence but water will not.

Fig. 3.2 Lemon juice causes effervescence with baking soda.

Acids Contain Replaceable Hydrogen Atoms

An acid is a compound containing hydrogen atom(s) which can be wholly or partially replaced by metal atom(s) or positive radical(s).

The replacement of the hydrogen atom(s) of an acid by a metal atom or a positive radical gives rise to a salt. Thus, the H atom of HCl can be replaced by an Na atom to give the salt NaCl (sodium chloride). The same H atom can be replaced by an NH_4 radical to give the salt NH_4Cl (ammonium chloride).

What happens when an acid has two replaceable H atoms, e.g., H_2SO_4? The two H atoms are replaced in two steps.

(i) On the replacement of only one H atom, i.e., on *partial replacement*, we get a salt like $NaHSO_4$ (sodium hydrogensulphate) or NH_4HSO_4 (ammonium hydrogensulphate).

(ii) On the *complete replacement* of H atoms, we get a salt like Na_2SO_4 (sodium sulphate) or $(NH_4)_2SO_4$ (ammonium sulphate).

When there are three replaceable H atoms, as in H_3PO_4 (phosphoric acid), the H atoms are replaced in three steps.

The basicity of an acid

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

Thus, HCl and HNO_3 have a basicity of 1 and are called monobasic acids. But H_2SO_4, H_2SO_3 or H_2CO_3 have a basicity of 2 and is called dibasic acids. Obviously, H_3PO_4 is a tribasic acid. Acids with a basicity higher than 1 are collectively known as polybasic acids.

Normal and acid salts

A salt formed by the complete replacement of the hydrogen atoms of an acid molecule by a metal atom or a positive radical is called a normal salt.

A salt formed by the partial replacement of the hydrogen atoms of a polybasic acid molecule by a metal atom or a positive radical is called an acid salt.

Thus, a monobasic acid like HCl or HNO_3 will form only a normal salt like NaCl, $MgCl_2$, $NaNO_3$ or NH_4NO_3. But a dibasic acid like H_2SO_4 will form an acid salt like $NaHSO_4$ and a normal salt like Na_2SO_4. Examples of such salts are given in Table 3.3.

Table 3.3 Examples of normal and acid salts

Acid	Basicity	Salt		
		Type	Formula	Name
HCl	1	Normal salt	NaCl	Sodium chloride
			$MgCl_2$	Magnesium chloride
			NH_4Cl	Ammonium chloride
HNO_3	1	Normal salt	KNO_3	Potassium nitrate
			NH_4NO_3	Ammonium nitrate
H_2SO_4	2	Acid salt	$NaHSO_4$	Sodium hydrogen-sulphate (or sodium bisulphate)
		Normal salt	Na_2SO_4	Sodium sulphate
			$(NH_4)_2SO_4$	Ammonium sulphate

Acid	Basicity	Salt		
		Type	Formula	Name
H_2CO_3	2	Acid salt	$NaHCO_3$	Sodium hydrogencarbonate (or sodium bicarbonate)
		Normal salt	Na_2CO_3	Sodium carbonate
H_3PO_4	3	Acid salt	NaH_2PO_4	Sodium dihydrogenphosphate
			Na_2HPO_4	Disodium hydrogenphosphate
		Normal salt	Na_3PO_4	Sodium phosphate

Formulae of salts containing compound radicals

As you know, some groups of atoms, like CO_3^{2-} (carbonate), SO_4^{2-} (sulphate) or PO_4^{3-} (phosphate), stay together in chemical reactions. They are also called compound radicals. Each of them has its own valency, which is equal to the charge on the radical. The formula of a salt containing a metal (or a positive radical) and a negative radical can be expressed by transposing the valencies.

Remember that you have to divide the valencies by a common factor, if any, after transposing them. For instance, the valencies of both Ca and CO_3 are 2. But the compound they form is $CaCO_3$ and not $Ca_2(CO_3)_2$. We have to divide the valencies (2) by the common factor (2).

$\overset{1}{Na}\ \overset{2}{CO_3} \Rightarrow Na_2CO_3$ sodium carbonate

$\overset{2}{Ca}\ \overset{2}{CO_3} \Rightarrow CaCO_3$ calcium carbonate

$\overset{1}{Na}\ \overset{1}{HCO_3} \Rightarrow NaHCO_3$ sodium hydrogencarbonate

$\overset{2}{Ca}\ \overset{1}{HCO_3} \Rightarrow Ca(HCO_3)_2$ calcium hydrogencarbonate

Table 3.4 Formulae of salts containing compound radicals

Metal/radical with valency		Formula	Metal/radical with valency		Formula
$\overset{1}{Na}$	$\overset{1}{NO_3}$ (nitrate)	$NaNO_3$	$\overset{1}{Na}$	$\overset{1}{HSO_3}$ (hydrogensulphite or bisulphite)	$NaHSO_3$
$\overset{1}{NH_4}$	$\overset{1}{NO_3}$	NH_4NO_3	$\overset{1}{Na}$	$\overset{2}{SO_3}$ (sulphite)	Na_2SO_3
$\overset{2}{Ca}$	$\overset{1}{NO_3}$	$Ca(NO_3)_2$	$\overset{2}{Ca}$	$\overset{2}{SO_3}$	$CaSO_3$
$\overset{2}{Pb}$	$\overset{1}{NO_3}$	$Pb(NO_3)_2$	$\overset{1}{Na}$	$\overset{1}{HSO_4}$ (hydrogensulphate or bisulphate)	$NaHSO_4$
$\overset{1}{Na}$	$\overset{1}{HCO_3}$ (hydrogencarbonate or bicarbonate)	$NaHCO_3$	$\overset{1}{Na}$	$\overset{2}{SO_4}$ (sulphate)	Na_2SO_4
$\overset{1}{NH_4}$	$\overset{1}{HCO_3}$	NH_4HCO_3	$\overset{2}{Ca}$	$\overset{2}{SO_4}$	$CaSO_4$
$\overset{2}{Ca}$	$\overset{1}{HCO_3}$	$Ca(HCO_3)_2$	$\overset{1}{Na}$	$\overset{1}{H_2PO_4}$ (dihydrogenphosphate)	NaH_2PO_4
$\overset{1}{Na}$	$\overset{2}{CO_3}$ (carbonate)	Na_2CO_3	$\overset{1}{Na}$	$\overset{2}{HPO_4}$ (hydrogenphosphate)	Na_2HPO_4
$\overset{2}{Ca}$	$\overset{2}{CO_3}$	$CaCO_3$	$\overset{1}{Na}$	$\overset{3}{PO_4}$ (phosphate)	Na_3PO_4

The Action of Acids on Carbonates

Acids react with carbonates (and also bicarbonates) to liberate carbon dioxide with effervescence (CO_2 bubbles out vigorously). A salt that contains the same negative radical as the acid, and water, are formed simultaneously.

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

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

$$H_2SO_4 + CaCO_3 \rightarrow \underset{\text{calcium sulphate}}{CaSO_4} + H_2O + CO_2 \uparrow$$

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

(sodium hydrogen-carbonate) (sodium sulphate)

Experiment Add a few drops of dilute hydrochloric acid to some solid washing soda ($Na_2CO_3 \cdot 10H_2O$) placed in a test tube. There is an effervescence. The gas that evolves is carbon dioxide, which turns limewater milky.

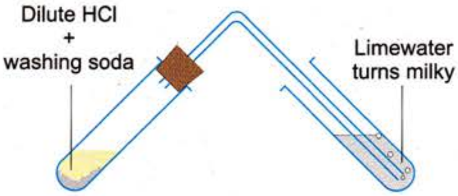


Fig. 3.3 Carbon dioxide evolves by the action of an acid on a carbonate. The gas turns limewater milky.

The same experiment can be repeated with baking soda ($NaHCO_3$) in place of washing soda.

If a drop of lemon juice or vinegar falls on a marble or cement floor, you may observe effervescence.

Marble monuments (like the Taj Mahal) are affected by acid rain because marble, which is calcium carbonate ($CaCO_3$), reacts with acids in the rain.

The Displacement of Hydrogen from Acids by Metals

Metals like potassium (K), calcium (Ca), sodium (Na), magnesium (Mg), aluminium (Al), zinc (Zn) and iron (Fe) are more active than hydrogen. So they displace hydrogen from an aqueous solution of an acid. (But only magnesium and manganese can displace hydrogen from nitric acid.)

$$2Na + 2HCl \rightarrow 2NaCl + H_2\uparrow$$

(sodium) (hydrochloric acid) (sodium chloride) (hydrogen)

$$Mg + 2HCl \rightarrow MgCl_2 + H_2\uparrow$$

(magnesium) (hydrochloric acid) (magnesium chloride) (hydrogen)

$$Fe + H_2SO_4 \rightarrow FeSO_4 + H_2\uparrow$$

(Iron) (sulphuric acid) (iron(II) sulphate) (hydrogen)

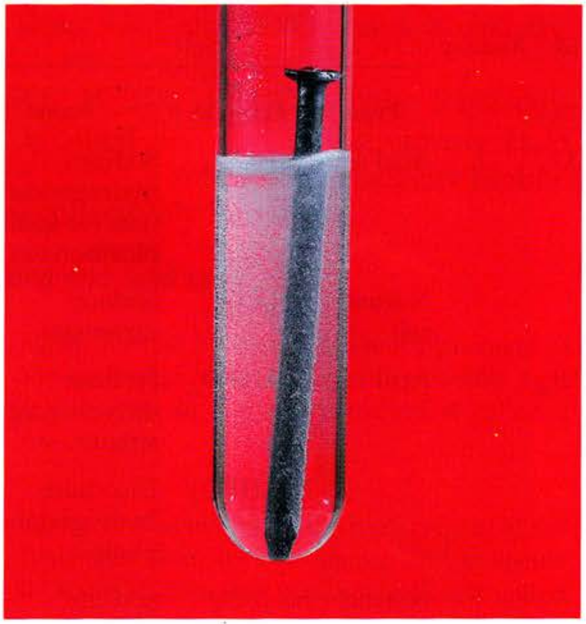


Fig. 3.4 Iron reacts with dilute sulphuric acid to form hydrogen gas and a green solution of iron(II) sulphate.

However, metals like copper (Cu) and mercury (Hg) are less active than hydrogen. So they do not displace hydrogen from an acid.

Uses of Acids

Inorganic acids find wide application in various industries, and organic acids, mainly in food processing (Table 3.5).

Table 3.5 Uses of acids

Inorganic acids	Uses
Hydrochloric acid	1. As a bathroom cleaner 2. As a pickling agent (for removing oxide scales from iron and steel before galvanisation; in galvanisation, an iron or steel article is immersed in molten zinc and cooled so as to have a firm coat of zinc on the article—this prevents rusting) 3. In the tanning of leather 4. In the dyeing and textile industry 5. In the manufacture of gelatine from bones

Inorganic acids	Uses
Nitric acid	1. In the manufacture of fertilisers like ammonium nitrate 2. In the manufacture of explosives like trinitrotoluene (TNT) and nitroglycerine (dynamite) 3. In the manufacture of rayon 4. In the manufacture of dyes and drugs
Sulphuric acid	1. In lead storage batteries 2. In the manufacture of hydrochloric acid 3. In the manufacture of alum 4. In the manufacture of fertilisers, drugs, detergents and explosives
Boric acid	As an antiseptic
Organic acids	**Uses**
Ascorbic acid	Vitamin C
Citric acid	Flavouring agent and food preservative
Acetic acid	Flavouring agent (vinegar) and food preservative
Tartaric acid	1. Souring agent for pickles 2. A component of baking powder (sodium hydrogencarbonate + tartaric acid)

Bases

Bases are compounds that react with acids to form salts, usually accompanied by water.

They are usually the oxides and hydroxides of metals. Ammonium hydroxide and ammonia also act as bases. Thus, sodium oxide (Na_2O), calcium oxide (CaO), iron oxides (FeO and Fe_2O_3), copper oxide (CuO), sodium hydroxide ($NaOH$), calcium hydroxide ($Ca(OH)_2$), ammonium hydroxide (NH_4OH), ammonia (NH_3), etc., are bases.

$$\underset{\text{base}}{Na_2O} + \underset{\text{acid}}{2HCl} \longrightarrow \underset{\text{salt}}{2NaCl} + \underset{\text{water}}{H_2O}$$

$$\underset{\text{base}}{CaO} + \underset{\text{acid}}{2HCl} \longrightarrow \underset{\text{salt}}{CaCl_2} + \underset{\text{water}}{H_2O}$$

$$\underset{\text{base}}{2NaOH} + \underset{\text{acid}}{H_2SO_4} \longrightarrow \underset{\text{salt}}{Na_2SO_4} + \underset{\text{water}}{2H_2O}$$

$$\underset{\text{base}}{NH_3} + \underset{\text{acid}}{HCl} \longrightarrow \underset{\text{salt}}{NH_4Cl}$$

In other words, if the product is a salt (with or without water) and one of the two reactants is an acid, the other reactant must be a base.

Antacids, soap and toothpaste are some of the things containing bases that we come across in our everyday lives.

Fig. 3.5 Things containing bases—soap, toothpaste and antacid tablets

Alkalis

Soluble bases are called alkalis.

Common bases soluble in water are sodium hydroxide ($NaOH$), potassium hydroxide (KOH), calcium hydroxide ($Ca(OH)_2$) and ammonium hydroxide (NH_4OH). Bases like magnesium hydroxide ($Mg(OH)_2$), iron(III) hydroxide ($Fe(OH)_3$) and copper(II) hydroxide ($Cu(OH)_2$) are not soluble in water and are therefore not alkalis.

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

How are Bases Prepared?

Bases are generally prepared by the following methods.

1. By the direct combination of a metal with oxygen

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

$$2Mg + O_2 \xrightarrow{\text{heat}} \underset{\text{magnesium oxide}}{2MgO}$$

2. By the action of water or steam on some active metals

$$2Na + 2H_2O \xrightarrow{\text{cold}} \underset{\text{sodium hydroxide}}{2NaOH} + H_2\uparrow$$

$$Mg + \underset{\text{steam}}{H_2O} \xrightarrow{\text{heat}} \underset{\text{magnesium oxide}}{MgO} + H_2\uparrow$$

3. By heating some metal carbonates

$$\underset{\text{calcium carbonate}}{CaCO_3} \xrightarrow{\text{heat}} \underset{\text{calcium oxide}}{CaO} + CO_2\uparrow$$

$$\underset{\text{zinc carbonate}}{ZnCO_3} \xrightarrow{\text{heat}} \underset{\text{zinc oxide}}{ZnO} + CO_2\uparrow$$

4. By the action of an alkali on a salt solution

$$\underset{\text{magnesium sulphate}}{MgSO_4} + \underset{\text{sodium hydroxide}}{2NaOH} \longrightarrow \underset{\text{magnesium hydroxide}}{Mg(OH)_2} + Na_2SO_4$$

> The acidity of a base is the number of hydroxyl groups present in a molecule of it.

Thus, NaOH, KOH and NH_4OH are monoacidic bases, $Ca(OH)_2$ and $Cu(OH)_2$ are diacidic bases, and $Fe(OH)_3$ and $Al(OH)_3$ are triacidic bases.

Neutralisation Reactions

> A reaction between an acid and a base, giving a salt and water, is called a neutralisation reaction.

> Acid + Base ⟶ Salt + Water

$$\underset{\text{hydrochloric acid}}{HCl} + \underset{\text{sodium hydroxide}}{NaOH} \longrightarrow \underset{\text{sodium chloride}}{NaCl} + H_2O$$

$$2HCl + \underset{\text{calcium hydroxide}}{Ca(OH)_2} \longrightarrow \underset{\text{calcium chloride}}{CaCl_2} + 2H_2O$$

$$\underset{\text{sulphuric acid}}{H_2SO_4} + \underset{\text{potassium hydroxide}}{2KOH} \longrightarrow \underset{\text{potassium sulphate}}{K_2SO_4} + 2H_2O$$

$$H_2SO_4 + \underset{\text{magnesium hydroxide}}{Mg(OH)_2} \longrightarrow \underset{\text{magnesium sulphate}}{MgSO_4} + 2H_2O$$

In all these reactions, the acid and the base lose their acidic and basic properties, or are neutralised. Hence these reactions are called neutralisation reactions.

Balancing neutralisation reactions

In these equations, the hydrogen of an acid reacts with the hydroxyl (OH) or oxygen of a base to form water. So, if the hydrogen and hydroxyl/oxygen are balanced, the equation will also be balanced. Let us consider the following examples.

When the base is a hydroxide In such a case, 1 H atom will react with 1 OH group to form 1 H_2O molecule.

1. $\underset{1H}{HNO_3} + \underset{1OH}{KOH} \rightarrow KNO_3 + H_2O$

   As 1 H atom of the acid combines with 1 OH group of the base, the equation is balanced.

2. $\underset{1H}{HCl} + \underset{2OH}{Mg(OH)_2} \rightarrow MgCl_2 + H_2O$

   As there are 2 OH groups, there must be 2 H atoms. Hence the balanced equation is

   $$2HCl + Mg(OH)_2 \rightarrow MgCl_2 + 2H_2O$$

3. $\underset{2H}{H_2SO_4} + \underset{1OH}{NaOH} \rightarrow Na_2SO_4 + H_2O$

   As there are 2 H atoms, there must be 2 OH groups to form 2 H_2O molecules. So, the balanced equation will be

   $$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$$

4. $\underset{2H}{H_2SO_4} + \underset{3OH}{Al(OH)_3} \rightarrow Al_2(SO_4)_3 + H_2O$

This can be balanced only by multiplying 2 H by 3 and 3 OH by 2 so that 6 H_2O molecules are formed.

$$3H_2SO_4 + 2Al(OH)_3 \rightarrow Al_2(SO_4)_3 + 6H_2O$$

When the base is an oxide In such cases, 2 H atoms of the acid combine with 1 O atom of the base to form 1 H_2O molecule.

1. $\underset{1H}{HCl} + \underset{1O}{CaO} \rightarrow CaCl_2 + H_2O$

As 1 O atom will require 2 H atoms, the HCl will have to be multiplied by 2.

$$2HCl + CaO \rightarrow CaCl_2 + H_2O$$

This is a balanced equation.

2. $\underset{2H}{H_2SO_4} + \underset{1O}{Na_2O} \rightarrow Na_2SO_4 + H_2O$

As 1 O atom requires 2 H atoms, the equation is already balanced.

3. $\underset{1H}{HCl} + \underset{3O}{Al_2O_3} \rightarrow AlCl_3 + H_2O$

Three O atoms will require 6 H atoms. So multiply HCl by 6 so that 3 H_2O molecules are formed. Also multiply $AlCl_3$ by 2. The balanced equation will be

$$6HCl + Al_2O_3 \rightarrow 2AlCl_3 + 3H_2O$$

The Basic and Acid Radicals of a Salt

A salt is produced when an acid reacts with a base. For example, the salt NaCl is formed by the reaction of HCl with NaOH.

$$\underset{\text{acid}}{HCl} + \underset{\text{base}}{NaOH} \longrightarrow \underset{\text{salt}}{NaCl} + \underset{\text{water}}{H_2O}$$

It is clear that the sodium of sodium chloride has come from the base and the chloride from the acid. Hence sodium is called the basic radical, and chloride, the acid radical of the salt.

Similarly, ammonium is the basic radical and sulphate is the acid radical of the salt ammonium sulphate ($(NH_4)_2SO_4$).

In fact, all positive ions (like sodium, potassium, calcium, magnesium, aluminium and ammonium) are basic radicals, and all negative ions (like chloride, nitrate and sulphate) are acid radicals.

Basic Salts

Salts formed by the partial replacement of hydroxyl groups or the incomplete neutralisation of a base are known as basic salts.

For example, lead hydroxychloride (Pb(OH)Cl)) is a basic salt. It is formed by the replacement of only one of the two hydroxyl groups of the base $Pb(OH)_2$.

$$\underset{\text{lead hydroxide}}{Pb(OH)_2} + \underset{\text{hydrochloric acid}}{HCl} \longrightarrow \underset{\text{lead hydroxychloride}}{Pb(OHCl)} + \underset{\text{water}}{H_2O}$$

Other common examples of such salts are copper hydroxychloride (Cu(OH)Cl) and lead hydroxynitrate ($Pb(OH)NO_3$).

How are Salts prepared?

Salts are prepared by the following methods.

1. By the direct combination of elements

$$2Na + Cl_2 \xrightarrow{\text{heat}} \underset{\text{sodium chloride}}{2NaCl}$$

$$Mg + Cl_2 \xrightarrow{\text{heat}} \underset{\text{magnesium chloride}}{MgCl_2}$$

2. By the action of an acid on a metal

$$\underset{\text{magnesium}}{Mg} + \underset{\text{hydrochloric acid}}{2HCl} \longrightarrow \underset{\text{magnesium chloride}}{MgCl_2} + H_2\uparrow$$

$$\underset{\text{zinc}}{Zn} + \underset{\text{sulphuric acid (dilute)}}{H_2SO_4} \longrightarrow \underset{\text{zinc sulphate}}{ZnSO_4} + H_2\uparrow$$

3. By the action of an acidic oxide on a basic oxide

Generally, the oxides of nonmetals are acidic and those of metals are basic.

$$\underset{\text{sodium oxide}}{Na_2O} + \underset{\text{carbon dioxide}}{CO_2} \longrightarrow \underset{\text{sodium carbonate}}{Na_2CO_3}$$

4. By a neutralisation reaction

$$\underset{\text{sodium hydroxide}}{NaOH} + \underset{\text{hydrochloric acid}}{HCl} \longrightarrow \underset{\text{sodium chloride}}{NaCl} + H_2O$$

$$\underset{\text{magnesium oxide}}{MgO} + \underset{\text{sulphuric acid}}{H_2SO_4} \longrightarrow \underset{\text{magnesium sulphate}}{MgSO_4} + H_2O$$

Salts Found in Nature

Salts are found in abundance in the earth's crust. A large number of salts dissolve in river water and are discharged into lakes and seas. Salts such as chlorides, bromides, iodides and sulphates of sodium, potassium, magnesium and calcium are obtained from sea water.

Soil and *rocks* are vast stores of salts, some of which are mentioned in Table 3.6.

Table 3.6 Salts commonly found in soil and rocks

Salt	Occurrence
Sodium chloride	Rocks of common salt (common salt derived from this source is called rock salt)
Sodium carbonate	Soils of some areas (such soil is called *sajji mitti* in Hindi and is used in place of washing soda)
Sodium nitrate	Saltpetre—a white, woolly crust on the soil
Potassium nitrate	Nitre—a white, woolly crust on the soil
Calcium carbonate (limestone)	1. All soils 2. Limestone rocks
Calcium phosphate	1. All soils 2. Phosphate rocks
Potassium aluminium silicates	1. All soils 2. Mica 3. China clay

Fruits and vegetables are also rich in salts. For example, bananas, guavas and apples are rich in iron salts, and cabbages are rich in calcium salts.

Uses of Salts

Salts are used for various purposes. The common uses are mentioned in Table 3.7.

Table 3.7 The common uses of some salts

Salt	Use
Sodium chloride	1. As a flavouring agent in food 2. In saline water for a patient of dehydration 3. In the manufacture of hydrochloric acid
Sodium iodate	A supplement to common salt in iodised salt (iodine in food prevents the disease goitre)
Sodium carbonate	1. As washing soda 2. In the manufacture of glass
Sodium benzoate	As a food preservative, especially for pickles
Potassium nitrate	1. As a fertiliser, giving both potassium (K) and nitrogen (N) to the soil 2. In gunpowder ($C + S + KNO_3$) 3. In matchsticks
Calcium chloride	Dehydrating agent, used for removing moisture from gases
Calcium carbonate (limestone)	1. In the construction of buildings 2. In the cement industry 3. In the extraction of metals
Calcium sulphate	1. Plaster of Paris—$2CaSO_4 \cdot H_2O$ (A paste of plaster of Paris with water, when applied over broken limbs, sets like ordinary plaster, helping the limbs remain firm.) Plaster of Paris is also used in making moulds and statues. 2. In the cement industry (in the form of gypsum, $CaSO_4 \cdot 2H_2O$)

Salt	Use
Calcium phosphate	As a fertiliser (for making superphosphate of lime)
Bleaching powder	1. As a disinfectant 2. As a bleaching agent (i.e., for removing colours)
Alum (potassium aluminium sulphate)	1. In the purification of water (the muddy substance settles down upon treatment with alum) 2. In the dyeing industry 3. As an aftershave application

Testing for Acids and Bases

How can you find out if a solution is acidic or basic (alkaline)? You can do so by using a substance known as an acid–base indicator (or simply an indicator).

Acid–Base Indicators

An acid–base indicator is a substance that gives different colours in acidic and basic (alkaline) media.

Litmus, phenolphthalein, turmeric and red-cabbage juice show different colours in acidic and alkaline media. They are the commonly used indicators—some in the laboratory and some at home.

The common laboratory indicators

Litmus Litmus is obtained from certain lichens (small plants) and used as a dilute solution. A drop of it is added to a solution whose acid–base behaviour is to be found out. It turns red in acidic and blue in alkaline solutions.

Alternatively, a finger-sized strip of filter paper soaked in litmus solution and dried, called litmus paper, is used. Litmus paper, often more convenient to work with, also turns red in acidic and blue in alkaline media.

Phenolphthalein A dilute solution of phenolphthalein (a colourless chemical) in alcohol is used as an indicator. It turns pink in alkaline solutions and remains colourless in an acidic medium.

Household indicators

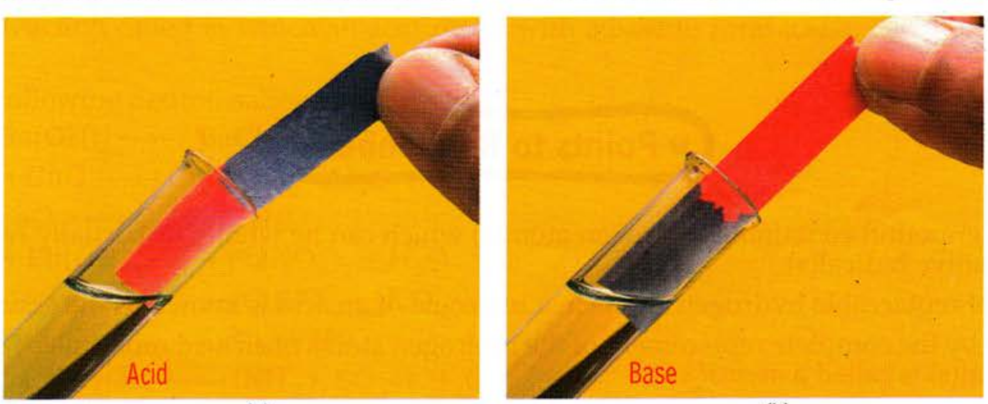
Turmeric juice and red-cabbage juice can be used as household indicators.

Turmeric juice The yellow turmeric juice turns reddish to deep brown in a basic medium and remains yellow in an acidic or neutral medium. Turmeric paper is prepared in the same way as litmus paper.

Red-cabbage juice Red-cabbage juice, purple in colour, turns red in an acidic solution and green in an alkaline medium.

Identifying acidic and basic household substances

Using an indicator, you can easily identify some household substances as acidic or basic. For testing solids, you would need to dissolve them in water first. It would be a good idea to dilute bathroom acid by adding a few drops of acid to water. The acidic or basic nature of certain household substances is given in Table 3.8.



(a) (b)

Fig. 3.6 (a) Acids turn blue litmus red. (b) Bases turn red litmus blue.

Table 3.8 Some acidic and basic household substances

Acidic	Basic (alkaline)
1. Bathroom acid	1. Milk of magnesia (antacid)
2. Vitamin C tablets (ascorbic acid)	2. Toothpaste
3. Lemon juice	3. Soap solution or detergent solution
4. Orange juice	4. Solution of washing soda
5. Tomato juice	5. Slaked lime and white-wash
6. Vinegar	
7. Fizzy drinks (colas and soda water)	

The pH Scale

An acid–base indicator helps us find out whether a solution is acidic or basic (alkaline). But it does not suggest how acidic or how basic a solution is. If we have two solutions containing different amounts of an acid, a litmus paper or solution will turn red in both of them.

However, the pH of the solution tells us which solution is more acidic or more basic than the other. This method of grading was given by the Danish chemist Sørensen.

The pH scale runs from 0 to 14. A neutral solution has a pH of 7. Solutions with pH below 7 are acidic and the acid content increases with decreasing pH. For example, a solution of pH 2 is more acidic than one of pH 3.

Similarly, solutions with pH above 7 are alkaline; the higher the pH value, the more alkaline is the solution. For example, a solution of pH 12 is more alkaline than one of pH 11.

It should be remembered that the concept of pH is useful only for dilute solutions.

How is pH measured?

The pH of a solution is generally measured by a strip of pH paper. On being treated with a solution, the strip gives a particular colour. This colour is matched with a printed chart (Figure 3.7) showing different colours for different pH values.

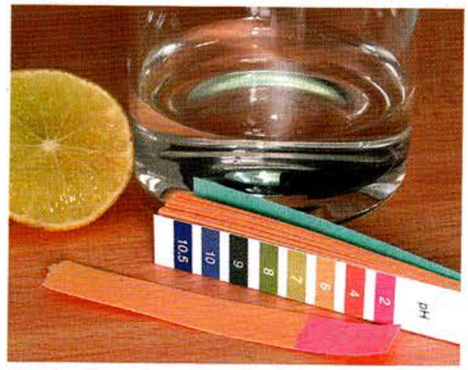


Fig. 3.7 The colour chart that comes with pH paper indicates the pH of the liquid being tested.

The pH values of some common liquids are given in Table 3.9.

Table 3.9 The pH values of some common liquids

Liquid	pH	Liquid	pH
Apple juice	3.0	Vinegar	3.0
Coffee	5.0	Blood	7.4
Lemon juice	2.5	Toothpaste	9.0
Milk	6.5		

Points to Remember

- An *acid* is a compound containing hydrogen atom(s) which can be wholly or partially replaced by metal atom(s) or positive radical(s).
- The number of replaceable hydrogen atoms in a molecule of an acid is known as the *basicity of the acid.*
- A salt formed by the complete replacement of the hydrogen atoms of an acid molecule by metal atom(s) or positive radical(s) is called a *normal salt.*
- A salt formed by the partial replacement of the hydrogen atoms of a polybasic acid molecule by a metal atom or a positive radical is called an *acid salt.*

- Acids react with carbonates (and also bicarbonates) to liberate carbon dioxide with effervescence.
- *Bases* are compounds that react with acids to form salts, usually accompanied by water.
- Bases are usually the oxides and hydroxides of metals. Ammonium hydroxide and ammonia are also bases.
- Soluble bases are called *alkalis*.
- All alkalis are bases, but all bases are not alkalis.
- The *acidity of a base* is the number of hydroxyl groups present in a molecule of it.
- The reaction between an acid and a base, giving salt and water, is called a *neutralisation reaction*.
- Salts formed by the partial replacement of hydroxyl groups, or the incomplete neutralisation of a base, are known as *basic salts*.
- An *acid–base indicator* is a substance that gives different colours in acidic and basic (alkaline) media.
- A neutral solution has pH 7. Solutions having pH lower than 7 are acidic and those having pH higher than 7 are alkaline.

Exercise

Short-Answer Questions

1. Define an acid.
2. Name two inorganic and two organic acids.
3. What do you mean by the basicity of an acid?
4. Name a dibasic mineral acid.
5. Identify the acid salts and the normal salts among the following.
   (a) Sodium carbonate (Na_2CO_3)
   (b) Potassium hydrogencarbonate ($KHCO_3$)
   (c) Disodium hydrogenphosphate (Na_2HPO_4)
   (d) Calcium sulphate ($CaSO_4$)
   (e) Ammonium carbonate ($(NH_4)_2CO_3$)
   (f) Sodium hydrogensulphate ($NaHSO_4$)
6. Give the formulae of the salts containing the following pairs of radicals.
   (a) Na^+ SO_4^{2-}
   (b) Mg^{2+} SO_4^{2-}
   (c) NH_4^+ SO_3^{2-}
   (d) Al^{3+} NO_3^-
   (e) Na^+ PO_4^{3-}
   (f) Na^+ $H_2PO_4^-$
   (g) NH_4^+ HPO_4^{2-}
   (h) Fe^{3+} PO_4^{3-}
   (i) Fe^{2+} PO_4^{3-}
   (j) Ca^{2+} HCO_3^-
7. Define a base.
8. What do you mean by the acidity of a base?
9. What is the reaction called in which an acid reacts with a base to form a salt, usually accompanied by water?
10. Balance the following neutralisation reactions.
   (a) $HCl + Ba(OH)_2 \longrightarrow BaCl_2 + H_2O$
   (b) $HNO_3 + CuO \longrightarrow Cu(NO_3)_2 + H_2O$
   (c) $HCl + CaO \longrightarrow CaCl_2 + H_2O$
   (d) $HNO_3 + Pb(OH)_2 \longrightarrow Pb(NO_3)_2 + H_2O$
   (e) $H_2SO_4 + Cu(OH)_2 \longrightarrow CuSO_4 + H_2O$
   (f) $HCl + Zn(OH)_2 \longrightarrow ZnCl_2 + H_2O$
   (g) $H_2SO_4 + NH_4OH \longrightarrow (NH_4)_2SO_4 + H_2O$
   (h) $H_2SO_4 + Fe(OH)_3 \longrightarrow Fe_2(SO_4)_3 + H_2O$

11. What do you mean by a basic salt?
12. What is that substance called which shows different colours in acidic and basic solutions?
13. You have a red litmus paper, but you need a blue one for some purpose. How would you convert the red litmus paper into a blue one?
14. Name the yellow substance kept on your kitchen shelf that turns reddish brown in alkaline solutions, but remains yellow in acidic and neutral solutions.
15. The pH of blood is 7.4 and that of a toothpaste is 9.0. Which of the two substances is more basic?
16. Is the pH of lemon juice or vinegar higher or lower than 7?

Objective Questions

Choose the correct option.

1. Which of the following compounds is an acid?
   (a) Na_2O (b) FeO (c) HCl (d) $Ca(OH)_2$
2. Which of the following is a tribasic acid?
   (a) HNO_3 (b) H_2CO_3 (c) H_3PO_4 (d) H_2SO_4
3. Which of the following is not a base?
   (a) KOH (b) $Ca(OH)_2$ (c) CuO (d) K_2SO_4
4. Which of the following compounds will react with hydrochloric acid to form a salt and water?
   (a) Na_2SO_4 (b) H_2SO_4 (c) NaOH (d) $CaCl_2$
5. Which of the following is a basic salt?
   (a) $CaCl_2$ (b) $Pb(OH)NO_3$ (c) $CuCO_3$ (d) Na_2SO_4.
6. With which of the following compounds in solution will phenolphthalein give a pink colour?
   (a) NH_4OH (b) HCl (c) H_2O (d) H_2SO_4
7. The pH of pure water is
   (a) 0.0 (b) 1.0 (c) 7.0 (d) 14.0

Fill in the blanks.

1. An acid salt can be formed by a ...... acid. (monobasic/polybasic)
2. ...... bases are called alkalis. (Soluble/Insoluble)
3. An alkali reacts with a/an ...... to give a/an ...... and water. (acid/base/salt)
4. Complete the following reactions.
   (a) $3HCl + ... \longrightarrow AlCl_3 + 3H_2O$
   (b) $H_2SO_4 + ... \longrightarrow CuSO_4 + H_2O$
   (c) $...... + 2NH_4OH \longrightarrow (NH_4)_2SO_4 + 2H_2O$
   (d) $HNO_3 + NH_4OH \longrightarrow ...... + H_2O$
   (e) $...... + ... \longrightarrow K_2SO_4 + 2H_2O$
5. Complete the following table.

Indicator	Solution	Colour
Litmus	Lemon juice	
Litmus	Ammonium hydroxide	
Phenolphthalein	Ammonium hydroxide	
Phenolphthalein	Hydrochloric acid	
Turmeric juice	Soap solution	
Turmeric juice	Orange juice	
Red-cabbage juice	Soap solution	
Red-cabbage juice	Hydrochloric acid	

Indicate which of the following statements are true and which are false.

1. The hydrogen of an acid can be replaced by a negative radical.
2. Acids taste sour.
3. Acids react with carbonates to liberate carbon dioxide with effervescence.
4. All bases are alkalis, but all alkalis are not bases.
5. Basic salts are formed by the complete neutralisation of a polyacidic base.
6. Acid–base indicators give different colours with acids and bases.

Identifying Acids and Bases at Home

You may want to find out for yourself whether a household substance is acidic or basic (alkaline). You can easily do so by using two household indicators—turmeric juice and red-cabbage juice. You can test some of the household substances mentioned in Table 3.8.

Turmeric juice

Prepare turmeric juice by straining grated turmeric with the help of a cloth. Take small quantities (say 10–20 drops) of the juice in a few test tubes. Add the test solutions to them separately.

Add soap solution to the turmeric juice; you will find that the yellow colour of the juice changes to red-brown. So soap solution is basic (alkaline).

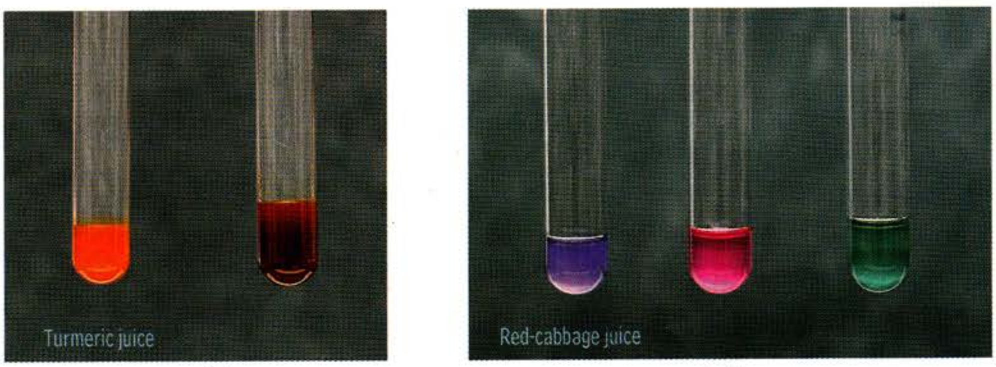
Pour some vinegar into another test tube containing the juice. Vinegar does not change the yellow colour of the juice. So it is either acidic or neutral. From another experiment you will find that vinegar is acidic.

Thus, using turmeric juice, you can find out whether or not a substance is basic.

Red-cabbage juice

Extract red-cabbage juice from a chopped red cabbage by squeezing it or using a juicer. The juice is purple in colour.

Take small quantities of the juice in separate test tubes. Treat it with different test solutions and note the change in colour. Acidic solutions like vinegar and lemon juice will change the colour of the juice to red. Alkaline solutions like those of soap and whitewash will turn the juice green.



(a) (b)

Fig. 3.8 (a) Bases turn turmeric juice reddish to deep brown.
(b) Acids turn red-cabbage juice (purple) red, and bases turn the juice green.

❑