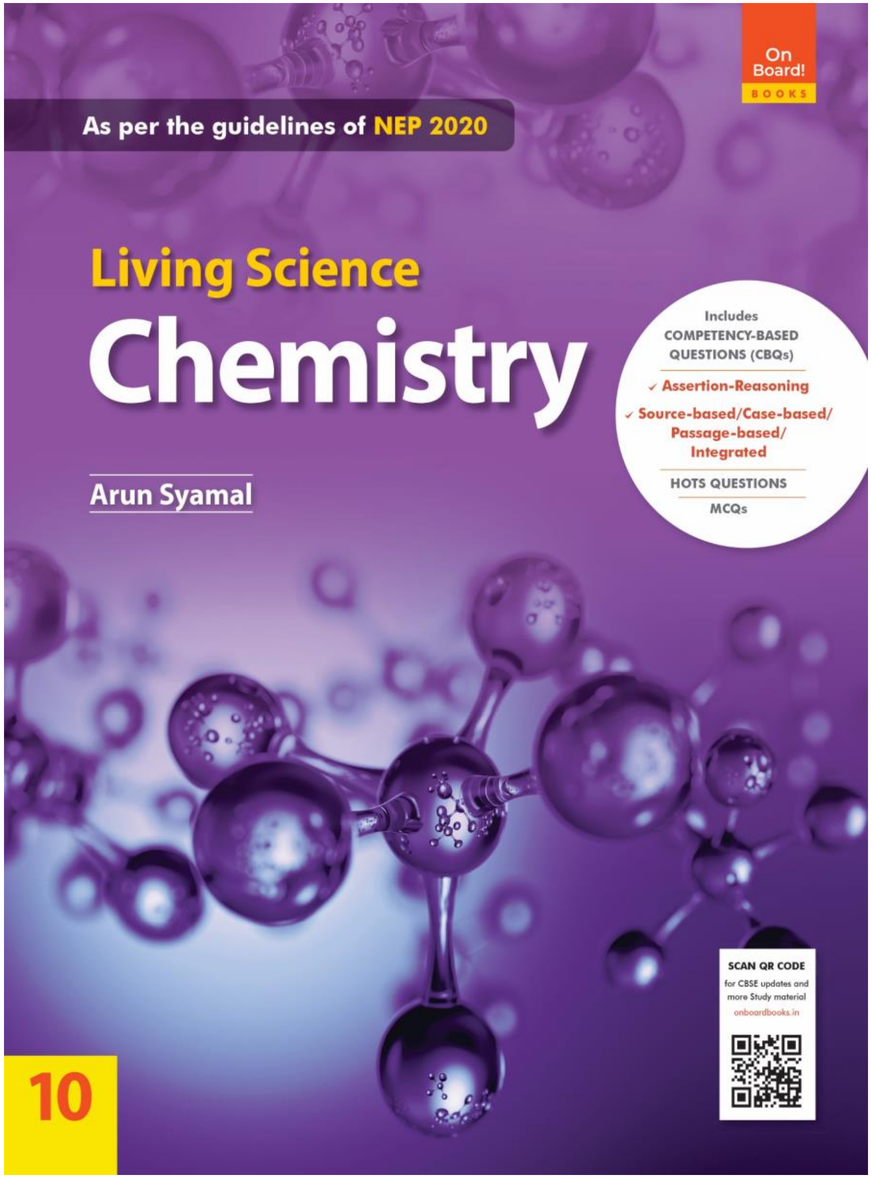
On Board!

BOOKS

CBSE Living Science CHEMISTRY



CBSE LIVING SCIENCE CHEMISTRY

CLASS 10

Chapter 2

Acids, Bases and Salts

Learning Objectives

- ❖ Indicators
- ❖ Acids, bases and salts:
  - General properties
  - Examples
  - Common uses
- ❖ *p*H scale and universal indicator
- ❖ Salts

In our daily life we come across many acidic substances such as citrus fruits, tomato, vinegar, tamarind, black coffee, cleansing agents used in toilets, eye-wash solutions, medicines such as aspirin, folic acid,etc. There are some other substances known as alkalis and bases, whose properties are different and opposite to that of acids.

All the chemical compounds can be classified on the basis of their chemical properties as acids, bases and salts. Acids are sour in taste while bases are bitter in taste. Acids and bases can be distinguished with the help of indicators.

A Swedish chemist, Svante Arrhenius defined acids and bases as follows:
An acid is a substance which produces hydrogen ions when dissolved in water.
A base is a substance which produces hydroxyl ions when dissolved in water.

INDICATORS

An indicator or an acid-base indicator is a substance which indicates the presence of an acid or a base. These substances show a characteristic colour or odour in the presence of an acidic and a basic solution. There are three types of indicators – natural, synthetic and olfactory.

Natural Indicators

These indicators are found in nature. Litmus, which is a purple coloured dye obtained from lichen plant is a commonly used natural indicator in the laboratory. It can be used in the form of solution or in the form of litmus paper. In the neutral solution, it has purple colour. In the acidic solution, it turns red whereas in the basic solution, it turns blue. Litmus papers are available in two colours, i.e., red and blue. An acid turns blue litmus to red and a base turns red litmus to blue.

Other natural indicators like turmeric powder, red cabbage extract and extracts from coloured petals of flowers like Petunia, Hydrangea and Geranium also show characteristic colour in the presence of acidic and basic substances. Red cabbage extracts show red colour in acidic medium and green in basic medium. In acidic medium turmeric shows yellow colour and in basic medium it shows reddish-brown colour.

Synthetic Indicators

These indicators are prepared in the laboratory. Two common examples of synthetic indicators are phenolphthalein and methyl orange. Phenolphthalein turns pink in a basic solution and remains colourless in an acidic solution while methyl orange turns yellow in a basic solution and red in acidic solution.

Olfactory Indicators

Olfactory indicators help to identify whether a given solution is acidic or basic by changing their odour instead of colour. Examples are onion extract, garlic extract, clove oil, vanilla essence, etc. Onion extract has a characteristic odour in acidic medium and this odour is completely destroyed in the basic medium. The sweet pleasant odour of vanilla extract is retained in the acidic solution but is completely lost in the basic solution.

ACIDS

Physical properties of acids

1. Acids are sour in taste.
2. Acids such as HCl, H_2SO_4 and HNO_3 are highly corrosive.

3. Acids can be present in the liquid or solid state.

Solid, liquid, volatile and non-volatile acids

Acid	Formula	State/Property
Boric acid	H_3BO_3	Solid
Oxalic acid	$(COOH)_2$	Solid
Phosphoric acid	H_3PO_4	Solid/Non-volatile
Acetic acid	CH_3COOH	Liquid
Formic acid	$HCOOH$	Liquid
Hydrochloric acid	HCl	Liquid/Volatile
Nitric acid	HNO_3	Liquid/Volatile
Sulphuric acid	H_2SO_4	Liquid/Non-volatile
Carbonic acid	H_2CO_3	Liquid/Volatile
Sulphurous acid	H_2SO_3	Liquid/Volatile

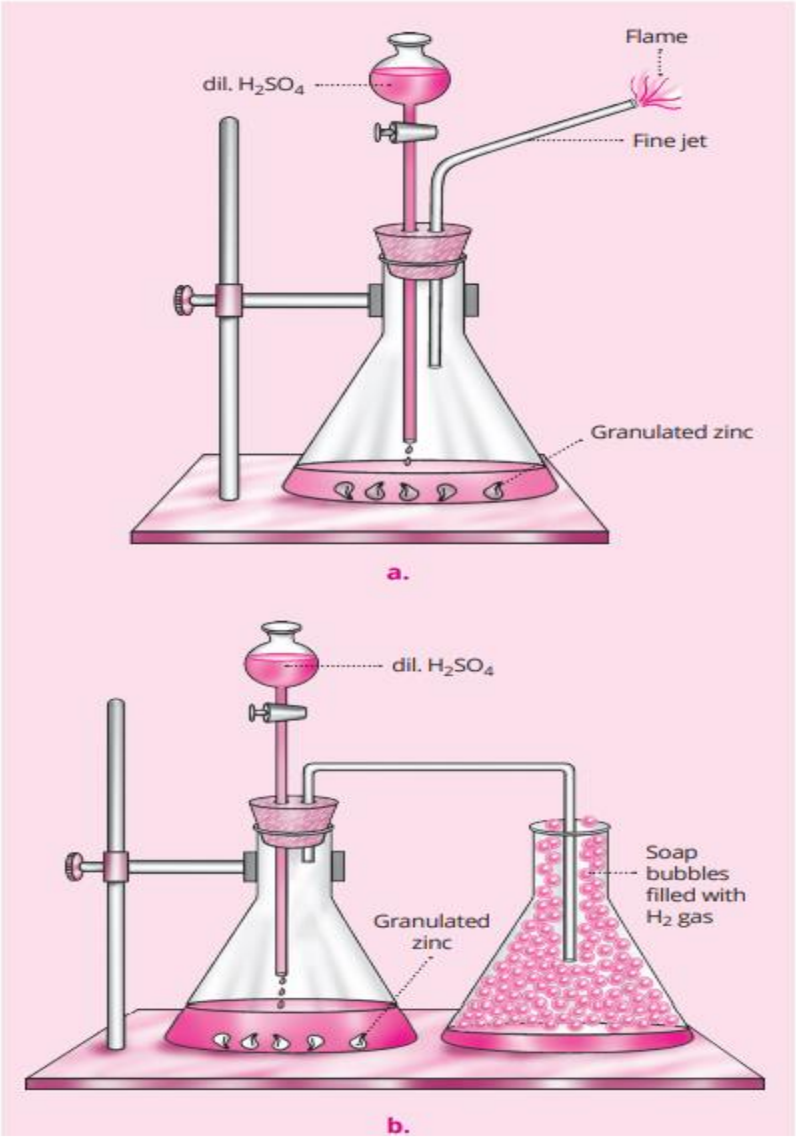
4. Aqueous solutions of acids conduct electricity.

Chemical properties of acids

1. Reaction with metals

Metals which are more reactive than hydrogen react with acids to liberate hydrogen gas and corresponding salts. The hydrogen gas evolved burns with a pop sound when a burning splinter is brought near to it.

For example,
$Zn + 2HCl \rightarrow ZnCl_2 + H_2(\uparrow)$
$Mg + 2HCl \rightarrow MgCl_2 + H_2(\uparrow)$



Evolution of hydrogen gas by the reaction of dil. H_2SO_4 with zinc:
a. testing hydrogen gas by burning
b. action of hydrogen gas on soap solution

2. Reaction With Metal Carbonates and Metal Hydrogencarbonates

Acids on reaction with metal carbonates and metal hydrogencarbonates give the corresponding salts, carbon dioxide gas and water. For example,

$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2(\uparrow)$

$Na_2CO_3 + H_2SO_4 \rightarrow Na_2SO_4 + H_2O + CO_2(\uparrow)$

When the carbon dioxide gas evolved is passed through lime water, it turns milky due to the formation of a white precipitate of calcium carbonate.

$Ca(OH)_2(aq) + CO_2\ (g) \rightarrow CaCO_3\ (s) + H_2O\ (l)$

Calcium hydroxide (lime water)	Carbon dioxide	Calcium carbonate (white ppt)	water

However, if excess of carbon dioxide gas is passed through lime water, the white precipitate of calcium carbonate dissolves and the solution becomes clear due to the formation of soluble calcium hydrogen carbonate.

$CaCO_3\ (s) + H_2O\ (l) + CO_2\ (g) \rightarrow Ca(HCO_3)_2\ (aq)$

Calcium Carbonate	Water	Carbon dioxide	Calcium hydrogen carbonate

3. Reaction with bases

Acids form salt and water on reaction with bases. The process of formation of salt and water when an acid reacts with a base is called neutralisation. For example,

$NaOH + HCl \rightarrow NaCl + H_2O$

Base Acid Salt Water

4. Reaction with metallic oxides

Acids react with metal oxides to form salt and water. For example,

$CaO(s) + 2HCl \rightarrow CaCl_2 + H_2O$

$CuO(s) + 2HCl \rightarrow CuCl_2 + H_2O$

This shows that metallic oxides are basic in nature.

Chemical nature of acids

According to Arrhenius, an acid is a substance which produces hydrogen ions (H^{+}) when dissolved in water. The process in which the ions are formed from any substance is called ionization. Acids such as HCl, H_2SO_4, HNO_3, H_2CO_3, H_3PO_4 ,CH_3COOH, etc produce hydrogen ions in aqueous solutions. This indicates that hydrogen ion (H^+) is common in all acids.

In aqueous solution, a hydrogen ion always combines with a molecule of water to form a hydronium ion, H_3O^+. All acids produce hydronium ion H_3O^+ when dissolved in water. The presence of hydronium ion gives an acidic solution its acidic properties.

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

Thus, when hydrochloric acid dissolves in water, it undergoes ionization as follows:

$HCl\ (aq) + H_2O\ (l) \rightarrow H_3O^+\ (aq) + Cl^-\ (aq)$

All acids produce $H^+(aq)$ ions in aqueous solution, which is responsible for their acidic behaviour. Due to the presence of ions in solution, the aqueous solution of all the acids conduct electricity.

On the other hand, hydrogen containing compounds such as alcohol (C_2H_5OH) and glucose ($C_6H_{12}O_6$) do not conduct electricity in aqueous solution as they do not undergo ionisation in aqueous solution to produce hydrogen ions or any other ions. Hence, the aqueous solutions of alcohol and glucose do not show acidic character even though they contain hydrogen atoms.

Classification of acids

On the basis of strength of acids, they are classified as:

1. Strong acids
2. Weak acids

Strong acids

Acids which undergo ionisation to a large extent in a solution, are called strong acids. Hydrochloric acid (HCl), sulphuric acid (H_2SO_4), nitric acid (HNO_3) are some examples of strong acids. These strong acids produce a high concentration of hydrogen ions (H^+) or hydronium ions (H_3O^+) in solution. They dissociate completely in aqueous solutions. For example, a solution of sulphuric acid in water is a good conductor of electricity because it dissociates completely in solution.

Weak acids

Acids which undergo ionisation to a small extent only, are called weak acids. Phosphoric acid (H_3PO_4), nitrous acid (HNO_2), carbonic acid (H_2CO_3), ethanoic acid or acetic acid (CH_3COOH), methanoic acid or formic acid (HCOOH), citric acid and oxalic acid ($C_2H_2O_4$) are some examples of weak acids. A solution of ethanoic acid in water is a poor conductor of electricity because very few molecules of ethanoic acid undergo ionisation in aqueous solution.

On the basis of the concentration of acids in solution, they are classified as:
1. Concentrated acids
2. Dilute acids

Concentrated acids

A concentrated acid is almost a pure acid with very little water present in it.

Dilute acids

A dilute acid has more quantity of water and less quantity of acid. Mixing of an acid with water leads to the decrease in the concentration of hydronium ion (H_3O^+) per unit volume. Such a process is called dilution and the acid is said to be diluted.

Dilution of a concentrated acid is a highly exothermic process. A large amount of heat is evolved when concentrated acid is mixed with water. Concentrated acid should never be diluted by adding water to the acid. The heat evolved is so large that it will instantly turn water into steam resulting in splashing of acid and may cause severe acid burns. Dilution of concentrated acid is always done by adding the acid gradually to water. When a concentrated acid is added to water to make a dilute solution, small amount of heat is gradually evolved which is absorbed by large volume of water.

On the basis of sources, acids are classified into **organic acids** and **inorganic acids**.

Organic acids: Acids which are obtained from natural organic matter such as plants and animals are called organic acids. All organic acids contain carbon as one of the elements. For example, acetic acid (CH_3COOH), oxalic acid [$(COOH)_2$], etc. All organic acids are weak acids and they do not ionise completely in aqueous solution. Their aqueous solutions contain both ions as well as molecules.

Acid	Source	Acid	Source
Oxalic acid	Spinach, Tomato	Amino acids	Proteins
Lactic acid	Sour milk	Ascorbic acid	Orange, banana
Citric acid	Lemon, orange	Tartaric acid	Tamarind
Formic acid	Sting of ants and bees, nettle sting	Butyric acid	Rancid butter
Succinic acid	Grape	Uric acid	Urine
Acetic acid	Vinegar	Stearic acid	Rancid oils and fats
Malic acid	Apple		

Some organic acids

Inorganic acids: Acids which are obtained from minerals are called inorganic acids. For example, hydrochloric acid (HCl), sulphuric acid (H_2SO_4), nitric acid (HNO_3), phosphoric acid (H_3PO_4), etc. are mineral acids. Inorganic acids are strong acids and they dissociate completely in aqueous solutions. Their solutions contain only ions.

Basicity of an acid is the number of hydrogen ions that can be produced by the ionisation of one molecule of the acid in its aqueous solution. On the basis of basicity, acids can be classified into **monobasic acids**, **dibasic acids**, and **tribasic acids**.

Monobasic acids: An acid which produces one hydrogen or hydronium ion by the ionisation of one molecule of the acid, is called a monobasic acid or monoprotic acid. For example, HCl, HBr, HI, HNO_3 and CH_3COOH are monobasic acids.

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

Dibasic acids: An acid which produces two hydrogen or hydronium ions by the ionisation of one molecule of the acid, is called a dibasic acid or diprotic acid. For example, H_2CO_3, H_2SO_4, etc. They ionise in two steps as follows:

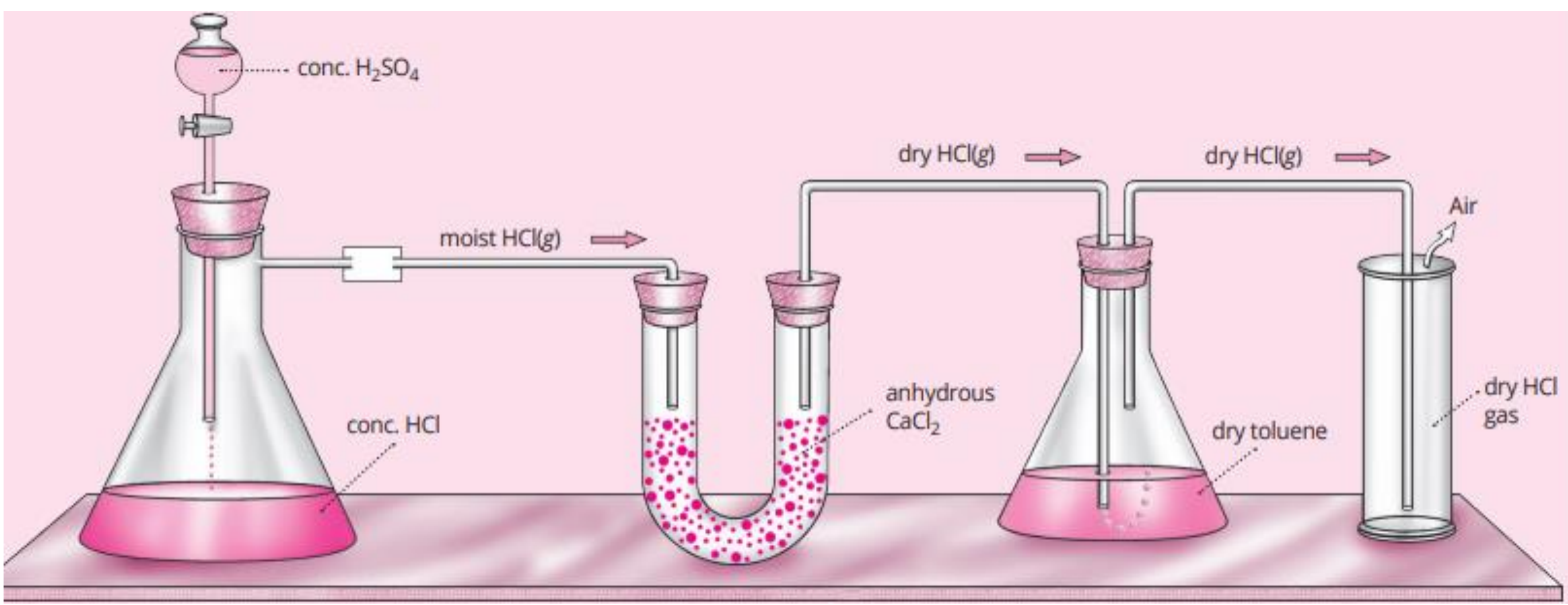
$$H_2CO_3 + H_2O \longrightarrow H_3O^+ + HCO_3^-$$
$$HCO_3^- + H_2O \longrightarrow H_3O^+ + CO_3^{2-}$$

Tribasic acids: An acid which produces three hydrogen or hydronium ions by the ionisation of one molecule of the acid, is called a tribasic acid or triprotic acid. For example, H_3PO_3, H_3PO_4, etc. They ionise in three steps as shown below.

$$H_3PO_4 + H_2O \longrightarrow H_3O^+ + H_2PO_4^-$$
$$H_2PO_4^- + H_2O \longrightarrow H_3O^+ + HPO_4^{2-}$$
$$HPO_4^{2-} + H_2O \longrightarrow H_3O^+ + PO_4^{3-}$$

Preparing dry hydrogen chloride gas and testing the acidic nature of dry and moist HCl gas

Take 100 mL of conc. HCl in a 500 mL filtering flask fitted with a dropping funnel containing conc. H_2SO_4. Add some conc. H_2SO_4 from the dropping funnel to the filtering flask. As soon as conc. HCl comes in contact with conc. H_2SO_4, the hydrogen chloride gas begins to evolve which comes out of the side tube of the filtering flask. Pass the evolved gas through a drying tube containing anhydrous $CaCl_2$. Then pass the dry gas through dry toluene kept in a conical flask. A part of HCl gas gets soluble in toluene. Collect the dry HCl gas in a dry gas jar by the upward displacement of air. Hold a dry blue litmus paper over the gas jar. It is observed that HCl gas does not change the colour of blue litmus paper. Hold a moist blue litmus paper over the gas jar. It is observed that the colour of moist blue litmus paper changes to red. Put a drop of solution of HCl gas in toluene on a dry blue litmus paper. It is observed that the solution of HCl gas intoluene does not change the colour of blue litmus paper.



Acids show acidic behaviour in the presence of water

When a dry blue litmus paper comes in contact with dry HCl gas, there occurs no change of colour. But when a moist blue litmus paper comes in contact with dry HCl gas, the colour of blue litmus paper changes to red.

This indicates that ionisation of HCl gas to H^+ ions does not take place in absence of water. Water is essential for ionisation of acid. Therefore, ionisation of HCl gas to produce $H^+(aq)$ ions occurs when dry HCl gas comes in contact with moist blue litmus paper. These $H^+(aq)$ ions are responsible for the change of colour of moist blue litmus paper to red.

$$HCl(g) \xrightarrow{\text{(moist blue litmus paper)}} H^+(aq) + Cl^-(aq)$$

BASES

Physical properties of bases

1. Bases have a bitter taste.
2. The caustic alkalis such as NaOH and KOH are highly corrosive and they react with fats and oils in the skin.
3. Alkalis are soapy to feel.

4. **Conduction of electricity:** Similar to acids, the solutions of bases in water also conduct electricity.

Chemical properties of bases

1. Reaction with metals

Some metals react with bases to form salt and hydrogen gas. For example,

$$\underset{\text{Sodium hydroxide}}{2NaOH} + \underset{\text{Zinc metal}}{Zn} \rightarrow \underset{\text{Sodium zincate}}{Na_2ZnO_2} + \underset{\text{Hydrogen gas}}{H_2(\uparrow)}$$

2. Reaction with acids

Bases form salt and water when treated with acids. For example,

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

$$Ca(OH)_2 + H_2SO_4 \rightarrow CaSO_4 + 2H_2O$$

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

3. Reaction with non-metallic oxides

Bases reacts with non-metallic oxides to form salt and water. For example,

$$\underset{\substack{\text{Carbon}\\\text{dioxide}\\\text{(non-metallic}\\\text{oxide)}}}{CO_2} + \underset{\substack{\text{Calcium hydroxide}\\\text{(base)}}}{Ca(OH)_2} \rightarrow \underset{\substack{\text{Calcium}\\\text{carbonate}\\\text{(salt)}}}{CaCO_3} + \underset{\text{Water}}{H_2O}$$

This shows that non-metallic oxides are acidic in nature.

Chemical nature of bases

According to Arrhenius, a base (alkali) is a substance which produces hydroxide ions (OH^-) when dissolved in water. This indicates that the hydroxide ion (OH^-) is common in all bases and it is responsible for their basic behaviour. All bases show basic behaviour only in the presence of water.

The ionisation of some bases in aqueous solution are represented below:

$$NH_4OH(aq) \rightarrow NH_4^+(aq) + OH^-(aq)$$

$$Ca(OH)_2(aq) \rightarrow Ca^{2+}(aq) + 2OH^-(aq)$$

$$Al(OH)_3(aq) \rightarrow Al^{3+}(aq) + 3OH^-(aq)$$

Similar to the acids, the aqueous solution of bases also conduct electricity due to the presence of hydroxide ions.
Some compounds such as ethyl alcohol (C_2H_5OH) contains the –OH group but they do not get ionized in aqueous solution to form OH^- ions. Hence, they are not termed as base. On the other hand, ammonia is alkaline in nature because it dissolves in water to form ammonium hydroxide which gives hydroxide ions (OH^-) when dissolved in water.

$$\underset{\text{Ammonia}}{NH_3} + H_2O \rightarrow \underset{\text{Ammonium hydroxide}}{NH_4OH} \rightarrow NH_4^+ + OH^-$$

Classification of bases

On the basis of their strength, bases are classified as:

1. Strong bases
2. Weak bases

Strong bases

Bases which undergo complete ionisation to produce a high concentration of hydroxide ion (OH^-) in a solution are strong bases. For example, NaOH and KOH, etc.

Weak bases

Bases which undergo partial ionization to produce a low concentration of hydroxide ion (OH^-) in a solution are weak bases. For example, $Mg(OH)_2$, $Ca(OH)_2$ and NH_4OH, etc.

Dilution of bases

When a solution of a base is diluted in water, the concentration of hydroxide ion (OH^-) per unit volumedecreases. Dilution of bases with water is a exothermic process. If bases are dissolved in water, heat is evolved and solution is found to be warmer.

Hydrogen (H^+) ions are present in both acidic and basic solution

Acids dissociates to produce hydrogen ions in solutions. When an acid is added to water, the concentration of hydrogen ion increases in solution. Therefore, acidic solution have excess of H^+ ions.

Bases ionise to produce hydroxide ions in solutions. When a base is added to water, the concentration of hydroxide (OH^-) ion increases in solution. Therefore, basic solutions have excess of hydroxide (OH^-) ions. Basic solutions also contain hydrogen (H^+) ions which come from dissociation of water. However, the concentration of hydrogen ions in basic solutions is much less than that of hydroxide ions.

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Uses of some acids and bases

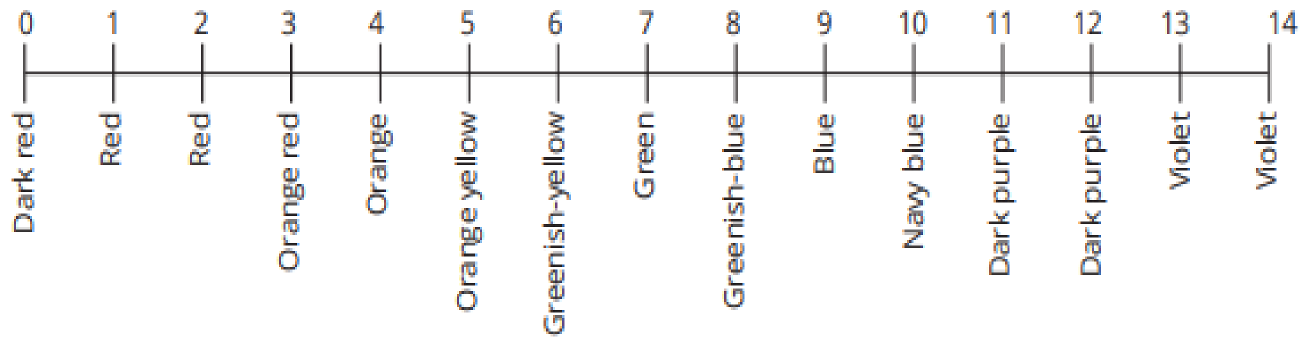
Acid	Uses	Base	Uses
1. Hydrochloric acid	Toilet cleaner, pickling of metals, stain remover, swimming pools, digestion of food and killing of bacteria in the stomach	1. Sodium hydroxide	Manufacture of soap, synthetic fibres (e.g., rayon), drain cleaner, oven cleaner, in paper industry
2. Boric acid	Eye-wash, talcum powder, dusting powder	2. Potassium hydroxide	Drain cleaner, in nickel-iron storage battery, manufacture of toilet soap, for absorbing CO_2 gas
3. Acetic acid	Cooking (in the form of vinegar), manufacture of pickles containing vinegar, food preservation, manufacture of rubber	3. Ammonium hydroxide	Grease-stain remover, dry cleaning, household cleaning
4. Tartaric acid	Baking powder	4. Calcium hydroxide	Manufacture of bleaching powder, in softening of water, whitewashing, condiments (pan), to make brick mortar, in testing of CO_2 gas
5. Carbonic acid	Carbonated beverages	5. Aluminium hydroxide	As a foaming agent in fire extinguishers
6. Oxalic acid	Ink-stain remover, rust-stain remover	6. Magnesium hydroxide	As an antacid for relief from acidity, a laxative
7. Citric acid	Food preservation, rust-stain remover, coagulation of milk to form casein, baking powder	7. Copper(II) hydroxide	As a pigment in condiments, soil alkaliser
8. Formic acid	Soft drink		
9. Benzoic acid	Food preservation, perfumes, skin ointments		
10. Nitric acid	Explosives, jewellery		

*p*H SCALE AND UNIVERSAL INDICATOR

The strength of an acid or a base depends on the number of H^+ ions or OH^- ions produced by them, respectively. Larger the number of H^+ ions produced by an acid in a solution, stronger is the acid. Similarly, larger the number of OH^- ions produced by a base in a solution, stronger is the base.

Universal Indicator

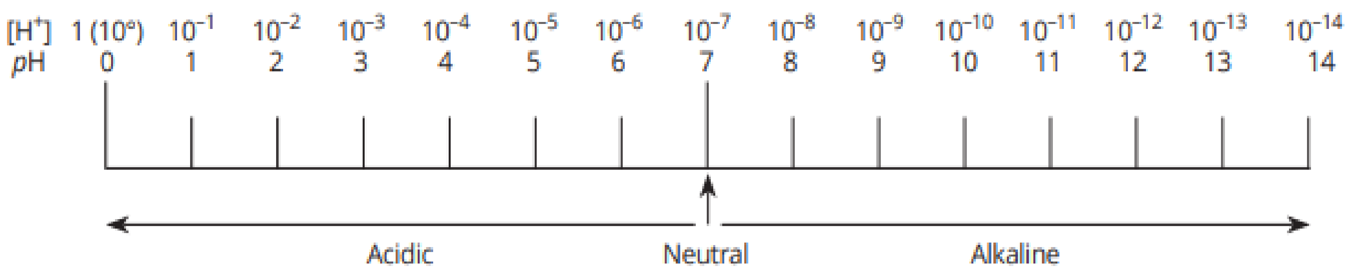
A mixture of several indicators which can show different colours at different concentrations of hydrogen ions in a solution is called a universal indicator. The *p*H of any solution can be determined using a *p*H paper. The colour changes of universal indicator at different *p*H values.



Colour changes of universal indicator at different *p*H values

*p*H: A measure of strength of acidic and basic solution

*p*H scale which indicates the hydrogen ion concentration of solutions is known as *p*H scale. Here *p*H stands for hydrogen potenz (hydrogen power). The *p*H of a solution is inversely proportional to the hydrogen ion concentration in the solution. Higher the concentration of H^+(aq) ions, the lower is the *p*H of a solution and lower the concentration of H^+(aq) ions, the higher is the *p*H of a solution. The *p*H scale is expressed by a series of positive numbers between 0 and 14. Neutral solutions have *p*H of 7. Acids have *p*H less than 7 and alkalis have *p*H more than 7. The more acidic a solution, lesser will be its *p*H. The more alkaline is a solution, higher will be its *p*H.



Relation between [H^+] (in mol L^{-1}) and *p*H in acidic and alkaline solution

Importance of *p*H in everday life

The pH plays vital roles in our daily life. This is because most biochemical reactions in our body occur at specific pH values. The functions of enzymes depend upon the specific pH values. Some important applications of pH are described below:

***p*H in our digestive system:** The *p*H of gastric juice is 1.0 – 2.0 due to the secretion of hydrochloric acid in our stomach. During indigestion, the *p*H of our gastric juice is < 1.4 due to the secretion of large amount of hydrochloric acid. This leads to irritation and pain in the stomach and heart burn.

In order to get relief from pain and acidity, we take antacids such as gelusil, milk of magnesia, etc., containing mild bases such as $Mg(OH)_2$, $Al(OH)_3$, etc. These antacids neutralise the excess hydrochloric acid and increase the *p*H of gastric juice.

***p*H dependent tooth decay:** Carbohydrates and food particles present in our mouth after eating sweet-tasting foods such as sweets and chocolates undergo bacterial decomposition and as a result organic acids such as ethanoic acid, propanoic acid, butanoic acid, lactic acid, etc. are produced. When the *p*H of our mouth is < 5.5, the tooth decay starts. Tooth enamel, which is one of the hardest substance in our body, made up of calcium hydroxyapatite (a crystalline form of calcium phosphate). These organic acids react with calcium phosphate present in tooth enamel to form soluble calcium salts and in the long run we get cavities in our teeth.

Self protection of plants and animals through chemical warfare: Many plants and animals protect themselves from their enemies by injecting painful acids and bases in the skin. When honey bee or ant stings, an acid, methanoic acid is injected in the skin. It causes pain and irritation. Rubbing a solution of a mild base like baking soda provides immediate relief. The herbaceous nettle plant protects itself by covering its jagged leaves with stinging hair. When our body comes in contact with nettle leaves, the hair are stung on our skin and we get burning pain due to the injection of methanoic acid by the hair. A traditional remedy is to rub the affected skin with the leaves of the dock plant, which usually grows in the wild around the nettles. The extract of the leaves of dock plant is alkaline in nature and the methanoic acid is neutralised when we rub our skin with the leaves of the dock plant.

Soil *p*H and plant growth: Plants grow best when the *p*H of the soil is close to 7. Soils having *p*H values in the alkaline region or highly acidic region are not favourable for growth of plants. Hence, a farmer should treat the soil of his fields with quicklime/slaked lime/chalk, if the *p*H value of the soil of his fields is in highly acidic region. In case of soils with *p*H values in the alkaline region, manure or compost can be added to the soil. These are acidic in nature which will neutralise the base and reducing the alkalinity.

SALTS

A salt is a compound formed by the neutralization reaction of an acid with a base. For example, sodium chloride (common salt, NaCl), calcium carbonate ($CaCO_3$), sodium hydrogen carbonate ($NaHCO_3$), etc.

Properties of salts

Some important properties of salts are given below:

1. Salts are generally non-volatile ionic compounds having high melting and boiling points.
2. Salts conduct electricity in aqueous solution or in molten state. Tap water containing dissolved salts which ionise in water and hence tap water conducts electricity. But distilled water does not contain any salt and hence it does not conduct electricity.
3. Salts are either crystalline or amorphous. Many salts contain water of crystallization. The fixed number of water molecules which are present in one formula unit of a salt are called water of crystallization. The water of crystallization can usually be removed from a crystalline salt by heating the salt at a temperature above 100 °C. When the crystalline salt loses its water of crystallization, it becomes amorphous.

$$\underset{\text{Washing soda (crystalline)}}{Na_2CO_3\cdot 10H_2O} \xrightarrow[-9H_2O]{373K} \underset{\text{(Amorphous)}}{Na_2CO_3\cdot H_2O}$$

$$\xrightarrow[-H_2O]{\text{above } 373K} \underset{\text{Soda ash (amorphous)}}{Na_2CO_3}$$

The water of crystallisation is often responsible for the colour and crystalline nature of a salt. For example, copper(II) sulphate pentahydrate is crystalline and blue, but anhydrous copper(II) sulphate is colourless and amorphous. Many crystalline salts do not contain water of crystallization, for example, NaCl, KCl, NH_4Cl, etc.

*p*H of salts

Although salts are formed by the neutralisation of acids with bases, not all salts are neutral. The phenomenon of the interaction of a salt with the H^+ and OH^- ions of water is called hydrolysis. Depending upon the nature of acid and base produced when a salt reacts with water, the salts are classified into the following four types:

Salts of strong acid and strong base

Salts of strong acid and strong base are neutral with a pH 7. For example, NaCl, KCl, Na_2SO_4, $NaNO_3$, KNO_3, K_2SO_4, etc.
These salts on dissolving in water produce strong acid and strong base. For example,

$$\underset{\substack{\text{Sodium}\\ \text{chloride}\\ \text{(salt)}}}{NaCl} + H_2O \rightarrow \underset{\substack{\text{Hydrochloric}\\ \text{acid}\\ \text{(strong acid)}}}{HCl} + \underset{\substack{\text{Sodium}\\ \text{hydroxide}\\ \text{(strong base)}}}{NaOH}$$

Salts of strong acid and weak base

Salts of strong acid and weak base are acidic with a pH less than 7. For example, NH_4Cl, $CuSO_4 \cdot 5H_2O$, $ZnSO_4$, $BaCl_2$, etc. These salts when dissolved in water produce a strong acid and a weak base. For example,

$$AlCl_3 + 3H_2O \rightarrow \underset{\text{Strong acid}}{3HCl} + \underset{\text{Weak base}}{Al(OH)_3}$$

Salts of weak acid and strong base

Salts of strong base and weak acid are basic with a pH more than 7. For example, Na_2CO_3, CH_3COONa, $NaHCO_3$, CH_3COOK, KCN, etc. These salts when dissolved in water produce a weak acid and a strong base. For example,

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

Salts of weak acid and weak base

A salt of a weak acid and a weak base are neutral with a pH close to 7. These salts when dissolved in water produce a weak acid and a weak base. For example,

$$\underset{\text{Ammonium acetate}}{CH_3COONH_4} + H_2O \rightarrow \underset{\text{Weak acid}}{CH_3COOH} + \underset{\text{Weak base}}{NH_4OH}$$

Families of salts

Salts having the same positive or negative radicals are said to belong to a family. For example, NaCl and $NaNO_3$ belong to the family of sodium salts. NaCl and KCl belong to the family of chloride salts.

On the basis of common acids

Sulphates: Na_2SO_4, K_2SO_4, $CaSO_4$, $MgSO_4$, $CuSO_4$

Chlorides: NaCl, NH_4Cl

Carbonates: Na_2CO_3, K_2CO_3

On the basis of common bases

Sodium salts: Na_2SO_4, NaCl, $NaNO_3$, Na_2CO_3

Potassium salts: K_2SO_4, KCl, KNO_3, K_2CO_3

Calcium salts: $CaSO_4$, $CaCl_2$

Magnesium salts: $MgSO_4$, $MgCl_2$

COMMON SALT – A RAW MATERIAL FOR CHEMICALS

Sodium chloride (common salt) is formed by the reaction of dilute sodium hydroxide (NaOH) and dilute hydrochloric acid (HCl).

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

It occurs in nature as large brown crystals due to the presence of various impurities. This natural brown salt is known as rock salt. It occurs as beds under the earth and is mined similarly as coal. The main source of sodium chloride is seawater.

It is prepared by evaporation of seawater followed by fractional crystallisation when it is separated from impurities such as KCl, $MgCl_2$, $MgSO_4$, etc.

Concentrated aqueous solution of sodium chloride is known as brine. It is used in the manufacture of various chemicals. When electric current is passed through a concentrated aqueous solution of sodium chloride (brine), sodium chloride decomposes to give sodium hydroxide which is formed in the solution near the cathode. The other products of electrolysis are chlorine gas and hydrogen gas. Chlorine gas is evolved at the anode and hydrogen gas is given off at the cathode. This process of production of sodium hydroxide from sodium chloride is called chlor-alkali process. It is so called because chlor stands for chlorine and alkali stands for sodium hydroxide.

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

The products of electrolysis of a solution of sodium chloride and their uses are given as follows:

$NaCl(aq) \xrightarrow{\text{electrolysis}}$

NaOH	**Uses:** In industries such as soap and detergent, dyes, synthetic fibres and textiles, paper, drugs, vegetable oils, petroleum refining, as a laboratory reagent, as a degreasing agent for metals.
Cl_2	**Uses:** As a bleaching agent, bactericidal, sterilisation of water in swimming pools, an industrial chemical, in the manufacture of pesticides, PVC, chlorofluorocarbons, hydrochloric acid and bleaching powder.
H_2	**Uses:** In balloons, hydrogenation of unsaturated oils, production of hydrochloric acid, ammonia, methanol, synthetic petrol, oxy-hydrogen flame, atomic hydrogen flame, as a reducing agent, as a fuel.

Products of electrolysis of sodium chloride and their uses

Bleaching powder

Bleaching powder can be represented as $CaOCl_2$ and its actual composition is quite complex. It is prepared by the action of chlorine on dry slaked lime. Chlorine obtained as a by-product in chlor-alkali process of manufacture of sodium hydroxide is used.

$$\underset{\text{Slaked lime}}{Ca(OH)_2(s)} + \underset{\text{Chlorine}}{Cl_2(g)} \rightarrow \underset{\text{Bleaching powder}}{CaOCl_2(s)} + H_2O(l)$$

Uses of bleaching powder

The uses of bleaching powder are as follows:

1. It is used as a disinfectant and germicide.

2. It is used for sterilisation of drinking water.

3. It is used to bleach cotton fibre and cotton fabrics in textile industry and wood pulp in paper factories.

4. It is used as an oxidising agent.

Baking soda ($NaHCO_3$)

The chemical name of baking soda is sodium hydrogencarbonate. It is a mild non-corrosive basic salt. The manufacture of baking soda is carried out by Solvay process. The main raw materials required in the manufacture of baking soda by Solvay process are:

1. Sodium chloride in the form of its concentrated aqueous solution (brine)
2. Ammonia
3. Lime

In this process, ammonia gas is bubbled through brine to produce ammoniacal brine. Carbon dioxide gas is then passed through ammoniacal brine to produce sodium hydrogencarbonate and ammonium chloride.

$$\underbrace{NaCl(aq) + NH_3(g)}_{\text{Ammoniated brine}} + H_2O(l) + CO_2(g) \longrightarrow \underset{\text{Sodium hydrogen-carbonate}}{NaHCO_3(s)} + \underset{\text{Ammonium chloride}}{NH_4Cl(aq)}$$

When sodium hydrogencarbonate is heated during cooking, sodium carbonate is formed with the evolution of CO_2 gas.

$$\underset{\text{Sodium hydrogencarbonate}}{2NaHCO_3(s)} \xrightarrow{\text{heat}} Na_2CO_3(s) + H_2O(g) + CO_2(g)$$

Uses of sodium hydrogencarbonate

The uses of sodium hydrogencarbonate are as follows:

1. It is used in baking powder. Baking powder is a mixture of sodium hydrogencarbonate and a mild edible acid such as tartaric acid or citric acid. The function of tartaric acid or citric acid is to neutralize sodium carbonate formed during heating. Otherwise, sodium carbonate being a mild base will make the cake or bread bitter in taste. On heating, baking powder gives out CO_2 which makes bread and cake to rise up and hence, they become soft and spongy.

$$\underset{\text{Sodium hydrogen carbonate}}{NaHCO_3} + \underset{\text{(from any acid)}}{H^+} \rightarrow \text{Sodium salt of acid} + CO_2 + H_2O$$

2. It is used in medicines as antacid to cure acidity of stomach. The excess acid produced in the stomach due to eating of spicy food is easily neutralised by sodium hydrogencarbonate, which is a mild base.
3. It is used in soda-acid fire extinguishers.

Washing Soda ($Na_2CO_3.10H_2O$)

Washing soda is sodium carbonate with 10 molecules of water of crystallisation, sodium carbonate decahydrate ($Na_2CO_3.10H_2O$). It is a basic salt. It is also manufactured by Solvay process with brine as the starting material. Here, dry sodium hydrogencarbonate is heated strongly to obtain sodium carbonate.

$$\underset{\text{Sodium hydrogencarbonate}}{2NaHCO_3(s)} \xrightarrow{\text{heat}} Na_2CO_3(s) + H_2O(g) + CO_2(g)$$

Then the recrystallisation of sodium carbonate produces washing soda.

$$\underset{\text{Sodium carbonate}}{Na_2CO_3} + 10H_2O \rightarrow \underset{\text{Washing soda}}{Na_2CO_3 \cdot 10H_2O}$$

Uses of washing soda (sodium carbonate)

The uses of sodium carbonate are as follows:

1. It is used as a cleansing agent in the household.
2. It is used to remove permanent hardness of water.
3. It is used in soap, glass and paper industries.
4. It is used in textile industry.
5. It is used in the manufacture of sodium compounds like borax.

Plaster of Paris

On heating gypsum ($CaSO_4 \cdot 2H_2O$) at 100 °C (373 K), it loses water molecules and becomes calcium sulphate hemihydrate ($CaSO_4 \cdot 1/2H_2O$) which is called plaster of Paris.

It is the white salt which the doctors use for plastering the fractured bones to keep the joints in a fixed position.

When the powder of plaster of Paris is mixed with water, it absorbs more water and changes back to gypsum. Its formula is written as $CaSO_4 \cdot 1/2H_2O$ because two formula units of $CaSO_4$ share one molecule of water. It is stored in a moisture-proof container in order to avoid its conversion to gypsum.

$$\underset{\text{Gypsum}}{CaSO_4 \cdot 2H_2O(s)} \xrightarrow{100^\circ C} \underset{\text{Plaster of Paris}}{CaSO_4 \cdot \frac{1}{2} H_2O(s)} + \frac{3}{2} H_2O(l)$$

$$\underset{\text{Plaster of Paris}}{CaSO_4 \cdot \frac{1}{2} H_2O(s)} + \frac{3}{2} H_2O(l) \rightarrow \underset{\substack{\text{Gypsum} \\ \text{(hard mass)}}}{CaSO_4 \cdot 2H_2O(s)}$$

Although the plaster of Paris is represented by the formula $CaSO_4 \cdot 1/2H_2O$ in which half a molecule of water is attached per $CaSO_4$ moiety, but in reality one water molecule is bonded to two $CaSO_4$ moieties.

Uses of plaster of Paris

The uses of plaster of Paris are as follows:

1. It is used for setting of fractured bones.
2. It is used for making casts for statues, toys and decorative objects.
3. It is used as a building material for making the surface of walls, ceilings, etc., smooth before painting.
4. It is used for making decorative designs on the pillars, ceilings, etc. in order to make the buildings beautiful.

SUMMARY

1. **Acid**: An acid is a substance which produces hydrogen ions when dissolved in water. Acidic nature of a substance is due to the presence of $H^+(aq)$ ions in solution.
2. **Base**: A base is a substance which produces hydroxyl ions in solution. Basic nature of a substance is due to the presence of $OH^-(aq)$ ions in solution.
3. **Neutralisation**: The process of formation of salt and water when an acid reacts with a base is called **neutralisation**. During neutralisation, the $H^+(aq)$ ion of an acid combines with $OH^-(aq)$ ion or O^{2-} ion of a base to form water, and the negative ion of the acid combines with the positive ion of the base to form a salt.
4. A strong acid dissociates to a large extent in aqueous solution. For example, hydrochloric acid, sulphuric acid, nitric acid, etc. A weak acid ionises only to a small extent in aqueous solution. For example, carbonic acid, acetic acid, nitrous acid, etc.
5. Acids react with metals which come above hydrogen in the activity series to liberate hydrogen and the corresponding salts are formed.
6. An acid reacts with a metal carbonate to form carbon dioxide, water and the corresponding salt.
7. An aqueous solution of an acid conducts electricity because it forms $H^+(aq)$ ions.
8. The mixing of conc. H_2SO_4 or conc. HNO_3 in water is a highly exothermic reaction.
9. **Alkali**: The water soluble bases are called **alkalis**. For example, NaOH, KOH, etc.
10. **Strong base**: A base which has strong affinity for a proton, is called **strong base**. Nearly all their molecules break up to form $OH^-(aq)$ ions. For example, sodium hydroxide, potassium hydroxide, calcium hydroxide, etc.
11. **Weak base**: A base which has weak affinity for a proton, is called **weak base**. Only some of their molecules break up to form $OH^-(aq)$ ions. For example, ammonium hydroxide, copper(II) hydroxide, iron(II) hydroxide.
12. A dilute acid has lesser moles of acid per litre of its solution in comparison to a concentrated acid which has more moles of acid per litre of its solution.
13. Bases form salt and water when reacted with acids.

14. **Indicator**: An indicator is a substance which changes colour in accordance with acidic or basic nature of a solution. Acid-base indicators are dyes or mixture of dyes and are used to indicate acids and bases. For example, methyl orange, phenolphthalein, litmus solution and universal indicator.
15. ***p*H and *p*H scale**: The acidity or basicity of a solution is expressed in terms of a parameter called ***p*H**. The scale indicating the hydrogen ion concentrations of solutions in terms of *p*H values is called ***p*H scale**. The higher the hydrogen ion concentration of a solution, the more acidic the solution is and the lower is its *p*H number. If $[H^+] = 10^{-x}$ M, then $pH = x$.
16. An acidic solution has a *p*H number < 7, an alkaline solution has a *p*H number > 7.
17. The *p*H of any solution can be determined by using *p*H paper. The *p*H of solutions is determined more accurately with the help of an instrument called ***p*H meter**.
18. The living organisms carry out their metabolic activities in specific *p*H ranges.
19. **Salt**: A salt is an ionic compound formed by the partial or complete replacement of ionisable hydrogen ions of an acid by cations. Salts are formed when H^+ ions of acids are replaced by cations or when OH^- ions of bases are replaced by anions. Salts find various uses in our everyday life and in industry.
20. **Acid salt**: An acid salt is formed when H^+ ions of an acid are only partially replaced by cations.
21. **Normal salt**: A normal salt is formed when H^+ ions of an acid are completely replaced by cations.
22. **Basic salt**: A basic salt is formed by the partial replacement of OH^- ions of a base by an anion.
23. **Water of crystallisation**: The fixed number of water molecules which remain in the crystal lattice of crystalline salts are called **water of crystallisation**.
24. **Hydrolysis**: The phenomenon of interaction of the cations and anions of a salt with the H^+ and OH^- ions of water is called **hydrolysis**.

MIND MAP

ACIDS, BASES AND SALTS

ACIDS

Physical properties
- sour taste
- turns blue litmus red
- produce H^+ ions in aqueous solution
- aqueous solutions conduct electricity

Chemical properties

Reaction with metals
- Acid + Metal → Salt + H_2
- $2HCl + Mg \rightarrow MgCl_2 + H_2\uparrow$

Reaction with metal carbonates/metal hydrogencarbonates
- Acid + Metal carbonate/Metal hydrogen-carbonate → Salt + CO_2
- $Na_2CO_3 + H_2SO_4 \rightarrow Na_2SO_4 + H_2O + CO_2\uparrow$
- $2NaHCO_3 + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O + 2CO_2\uparrow$

Reaction with bases (neutralisation)
- Acid + Base → Salt + Water
- $NaOH + HCl \rightarrow NaCl + H_2O$

Reaction with metallic oxides
- Acid + Metal oxide → Salt + Water
- $H_2SO_4 + CuO \rightarrow CuSO_4 + H_2O$

BASES

Physical properties
- bitter taste
- turns red litmus blue
- produce OH^- ions in aqueous solution
- soapy to feel
- water soluble bases are alkalis

Chemical properties

Reaction with metals
- Base + Metal → Salt + H_2
- $2NaOH + Zn \rightarrow Na_2ZnO_2 + H_2\uparrow$

Reaction with acids (neutralisation)
- Base + Acid → Salt + Water
- $Ca(OH)_2 + H_2SO_4 \rightarrow CaSO_4 + 2H_2O$

Reaction with non-metallic oxides
- Base + Non-metallic oxide → Salt + Water
- $2NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O$

STRENGTH OF ACIDS AND BASES IN SOLUTIONS

- depends on the number of H^+ ions and OH^- ions produced

$[H^+]$	1 (10^0)	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}	10^{-8}	10^{-9}	10^{-10}	10^{-11}	10^{-12}	10^{-13}	10^{-14}
*p*H	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14

← Acidic — Neutral (pH 7) — Alkaline →

On Board! BOOKS

MIND MAP

SALTS (combination of acids and bases)

Families of Salts

	Salt	Formula	Acid	Base
1.	Sodium sulphate	Na_2SO_4	H_2SO_4	NaOH
2.	Potassium sulphate	K_2SO_4	H_2SO_4	KOH
3.	Calcium sulphate	$CaSO_4$	H_2SO_4	$Ca(OH)_2$
4.	Magnesium sulphate	$MgSO_4$	H_2SO_4	$Mg(OH)_2$
5.	Copper(II) sulphate	$CuSO_4$	H_2SO_4	$Cu(OH)_2$
6.	Sodium chloride	NaCl	HCl	NaOH
7.	Sodium nitrate	$NaNO_3$	HNO_3	NaOH
8.	Sodium carbonate	Na_2CO_3	H_2CO_3	NaOH
9.	Ammonium chloride	NH_4Cl	HCl	NH_4OH

Families of salts:

1. **On the basis of common acids**
   Sulphates: Na_2SO_4, K_2SO_4, $CaSO_4$, $MgSO_4$, $CuSO_4$
   Chlorides: NaCl, NH_4Cl
   Carbonate: Na_2CO_3, K_2CO_3
2. **On the basis of common bases**
   Sodium salts: Na_2SO_4, NaCl, $NaNO_3$, Na_2CO_3
   Potassium salts: K_2SO_4, KCl, KNO_3, K_2CO_3
   Calcium salts: $CaSO_4$, $CaCl_2$
   Magnesium salts: $MgSO_4$, $MgCl_2$
   Copper(II) salts: $CuSO_4$, $CuCl_2$
   Ammonium salts: NH_4Cl, $(NH_4)_2SO_4$

pH of Salts

pH	Acid	Base	Salt
$pH = 7$	Strong	Strong	Neutral
$pH < 7$	Strong	Weak	Acidic
$pH > 7$	Weak	Strong	Basic

Water of crystallisation

- fixed number of water molecules present in one formula unit of a salt
- responsible for the colour and crystalline nature of a salt
- e.g., hydrated copper sulphate ($CuSO_4 \cdot 5H_2O$), gypsum ($CaSO_4 \cdot 2H_2O$), washing soda ($Na_2CO_3 \cdot 10H_2O$)

Some Important Salts

Bleaching powder
- $Ca(OH)_2 + Cl_2 \rightarrow CaOCl_2 + H_2O$
- used as an oxidising agent, in disinfecting of water, etc.

Baking soda
- $NaCl + H_2O + CO_2 + NH_3 \rightarrow NH_4Cl + NaHCO_3$
- used in antacids, soda-acid fire extinguishers, etc.

Washing soda
- $Na_2CO_3 + 10H_2O \rightarrow Na_2CO_3 \cdot 10H_2O$
- used in glass and soap industries, in removing permanent hardness of water, etc.

Common salt (NaCl)
- $NaOH + HCl \rightarrow NaCl + H_2O$
- important raw material for the preparation of NaOH, $NaHCO_3$, Na_2CO_3, etc.

Plaster of Paris
- $CaSO_4 \cdot 2H_2O \xrightarrow{100\ °C} CaSO_4 \cdot \frac{1}{2}H_2O + \frac{3}{2}H_2O$
- used for making toys, material for decoration, etc.

Gypsum
- $CaSO_4 \cdot \frac{1}{2}H_2O + \frac{3}{2}H_2O \rightarrow CaSO_4 \cdot 2H_2O$

CHLOR-ALKALI PROCESS

- electrolysis of an aqueous solution of NaCl (brine)
- chlorine gas is evolved at anode
- hydrogen gas is given off at cathode
- $2NaCl(aq) + 2H_2O(l) \rightarrow 2NaOH(aq) + Cl_2(g) + H_2(g)$