Acids, Bases and Salts

Nature of Metal Oxides and Non-Metal Oxides

You must have observed that in a laboratory, almost all acids are stored in a glass or plastic bottle. However, acids are never kept in metal containers. Do you know why?

This is because acids are corrosive in nature. They can react with metals and destroy them.

Do you know what happens when metals react with acids?

When an acid reacts with metals, salt and hydrogen gas are produced. Thus, metals react with acids and replace the available hydrogen(s) to form salt. This can be represented as follows:

$$\text{Acid} + \text{Metal} \rightarrow \text{Salt} + \text{Hydrogen gas}$$

For example, sulphuric acid (H_2SO_4) reacts with calcium (Ca) to produce hydrogen gas (H_2). Calcium sulphate (metal salt) is also produced in the reaction. The chemical equation involved is as follows:

$$H_2SO_{4(aq)} + Ca_{(s)} \rightarrow CaSO_{4(aq)} + H_{2(g)}$$

DO YOU KNOW?

When acid-containing food items such as pickles, curd, and citrus fruits are kept in metallic utensils, a reaction between the metal and the acid (present in the food item) takes place. Iron, aluminium, and copper are more prone to acid attack. Sometimes, these reactions result in the formation of toxic substances.

The following activity can be performed to confirm that hydrogen gas is produced when metals react with acids.

Now, let us see what happens when metals react with bases.

Metals react with bases and replace the available hydrogen(s) to form salt as follows:

$$\text{Base} + \text{Metal} \rightarrow \text{Salt} + \text{Hydrogen gas}$$

For example, metal (Zn) displaces hydrogen from the base (NaOH) and produces hydrogen gas. The reaction between sodium hydroxide and zinc can be represented as:

$$2NaOH + Zn \rightarrow \underset{\text{(Sodium zincate)}}{Na_2ZnO_2} + H_2$$

However, it should be noted that **not all metals react with bases**.

The following activity can be performed to confirm that hydrogen gas is produced on reacting metals with bases.

Activity:

Place a few pieces of zinc granules in a test tube. Then, add 2 mL sodium hydroxide (NaOH) in it and heat the solution. A reaction between bases (such as NaOH) and metals (such as Zn) is initiated on heating.

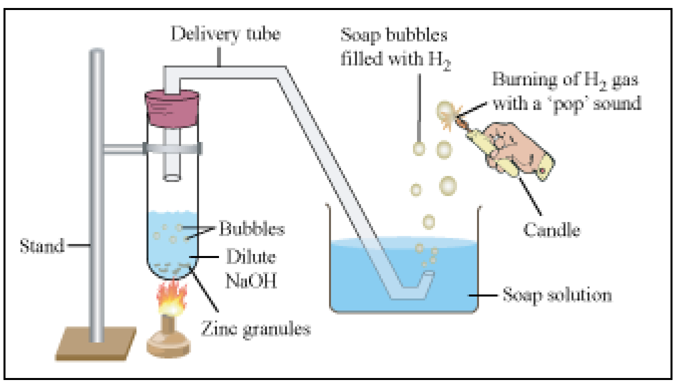


Figure 2: Experiment showing the reaction of bases with metals

We will observe that bubbles are formed in the test tube as soon as dilute sodium hydroxide solution is added to the zinc granules. This proves that gas is evolved in the reaction. The gas evolved in the test tube is then passed to the soap solution through the delivery tube. Soap bubbles filled with hydrogen gas will be seen in the soap solution. The presence of hydrogen gas is confirmed by its burning with a 'pop' sound when a candle is brought near the bubbles.

Hence, hydrogen gas is formed and evolved in the reaction.

Now, let us study some other chemical properties of acids and bases. **Do you know how metallic oxides react with acids and non–metallic oxides react with bases?**

Acids react with metal oxides such as copper oxide, zinc oxide, etc. to produce metal salts. The reaction between a metal oxide and an acid can be written as:

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

DO YOU KNOW?

Metal oxides:

Many metals react with oxygen to produce metal oxides. For example, sodium (Na) reacts with oxygen (O_2) to produce sodium oxide (Na_2O). The chemical equation for the same is as follows:

$2Na + O_2 \rightarrow Na_2O_2$

Metal oxides on reacting with strong acids produce salt and water (similar to the reaction of bases with acids). Hence, metal oxides are also known as basic oxides.

The following activity shows the reaction between an acid and a metallic oxide.

Activity:

Take 50 mg copper oxide in a beaker and slowly pour dilute hydrochloric acid on it, while stirring constantly. Observe the colour of the solution.

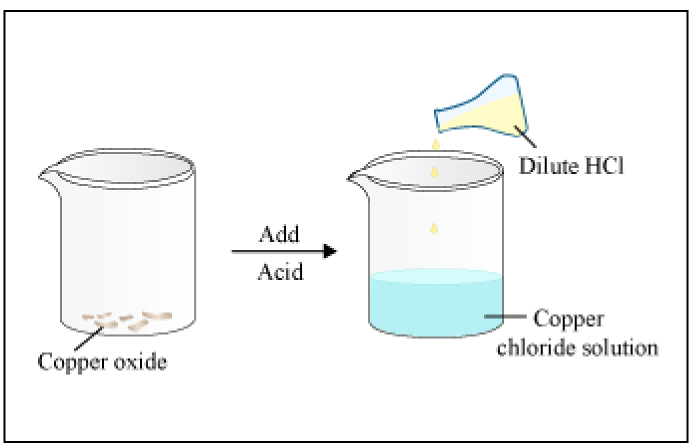


Fig 3: Reaction of metallic oxides with acids.

HCl reacts with copper oxide (CuO) to produce a metal salt i.e., copper chloride and water. It will be observed that copper chloride dissolves in water and forms a solution that is blue-green in colour.

$$CuO_{(s)} + 2HCl_{(dil)} \rightarrow CuCl_{2(aq)} + H_2O_{(l)}$$

Hence, this shows that acids react with metal oxides to produce salt and water.

Similarly, non-metallic oxides react with bases to produce salt and water. The reaction between non-metallic oxides and bases is represented as follows:

$$\text{Non-metal oxide} + \text{Base} \rightarrow \text{Salt} + \text{Water}$$

DO YOU KNOW?

Non-metal oxides:

Non-metals react with oxygen to produce non-metallic oxides. For example, sulphur (S) reacts with oxygen (O_2) to produce sulphur dioxide (SO_2) as follows:

$$S + O_2 \rightarrow SO_2$$

Non-metallic oxides react with strong bases to produce salt and water (similar to the reaction of acids with bases). Hence, non-metallic oxides are also known as acidic oxides.

For example, a reaction between a non-metallic oxide such as carbon dioxide and a base such as calcium hydroxide produces salt and water. This reaction can be written as:

$$\underset{\text{(Lime water)}}{Ca(OH)_2(aq)} + CO_2(g) \rightarrow \underset{\text{(White precipitate)}}{CaCO_3(s)} + H_2O(l)$$

Hence, non-metallic oxides react with bases to produce salt and water.

Reaction Of Acids and Bases With Metal Carbonates And Metal Hydrogen Carbonates

You have already read about acids and bases. Now, let us learn more about them by exploring their chemical properties.

You must have observed that when baking soda (sodium hydrogen carbonate) is treated with vinegar (acetic acid), a brisk effervescence is observed. Similarly, when chalk (calcium carbonate) is treated with sulphuric acid, effervescence is observed. **Do you know what happens in these reactions? Which gas is evolved during these reactions?**

All metal carbonates and hydrogen carbonates react with acids to give a corresponding salt, carbon dioxide, and water. Thus, the reaction can be summarized as:

$$\text{Metal carbonate/Metal hydrogen carbonate} + \text{Acid} \rightarrow \text{Salt} + \text{Water} + \text{Carbon dioxide}$$

For example, zinc carbonate on reacting with sulphuric acid produces zinc sulphate, water, and carbon dioxide as follows:

$$\underset{\text{Zinc carbonate}}{ZnCO_{3(s)}} + \underset{\text{Sulphuric acid}}{H_2SO_{4(aq)}} \longrightarrow \underset{\text{Zinc sulphate}}{ZnSO_{4(aq)}} + \underset{\text{Carbon dioxide}}{CO_{2(g)}} + \underset{\text{Water}}{H_2O_{(l)}}$$

DO YOU KNOW?

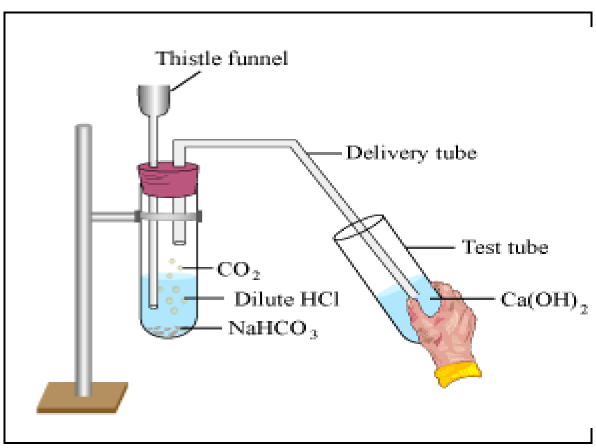
Acid rain contains mainly nitric acid and sulphuric acid, which are formed by the dissolution of nitrogen oxides and sulphur dioxide in air. Acid rain corrodes buildings and statues made with marble and stone. Marble and stone generally contain carbonates of metals. Hence, they react with acid rain. The Taj Mahal (situated in Agra), which is a heritage build

Similarly, zinc hydrogen carbonate on reacting with sulphuric acid produces zinc sulphate, water, and carbon dioxide as follows

$$\underset{\text{Zinc hydrogen carbonate}}{Zn(HCO_3)_2(s)} + \underset{\text{Sulphuric acid}}{H2SO_4(aq)} \rightarrow \underset{\text{Zinc sulphate}}{ZnSO_4(aq)} + \underset{\text{Carbon dioxide}}{2CO_2(g)} + \underset{\text{Water}}{2H_2O(l)}$$

The following activity can be performed to confirm that carbon dioxide gas is produced when acids react with metal carbonates.

The reaction of the hydrogen carbonates of metals with acid can be tested in a similar manner.



The reaction for the same is

$$NaHCO_3(s) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l) + CO_2(g)$$

Carbon dioxide reacts with calcium hydroxide (lime water) to form calcium carbonate (white precipitate). The reaction of carbon dioxide gas with limewater is as follows:

$$\underset{(\text{Lime water})}{Ca(OH)_2(aq)} + CO_2(g) \rightarrow \underset{(\text{White precipitate})}{CaCO_3(s)} + H_2O(l)$$

Sodium chloride salt produced in the reaction dissolves in water.

Hence, this activity shows that acids react with metal carbonates and metal hydrogen carbonates to produce salts, carbon dioxide gas, and water.

Metal carbonates and metal hydrogen carbonates do not react with bases.

Reactions Of Acids And Bases With Each Other

You must have observed that antacid tablets are used during indigestion. An antacid contains magnesium hydroxide, which is a mild base. Magnesium hydroxide neutralizes the effect of excess hydrochloric acid produced in the stomach during indigestion. Hence, it helps relieve the pain. **Do you know what actually happens when acids and bases react with each other?**

When acids are mixed with bases, they neutralize or cancel each other's effect. The products formed on mixing acids with bases are salt and water.

The process of treating an acid with a base to form salt and water is called neutralization. The general reaction for neutralization can be written as follows:

A lot of heat is produced during the reaction. Hence, it is an exothermic process. Thus, we have

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

Do you know that all acids generate hydrogen (H^+) and all bases generate hydroxyl (OH^-) ions in their aqueous solutions?

H^+ ions cannot exist independently; rather they combine with water molecules (H_2O) to form **hydronium ions** (H_3O^+).

$$H^+ + H_2O \rightarrow H_3O^+$$

Thus, in an aqueous solution of acids:

$$\underset{\text{Acid}}{HX} + \underset{\text{Water}}{H_2O} \rightarrow \underset{\text{Hydronium ion}}{H_3O^+} + \underset{\text{Halide ion}}{X^-}$$

Similarly, bases also dissociate in aqueous solutions. However, not all bases dissolve in water. The bases that dissolve in water are known as alkalis**.** Thus, it can be said that '***all bases are not alkalis, but all alkalis are bases***'.

Alkalis dissolve in water and produce OH^- ions.

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

These hydroxide ions (OH^- ions) can exist freely in water or in an aqueous solution.

These hydrogen (H^+) and hydroxyl (OH^-) ions react with each other in neutralization reactions to form water.

Hence, neutralization reactions, in terms of hydrogen and hydroxide ions can be represented as:

$$H\,X + M\,OH \rightarrow MX + HOH$$

Or, $H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(l)}$

DO YOU KNOW?

A bee sting leaves methanoic acid on the skin, which causes burning, pain, and irritation. Methanoic acid is a weak acid. If a mild base such as sodium hydrogen carbonate or baking soda is applied to the stung area, then it gives relief. This is because baking soda neutralizes the effect of methanoic acid.

This activity shows that an acid nullifies the effect of the base in the solution and vice-versa. Acids react with bases to produce salt and water. The chemical equation involved in the given activity can be represented as:

$$NaOH_{(aq)} + HCl_{(dil)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$$

Adding water to acidic or alkaline solutions decreases the concentration of H^+ and OH^- ions per unit volume. This process of decreasing the concentration of H^+ and OH^- ions per unit volume is known as **dilution.**

The process of dissolving an acid or a base in water is an exothermic process. If water is added directly to the concentrated acid, then the heat generated may cause burning. Hence, acids should always be added slowly to water with constant stirring.

Strengths of Acids and Bases

Acids and bases can be distinguished from each other with the help of acid-base indicators such as litmus. Litmus is a natural indicator, which can be used to distinguish between an acid and a base. Acids change the colour of blue litmus paper to red, while bases change the colour of red litmus paper to blue.

Do you know that the strength of all acids is not equal?

You must have observed how sulphuric acid is stored in a school laboratory. In all probability, you would notice that there is a bottle labelled as concentrated sulphuric acid and another labelled as dilute sulphuric acid. **What does this mean? Why is the same acid stored in two different bottles?**

There are a large number of chemicals that act as acids or bases. However, the strength of all these acids is not equal. A given acid may be stronger than some acids and weaker than others. For example, sulphuric acid is a stronger acid than acetic acid, which is a very weak acid.

Similarly, the strength of all bases is also not equal. For example, sodium hydroxide is a strong base, whereas magnesium hydroxide is a weak base.

The strength of an acid in a solution is determined by the concentration of H^+ ions present in the solution. An increase in the concentration of H^+ ions increases the strength of an acid.

Similarly, an increase in the concentration of OH^- ions increases the strength of a base.

Now, we know that different acids and bases have different strengths.

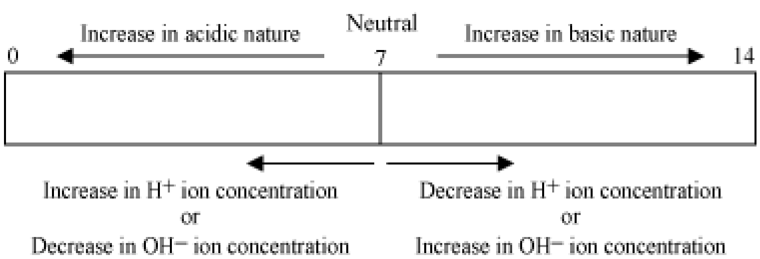
Can the relative strength of an acid be determined?

Or, Is there a way to find out whether a given acid is weaker or stronger than other acids?

pH is the measure of the acidity or alkalinity of a solution. The term pH stands for **'Potential of Hydrogen'**. The pH scale varies from 0 to 14. A pH value from 0 to 6.9 represents acidic solutions, while a pH value from 7.1 to 14 represents basic solutions. A pH value of 7 indicates that a solution is neither acidic nor basic i.e. it is neutral.

Acidity is the measure of H^+ ions and alkalinity is the measure of OH^- ions in an aqueous solution. If the pH value of an aqueous solution increases, then it represents an increase in the concentration of OH^- ions. When the pH value decreases, it represents an increase in H^+ ion concentration. Thus, we can say that the higher the H^+ ion concentration, the lower is the pH value.

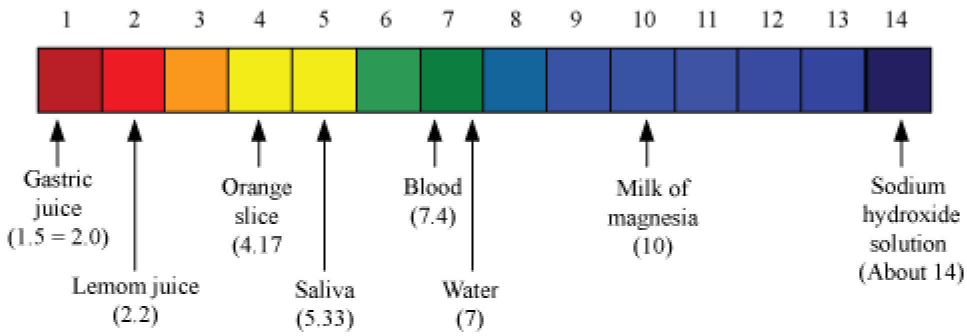
Acids which give rise to more H^+ ions are said to be strong acids, while acids that give rise to less H^+ ions are said to be weak acids. Hence, hydrochloric acid, which gives rise to more H^+ ions, is a strong acid. On the other hand, acetic acid having the same concentration as that of hydrochloric acid is a weak acid, as it gives rise to less H^+ ions. The figure given below represents the variation of pH with a change in the concentration of H^+ and OH^- ions.



$[H_3O^+]$ in aquous solution (In molarity)	**pH= $-\log_{10} [H_3O^+]$**	**pH of aquous solution**
10^{-4}	pH= $-\log 10^{-4}$ = 4 log 10= 4	4
10^{-3}	pH= $-\log 10^{-3}$ = 3 log 10= 3	3
10^{-2}	pH= $-\log 10^{-2}$ = 2 log 10= 2	2
10^{-1}	pH= $-\log 10^{-1}$ = 1 log 10= 1	1

pH of aquous acidic solutions

In laboratories, we use a pH paper or universal indicator to measure the pH. This gives an approximate measure of the pH. The pH values of some common substances are indicated in the pH paper as shown in the following figure.



$[H_3O^+]$ in aquous solution (In molarity)	**pH= $-\log_{10} [H_3O^+]$**	**pOH of aquous solution**	**pH of aquous solution**
10^{-4}	pH= $-\log 10^{-6}$ = 6 log 10= 6	6	8
10^{-3}	pH= $-\log 10^{-5}$ = 5 log 10= 5	5	9
10^{-2}	pH= $-\log 10^{-4}$ = 4 log 10= 4	4	10
10^{-1}	pH= $-\log 10^{-3}$ = 3 log 10= 3	3	11

pH of aquous basic solutions

Chemical properties of salts

- **Reaction of salt with acid:**

Salt + Acid → other salt + acid

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

- **Reaction of salt with base:**

Salt + Base → other salt + base

$Na_2SO_4 + Ba(OH)_2 \rightarrow\rightarrow BaSO_4 + 2\ NaOH$

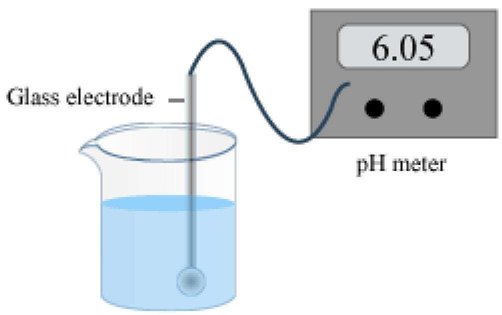
- **Reaction of salt with another salt:**

  Salt + other salt New salt + New salt

  $AgNO_3 + NaCl \rightarrow \rightarrow AgCl + NaNO_3$

Let Us Explore:

pH can be accurately detected by using a pH meter. A typical pH meter consists of a glass electrode connected to an electronic meter that measures and displays the pH readings.



Importance Of pH In Everyday Life

Do you know why it is advised to clean your mouth after consuming food?

Acids are produced in the mouth due to the degradation of sugar and food particles by certain bacteria. As a result, the pH of mouth is lowered.

pH is the measure of the acidity or alkalinity of a solution. The pH scale varies from 0 to 14. A pH value from 0 to 6.9 represents an acidic solution, whereas a pH value from 7.1 to 14 represents a basic solution. A pH value of 7 represents neutral solutions.

Tooth enamel, which is made of calcium phosphate, is sensitive to pH.It does not dissolve in water (neutral pH), but gets corroded when pH in the mouth is below 5.5.
Hence, tooth decay starts when the pH of mouth is lower than 5.5.

Do You Know:

pH change as the cause of tooth decay:

Toothpastes used by us for cleaning our teeth are generally basic in nature. Hence, it can neutralize excess acid present in the mouth and prevent tooth decay.

Let us study the **role of pH in our daily life**.

All living organisms are pH sensitive and can survive only in a narrow range of pH.

Most reactions in the human body take place in a pH range of 7.0 to 7.8. A change in the pH value inside the body can alter the biochemical reactions and prove fatal.

If the pH of rain water is less than 5.6, it is called **acid rain**. Acid rain contains mainly nitric and sulphuric acids, which are formed by the dissolution of nitrogen oxides and sulphur dioxide (respectively) in the atmosphere. When water from acid rain flows into the rivers, it results in a decrease in the pH value of river water. This decrease in the pH makes the survival of aquatic life very difficult.

Thus, acid rain causes extensive harm to soil, water resources, forests, and human health.

pH in our digestive system:
We know that our stomach produces gastric juice during digestion. Gastric juice contains hydrochloric acid, which helps in the digestion of food without harming the stomach. When the stomach produces an excess of acid, it causes irritation and pain and results in indigestion.

Gastric juice in our stomach has a pH value that falls in the range of 1.5 − 2.0.

Indigestion can be treated by taking antacids. Magnesium hydroxide called milk of magnesia is a mild base. It is used as an antacid, and can be used to neutralize the effect of excess acid in the stomach and cure indigestion.

Do You Know:

Sodium hydrogen carbonate, commonly known as baking soda, is also used as an antacid to neutralize stomach acidity. When sodium hydrogen carbonate is taken orally, it reacts with excess hydrochloric acid present in the stomach, and reduces its strength by neutralizing its effect.

Self defence by animals and plants through chemical warfare:
Baking soda is also used to neutralize the effect of a bee sting. A bee sting leaves methanoic acid inside our body, which causes pain and irritation. Thus, baking soda neutralizes the effect of methanoic acid.

Plants also require a specific value of pH for healthy growth. For example, there are a few plants that require a pH of 4.5 to 5.5. Such plants are called **acid loving plants.** Some evergreen shrubs and bushes are acid loving plants.

Plants are sensitive to pH changes:
Soil pH and plant growth:
pH of soil,which is required for healthy growth of plants can be easily measured. **Do you know how?**

To measure the pH of soil, take 2g of soil to be measured in a test tube. Add 5 mL water to it and shake the contents for some time. Now, filter the contents of the test tube and collect the filtrate in another test tube. You can measure the pH of the filtrate using a universal indicator.

Chemistry in Daily Life

Common salt is an important dietary substance and is essential for life. Common salt is chemically known as sodium chloride. An important method for obtaining common salt is by the evaporation of sea water. Seawater contains many salts dissolved in it. Sodium chloride is separated from this mixture of salts.

Salts can also be prepared by the process of neutralization reactions. For example, sodium chloride (NaCl) can be prepared by reacting hydrochloric acid (HCl) and sodium hydroxide (NaOH).

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

Potassium sulphate, sodium sulphate, calcium sulphate, magnesium sulphate, copper sulphate, sodium chloride, sodium nitrate, sodium carbonate, and ammonium chloride are other examples of salts.

Do you know which acids and bases are used to obtain these salts? First, let us try to write the chemical formulae of each of these salts. The given table shows the chemical formula of each salt with their acidic and basic components.

Salt	**Chemical formula**	**Acidic component**	**Basic component**
Potassium sulphate	K_2SO_4	SO_4^{2-}	K^+
Sodium sulphate	Na_2SO_4	SO_4^{2-}	Na^+
Calcium sulphate	$CaSO_4$	SO_4^{2-}	Ca^{2+}
Magnesium sulphate	$MgSO_4$	SO_4^{2-}	Mg^{2+}
Copper sulphate	$CuSO_4$	SO_4^{2-}	Cu^{2+}

Sodium chloride	$NaCl$	Cl^-	Na^+
Sodium nitrate	$NaNO_3$	NO_3^-	Na^+
Sodium carbonate	Na_2CO_3	CO_3^{2-}	Na^+
Ammonium chloride	NH_4Cl	Cl^-	NH_4^+

Salts having the same positive or negative radicals are said to be belonging to the same family. Some families are discussed below:

Family I (Sulphate salts):

This family contains SO_4^{2-} group as a common group. Potassium sulphate, sodium sulphate, calcium sulphate, magnesium sulphate, and copper sulphate are grouped in this family.

Family II (Chloride salts):

This family contains Cl^- group as the common group. Sodium chloride and ammonium chloride are grouped in this family.

Family III (Sodium salts):

This family contains Na^+ group as a common group. Sodium sulphate, sodium chloride, and sodium nitrate are grouped in this family.

Do you know salts can be acidic, basic, or neutral in nature? The salts of strong acids and strong bases are neutral with a pH value of 7. On the other hand, salts of strong acids and weak bases are acidic with a pH value of less than 7, and those of strong bases and weak acids are basic in nature with a pH value of more than 7.

Common salt is a neutral salt. It is formed by the combination of a strong acid (hydrochloric acid) and a strong base (sodium hydroxide). The following activity can be performed to know more about acidic, basic, and neutral salts.

Activity 1:

A small amount of sodium chloride, potassium nitrate, aluminium chloride, zinc sulphate, copper sulphate, sodium acetate, sodium carbonate, and sodium hydrogencarbonate are collected. A few crystals of each salt are separately dissolved in 2 mL distilled water. Then, the pH of each sample solution is checked by using a pH paper.

The given table lists the observations obtained in the activity.

Salt	Chemical formula	pH
Sodium chloride	NaCl	7
Potassium nitrate	KNO_3	7
Aluminium chloride	$AlCl_3$	Less than 7
Zinc sulphate	$ZnSO_4$	Less than 7
Copper sulphate	$CuSO_4$	Less than 7
Sodium acetate	CH_3COONa	More than 7
Sodium carbonate	Na_2CO_3	More than 7
Sodium hydrogencarbonate	$NaHCO_3$	More than 7

Hence, it can be concluded that sodium chloride and potassium nitrate are neutral salts. On the other hand, aluminium chloride, zinc sulphate, and copper sulphate are acidic salts, while sodium acetate, sodium carbonate, and sodium hydrogencarbonate are basic salts.

Do you know that common salt is an important raw material for various materials of daily use? For example, common salt is used in the formation of sodium hydroxide, baking soda, bleaching powder, and washing soda.

Do You Know:

Sodium chloride was an important symbol in our struggle for freedom. The Salt Satyagrah or Mahatma Gandhi's Dandi March was a non-violent protest against the British salt tax.

Sodium hydroxide:

It is produced from an aqueous solution of sodium chloride (called Brine)**.** Electrolysis (passing of electricity through a solution) of brine results in the decomposition of sodium chloride and formation of sodium hydroxide. This process is also called **chlor-alkali** process (chlor for chlorine and alkali for NaOH). The reaction for the above process can be written as follows:

$$2NaCl(aq) + 2H_2O(l) \rightarrow 2NaOH(aq) + Cl_2(g) + H_2(g)$$

Hydrogen and chlorine gas are released at thecathode and anode respectively.

Sodium hydroxide is a very useful substance. It is used in the manufacturing of paper, soaps, detergents, and synthetic fibres. It is also useful in the manufacturing of household bleaches and dyes.

Bleaching powder:

Chlorine gas obtained from mixing a hypochlorite(HClO) bleach with an acid(HCl), in the electrolysis it is used for the manufacture of bleaching powder. Chlorine gas on reacting with dry slaked lime [$Ca(OH)_2$] produces bleaching powder ($CaOCl_2$). The chemical equation involved in the reaction can be represented as:

$$Ca(OH)_2 + Cl_2 \rightarrow CaOCl_2 + H_2O$$

Bleaching powder is used for disinfecting water to make it germ-free. It is used in the textile industry to produce cotton and linen materials. It is also used as an oxidizing agent in many chemical industries.

Baking soda:

We know that baking soda is most commonly used in the kitchen for making delicious *pakoras*. The chemical name of baking soda is sodium hydrogencarbonate ($NaHCO_3$). Baking soda is produced by using sodium chloride as one of the raw materials. The chemical equation can be represented as follows:

$$NaCl + H_2O + CO_2 + NH_3 \rightarrow \underset{\text{(Ammonium Chloride)}}{NH_4Cl} + \underset{\text{(Sodium hydrogen carbonate)}}{NaHCO_3}$$

Do You Know:

Sodium hydrogencarbonate is used as an ingredient in antacids. It is alkaline in nature. Hence, it neutralizes excess acid in the stomach and provides relief.

Sodium hydrogencarbonate is also used in soda acid fire extinguishers. It is also used for cooking and sometimes, it is added for faster cooking. The following reaction takes place when it is heated during cooking:

$$\underset{\text{(Sodium Hydrogen carbonate)}}{2NaHCO_3} \rightarrow \underset{\text{(Sodium carbonate)}}{Na_2CO_3} + H_2O + CO_2$$

Washing soda:

Washing soda is also produced from common salt. The chemical name of washing soda is hydrated sodium carbonate and its chemical formula is $Na_2CO_3.10H_2O$. It is obtained by heating sodium hydrogencarbonate.

$$\underset{\text{(Sodium Hydrogen carbonate)}}{2NaHCO_3} \rightarrow \underset{\text{(Sodium carbonate)}}{Na_2CO_3} + H_2O + CO_2$$

The re-crystallization of sodium carbonate produces washing soda.

$$Na_2CO_3 + 10H_2O \rightarrow Na_2CO_3 \cdot 10H_2O$$

Sodium carbonate is used in the manufacturing of glass, soap, and paper. It is also used for the manufacturing of borax, for removing permanent hardness of water.

Calcium carbonate:

Calcium carbonate is formed when calcium hydroxide reacts with carbon dioxide.

$$\underset{\text{Calcium Hydroxide}}{Ca(OH)2} + \underset{\text{Carbon dioxide}}{CO2} \rightarrow \underset{\text{Calcium carbonate}}{CaCO3} + H2O$$

It is used in the manufacture of cement and glasses. It is also used in the extraction of iron from its ore.

Water of Crystallization

We know that washing soda is produced by mixing water and sodium carbonate. The molecular formula of washing soda is $Na_2CO_3.10H_2O$.

Sodium carbonate is obtained by heating sodium hydrogencarbonate.

$$\underset{\text{(Sodium Hydrogen carbonate)}}{2NaHCO_3} \rightarrow \underset{\text{(Sodium carbonate)}}{Na_2CO_3} + H_2O + CO_2$$

The re-crystallization of sodium carbonate then produces washing soda.

$$Na_2CO_3 + 10H_2O \rightarrow Na_2CO_3 \cdot 10H_2O$$

Ten water molecules are present in the formula of washing soda. These water molecules are called **water of crystallization.**

Water of crystallization refers to a fixed number of water molecules present in one formula unit of salt.

The following experiment will help in understanding the concept of water of crystallization.

Aim: To prepare crystals of copper sulphate ($CuSO_4$)

Material required: Beaker, distilled water, copper sulphate ($CuSO_4$) crystals, glass rod, thread, watch glass

Theory: Water of crystallization imparts the characteristic blue colour to copper sulphate ($CuSO_4$) crystals. These crystals are obtained by the process of *seeding*. In this process crystallization is induced with the help of small crystal of pure hydrated copper sulphate ($CuSO_4.5H_2O$) which is added in the saturated copper sulphate solution.

Procedure:

1. Take a beaker and prepare a saturated solution of copper sulphate ($CuSO_4$) at 80^o C and filter the solution to remove any undissolved impurity.
2. Cover the filtrate with watch glass.
3. Cool down the filtrate and leave it undisturbed for 24 hours.
4. Some crystals of copper sulphate ($CuSO_4.5H_2O$) will be formed at the bottom of the beaker. Collect a few of them.
5. Suspend one of the well formed small crystal in the saturated solution by tying to a glass rod using a thread.
6. Again cover the beaker with watch glass to avoid dust entering the solution.
7. Leave it undisturbed.

Observation: The suspended crystal grows in size with each passing day.

Water of crystallization is the fixed number of water molecules present in one formula unit of salt.

It is in chemical combination with a crystal
It is necessary for the maintenance of crystalline properties of the crystal
It can be removed by sufficient heat

The following experiment shows the effect of heat on solids that do not contain water of crystallisation.

Aim: To show effect of heat on solids that do not contain water of crystallisation.

Material required: Test tube, burner, potassium nitrate (KNO_3)

Theory: Not all crystalline solids contain water of crystallisation. These solids when heated decompose to form new compounds.

Procedure:

1. Take some potassium nitrate crystals in a test tube.
2. Heat the tube gently.

Observation: The crystals form a colourless solution giving off a gas, that bursts the glowing splinter. It signifies that oxygen is being involved. In the end, a pale yellow residue is left in the test tube.

$$\underset{\text{Potassium nitrate}}{2\ KNO_3} \xrightarrow{\Delta} \underset{\text{Potassium nitrite}}{2\ KNO_2} + O_2$$

Hydrated Substances

Those substances which contain water of crystallization like hydrated copper sulphate ($CuSO_4.5H_2O$), are called hydrated substances. The water of crystallisation gives their crystals shape and in some cases colour.

Gypsum is another salt that possesses the water of crystallization. It has a chemical formula of $CaSO_4.2H_2O$. It is also known as hydrated calcium sulphate.

When hydrated calcium sulphate ($CaSO_4.2H_2O$) or gypsum is heated at 373K, it loses its water molecules and forms calcium sulphate hemihydrate ($CaSO_4.\frac{1}{2}H_2O$). **This hemihydrate form of calcium sulphate is known as Plaster of Paris.** It is in the form of a white powder.

When the powder of Plaster of Paris is mixed with water, it becomes hard and solid gypsum. Plaster of Paris is generally used to support fractured bones in their correct positions.

$$\underset{\text{(Plaster of Paris)}}{CaSO_4.\frac{1}{2}H_2O} + 1\frac{1}{2}\ H_2O \rightarrow \underset{\text{(Gypsum)}}{CaSO_4.2H_2O}$$

In $CaSO_4.\frac{1}{2}H_2O$, only half a water molecule is shown as the water of crystallization because two formula unit of $CaSO_4$ share one molecule of water.

Plaster of Paris is used for making toys, materials for decoration, and for making smooth surfaces.

Determination of Water of Crystallization

Heat a known weight of a hydrated substance to a temperature above 100^o C. Weigh the residue. Repeat these two steps, till the weight of the residue becomes constant.
Use the following formula to obtain the percentage of water of crystallization in a link:

Initial weight of the hydrated substance = *x* g
Final constant weight of the substance after heating = *y* g

$$\% \text{ of water of crystallization } = \frac{x-y}{x} \times 100$$

Anhydrous Substances

Those substances which do not contain any water of crystallization or the substances from which the water of crystallization have been removed like sodium chloride (NaCl) are called anhydrous substances.
The water of crystallization can be removed by using any of the following methods:

- Direct heating of the hydrated substance
- Heating the hydrated substance in dry and hot air
- Heating the hydrated substance under vacuum
- Using dehydrating/desiccating agents

Drying Agents

The substances that absorb moisture from other substances without undergoing a chemical reaction with them are called drying agents or desiccants or desiccating agents. Examples of drying agents are anhydrous calcium chloride, anhydrous zinc chloride etc. Most of the hygroscopic substances are desiccating agents like concentrated sulphuric acid, silica gel etc.

The following table illustrates the techniques used to dry certain substances.

Substance	Drying technique
Gases	By passing through concentrated sulphuric acid Used for drying acidic gases like HCl gas

	By passing through a drying tower or a U-tube containing anhydrous sodium sulphate By passing through a drying bulb containing anhydrous calcium chloride
Liquids	By keeping them over anhydrous sodium sulphate or calcium chloride for over a night After this, solid is removed by filtration.
Solids	By placing them in a desiccator (air-tight vessel with a drying agent like calcium chloride spread at the bottom)

Dehydrating Agents

The substances that can remove chemically bounded water from compounds are called dehydrating agents. Concentrated sulphuric acid is a strong dehydrating agent. It can remove water molecules from hydrated copper sulphate ($CuSO_4.5H_2O$).

$$\underset{\text{(blue)}}{CuSO_4.5H_2O} \xrightarrow{Conc.\ H_2SO_4} \underset{\text{(white)}}{CuSO_4} + 5H_2O$$

The following table explains the differences between drying agents and dehydrating agents.

Drying Agents	Dehydrating Agents
Removes moisture from other substances	Removes chemically bounded water molecules from substances
Performs a physical change in the substance	Performs a chemical change in the substance