ACIDS, BASES AND SALTS

ACIDS & BASES – Acids are sour in taste and change the colour of blue litmus to red while bases are bitter and change the colour of red litmus to blue.

INDICATORS – are the substance used to test the presence of an acid or a base. Indicators can be classified as –

(i) **Natural indicators** – e.g. litmus, turmeric, red cabbage extract coloured petals of some flowers such as Hydrangea, Petunia etc.

Litmus – it is a purple dye, which is extracted from lichen. a plant belonging to group thallophyta. When litmus solution is neither acidic nor basic, its colour is purple. Blue litmus solution is obtained by acidifying the purple litmus extract and red litmus solution is obtained by making the purple extract alkaline.

Turmeric – contains a yellow dye which turns red in basic solution.

A yellow stain of curry on a white cloth (yellow stain is due to presence of turmeric in curry) turns reddish brown when soap is scrubbed on it. This is because soap solution is basic in nature. The stain turns yellow again when the cloth is washed with plenty of water because then the basic soap gets removed with water.

(ii) **Synthetic indicators** – e.g. phenolphtalein and methyl orange.

Indicator.	Colour in neutral solution	Colour in acidic solution	Colour in basic solution.
Phenolphthalein	Colourless	Colourless	Pink.
Methyl orange.	Orange	Red	Yellow

– There is another group of indicators which give different odours in acidic or basic medium – **OLFACTORY INDICATORS**. e.g. vanilla, onion, clove etc.

– **Vanilla extract** has a characteristic pleasant smell. In acidic solution its smell persists while in basic solution its smell cannot be detected.

Onion has a characteristic pungent smell. In acidic solution its smell persists while in basic solution its smell cannot be detected.

REACTIONS OF ACIDS AND BASES WITH METALS – When an acid reacts with active metals (e.g. Zn, Mg, Al etc), then salt and hydrogen gas are formed –

$$\text{Metal} + \text{Acid} \longrightarrow \text{Salt} + \text{Hydrogen gas}.$$

for example :-

$$Zn + \underset{\text{(dilute)}}{H_2SO_4} \longrightarrow ZnSO_4 + H_2$$

$$Zn + 2HCl \text{ (dil)} \longrightarrow ZnCl_2 + H_2.$$

Hydrogen gas evolved is passed through soap solution. Gas filled bubbles are formed in the soap solution which rise into the air. If we bring a burning candle near a gas filled soap bubble, the gas present in the soap bubble burns with a pop sound. It confirms the presence of hydrogen gas.

– Curd and other sour substances should not be kept in brass and copper vessels as curd other sour food-stuffs contain acids which can react with the metal of the vessel to form poisnous metal compounds which can cause food poisoning and damage our health.

- Some bases like NaOH and KOH react with metals like zinc and aluminium with the evolution of Hydrogen gas. However, such reactions are not possible with all metals -

Base + metal ⟶ salt + hydrogen gas.

for example :- $Zn + 2NaOH \longrightarrow Na_2ZnO_2 + H_2$
(sodium zincate)

$2Al + 2NaOH + 2H_2O \longrightarrow 2NaAlO_2 + 3H_2$
(sodium aluminate)

- REACTIONS OF ACIDS WITH METAL CARBONATES AND METAL HYDROGENCARBONATES -

Acid + Metal carbonate/Metal hydrogencarbonate ⟶ Salt + carbon-dioxide + water

for example :- $Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$.
$NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2$.

If evolved CO_2 is passed through lime water, it turns milky due to formation of insoluble white ppt. of calcium carbonate -

$Ca(OH)_2 + CO_2 \longrightarrow CaCO_3 \downarrow + H_2O$.

If excess of CO_2 is passed, the ppt. first formed dissolves due to the formation of soluble calcium bicarbonate -

$CaCO_3 + H_2O + CO_2 \longrightarrow Ca(HCO_3)_2$

- Limestone, marble and chalk are different forms of calcium carbonate. Even the egg shells are made of calcium carbonate. These all react with acid to give salt, water and carbondioxide -

$CaCO_3 + 2HCl \longrightarrow CaCl_2 + H_2O + CO_2$

- REACTION BETWEEN ACIDS AND BASES - When an acid reacts with a base, it forms salt and water. This reaction is known as neutralization reaction -

Acid + base ⟶ salt + water

for example :- $HCl + NaOH \longrightarrow NaCl + H_2O$.

Neutralization reaction can be explained by a simple experiment using phenolphthalein as an indicator. Take 2 ml of dil. NaOH in a test tube and add 2 or 3 drops of phenolphthalin indicator. The solution will turn pink showing that it is basic in nature. Now add dilute HCl dropwise and shake the tube after each addition. After adding certain volume of HCl, we find that pink colour disappears and the solution become colourless. This shows that all the NaOH taken in the test tube has been completely neutralized by acid added. and the reaction mixture has become neutral (or acidic). Now add few drops of NaOH in it. The solution becomes pink again as now the reaction mixture has become basic again.

REACTION OF METAL OXIDE WITH ACIDS - Acids react with metal oxide to give salt and water -.

Metal oxide + acid ⟶ salt + water.

for example:- $CaO + 2HCl \longrightarrow CaCl_2 + H_2O$.
$CuO + 2HCl \longrightarrow CuCl_2 + H_2O$.
(bluish green in colour)

As metal oxides react with acid to give salt and water similar to reaction of base with an acid, metal oxides are said to be basic in nature.

REACTION OF A NON METALLIC OXIDE WITH BASE - Base reacts with non metallic oxides (e.g. CO_2, SO_2, SO_3 etc) to give salt and water showing that these oxides are acidic in nature.

Non metal oxide + base ⟶ Salt + water

for example:- $CO_2 + Ca(OH)_2 \longrightarrow CaCO_3 + H_2O$.

WHAT DO ALL ACIDS AND ALL BASES HAVE IN COMMON -. All acids react with metal to produce hydrogen gas which shows that hydrogen is common to all acids. Acids dissolve in water and dissociate to give H^+ ions. Due to presence of H^+ ions; these show acidic character and conduct electricity.

- There are few hydrogen containing compounds like glucose and alcohol solution which do not conduct electricity (and do not behave as acid) because these are covalent compounds and do not dissociate in water to produce H^+ ions.
- Distilled water does not conduct electricity as it does not contain any ionic compound (like acids, bases or salts) dissolved in it and as such dissociation of water is very less. On the other hand, rain water conducts electricity because rain water while falling to the earth through the atmosphere dissolve acid gases like CO_2, SO_2, NO_2 etc from the air and form acid. These acids dissociate to give ions which help in conducting electricity.
- A common property of all the bases is that they all produce hydroxide ions (OH^- ions) when dissolved in water e.g. $NaOH$, KOH, $Ca(OH)_2$ etc. Due to presence of ions, these also conduct electricity.

WHAT HAPPENS TO AN ACID OR A BASE IN A WATER SOLUTION - The acidic behaviour of an acid is due to presence of H^+ ions which they produce only when dissolved in water. In absence of water, acid will not dissociate to give H^+ ions and will not show acidic behaviour.

e.g. dry HCl gas (produced by reacting $NaCl$ and conc. H_2SO_4) will have no effect on dry litmus paper while it turns moist blue litmus paper to red.

- In aqueous solution of acid, hydrogen ions cannot exist alone but they exist as hydronium ions after combining with water molecules -.

$$HCl + H_2O \longrightarrow H_3O^+ + Cl^-$$
(hydronium ion)

- When a base is dissolved in water, it gives OH^- ions -

$$NaOH(s) \xrightarrow{H_2O} Na^+_{(aq)} + OH^-_{(aq)}$$

$$Mg(OH)_2(s) \xrightarrow{H_2O} Mg^{+2}_{(aq)} + 2OH^-_{(aq)}.$$

Most of the bases do not dissolve in water. A base which is soluble in water is called an <u>ALKALI</u> e.g. $NaOH$, KOH, $Ca(OH)_2$, NH_4OH etc.

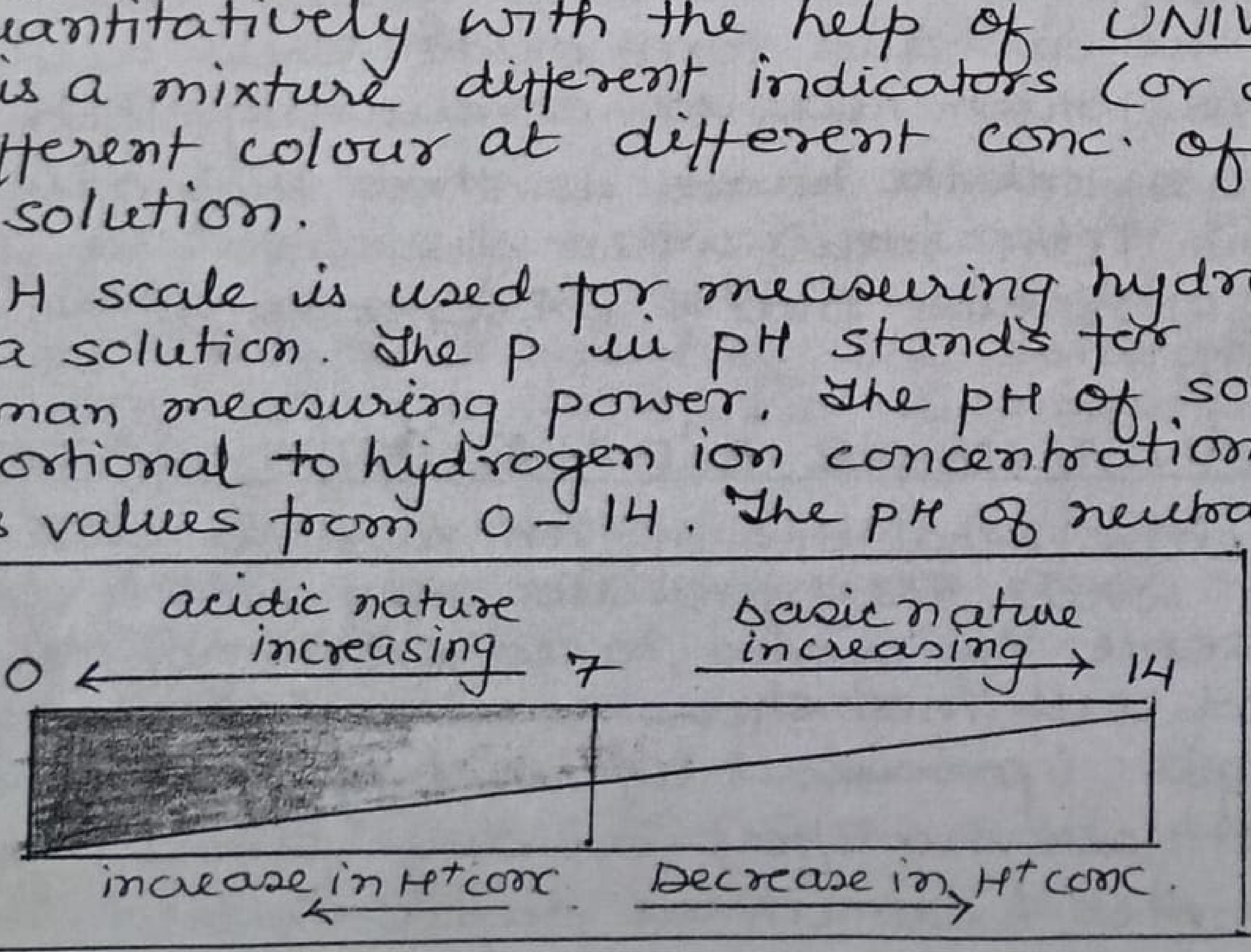
- As all acids generate H^+ ions and bases generate OH^- ions, therefore, neutralisation reaction can be written as follows :-

$$H^+_{(aq)} + OH^-_{(aq)} \longrightarrow H_2O_{(l)}$$

- The process of dissolving an acid or base in water is an exothermic reaction. While mixing concentrated acid with water, acid should be always added slowly to water with constant stirring. The heat is evolved gradually and easily absorbed by large amount of water. If, however, water is added to concentrated acid to dilute it, then a large amount of heat is evolved at once. This heat changes some water to steam explosively which can splash the acid on our clothes or face and cause acid burns. The glass container may also break due to excessive local heating.
- Mixing an acid or base with water results in decrease in concentration of ions (H_3O^+/OH^-) per unit volume. Such a process is called <u>DILUTION</u> and the acid or the base is said to be <u>DILUTED</u>.

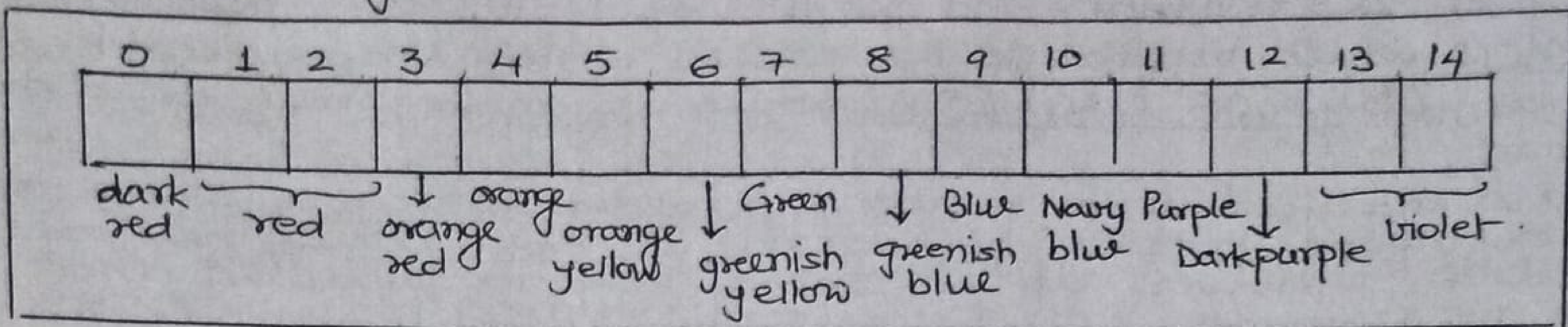
<u>HOW STRONG ARE ACID OR BASE SOLUTIONS</u> - The strength of an acid or a base depends upon the conc. of H_3O^+ and OH^- in a solution which can be measured quantitatively with the help of <u>UNIVERSAL INDICATOR</u>. It is a mixture different indicators (or dyes) which give different colour at different conc. of hydrogen ion in solution.

- pH scale is used for measuring hydrogen ion concentration in a solution. The p in pH stands for "protenz" in German measuring power. The pH of solution is inversely proportional to hydrogen ion concentration. The pH scale has values from 0-14. The pH of neutral solution is 7.



Value less than 7 on pH scale represent an acidic solution. As the pH value increases from 7 to 14, basic strength increases.

- pH paper give different colours in different pH range.



- water is slightly ionized into hydrogen ions and hydroxide ions. In pure water, the conc. of H^+ and OH^- ions are equal. Due to this water is neutral. When acid is dissolved in water, the conc. of hydrogen ions will be more than hydroxide ions and it will be acidic in nature. However, when base is dissolved in water, the conc. of hydroxide ions will be more than hydrogen ions and solution will be basic in nature.
- The strength of acids and bases depends on the number of H^+ ions and OH^- ions produced respectively and thus can be classified as weak or strong acid (or base).

(i) <u>Strong acids</u> - are those which completely ionised in water and thus produce a large amount of hydrogen ions. All the mineral acids (i.e. acid produced from minerals of earth) are strong acid except carbonic acid. (H_2CO_3). Strong acids react very rapidly with other substances (such as metals, metal carbonates and metal hydrogen carbonate etc) and have a high electrical conductivity due to high conc. of hydrogen ions in their solution e.g. HCl, H_2SO_4, HNO_3 etc.

(ii) <u>Weak acids</u> - are those which partially ionised in water and thus produce a small amount of hydrogen ions. The organic acids (present in plant materials and animal) are weak acids. and these do not react very rapidly. e.g. H_2CO_3, CH_3COOH, citric acid, tartaric acid etc.

(iii) <u>Strong base</u> - which completely ionize in water and thus produce a large amount of hydroxide ions. e.g. $NaOH$, KOH etc.

(iv) <u>weak base</u> - which is partially ionised in water and thus produces a small amount of hydroxide ions. e.g. $Mg(OH)_2$, NH_4OH, $Ca(OH)_2$ etc.

<u>IMPORTANCE OF pH IN EVERYDAY LIFE</u> - (i) Human blood, tears, saliva have pH range of 7 to 7.8. If pH falls below 7 or rises above 7.8, survival of living organisms becomes difficult.

(ii) When pH of rain water is less than 5.6, it is called acid rain. Acid rain may lower the pH of the river water and threaten the survival of aquatic life.

(iii) Plants have a healthy growth, if pH of soil is such that it is neither alkaline nor highly acidic.

(iv) Hydrochloric acid is produced in the stomach to help in digestion. However, if excess of acid is produced, it will cause pain and irritation. To get rid of this pain, people use ANTACID which neutralize the excess acid. Magnesium hydroxide (MILK OF MAGNESIA) which is mild base used an antacid.

(V) Acid is produced in the mouth due to degradation of sugar and left out food particles by bacteria. It is partially neutralized by saliva. However, if excess of acid is produced and the pH of mouth falls below 5.5, it may corrode the tooth enamel (made of calcium phosphate) and lead to tooth decay. Using toothpastes, which are generally basic, for cleaning the teeth can neutralize the excess acid and prevent tooth decay.

(vi) Some animals and plants have self defence through chemical means. The sting of honey bee or yellow ant or leaves of nettle plant inject methanoic acid into our body and we feel pain. Use of a mild base like baking soda on the sting area neutralizes the acid and give relief.

(vii) The tarnished surface of copper vessel due to copper oxide (which is basic) layer can be cleaned by rubbing with lemon (which is acidic).

SALTS - are ionic compounds formed by reaction of an acid with base in which the hydrogen of the acid is replaced by metal or other positive ions.

$$HCl + NaOH \rightarrow \underset{(salt)}{NaCl} + H_2O$$

PH OF SALT SOLUTIONS -

Salts of	Nature	PH
Strong acid and strong base (e.g. NaCl, KCl)	Neutral	7
Strong acid and weak base (e.g. NH_4Cl, $(NH_4)_2SO_4$)	Acidic	<7
Weak acid and strong base (eg. CH_3COONa, Na_2CO_3	Basic	>7

COMMON SALT (SODIUM CHLORIDE) - In lab sodium chloride is prepared by combination of sodium hydroxide and hydrochloric acid. -

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

- In nature common salt occurs in dissolved state in sea water and in solid form as rock salt.
- Common salt from sea water is obtained by evaporation and then purified.
- The large crystals of common salt found in underground deposits are called rock salt. It is brown in colour due to presence of impurties in it. Beds of rock salts were formed when the ancient seas dried up by evaporation, thousands of years ago. Rock salt is mined from the underground deposits just like coal.

Uses of common salt – (i) It is used as raw material for making a large number of useful chemicals in Industries such as $NaOH$, Na_2CO_3, $NaHCO_3$, HCl, H_2, Cl_2 etc.
(ii) It is used in cooking food and improves the flavour of food
(iii) It is used as a preservative in pickles.
(iv) It is used in manufacture of soap.
(v) It is used to melt ice which collects on the roads during winter in cold countries

SODIUM HYDROXIDE (CAUSTIC SODA) – Sodium hydroxide is prepared by electrolysis of a concentrated aqueous solution of sodium chloride (called BRINE) –

$$2NaCl + 2H_2O \rightarrow 2NaOH + Cl_2 + H_2$$

The above process is known as CHLOR-ALKALI PROCESS because of the products formed. – chlor for chlorine and alkali for sodium hydroxide. Chlorine gas is formed at the anode and hydrogen gas at the cathode. Sodium hydroxide solution is formed near the cathode.

- Uses of different products of chlor-alkali process are summarised as follows –

(i) Hydrogen – used as fuel, in preparation of NH_3 for fertilizer.
(ii) Chlorine – used as disinfectant, in water treatment, in preparation of PVC, CFCs etc.
(iii) NaOH – used for making soap, detergents, paper, artificial fibre and in de-greasing metals

Hydrogen + Chlorine → Hydrochloric acid – used in cleaning iron sheets and in medicines and cosmetics
Chlorine + NaOH → Bleach – used for household bleaches and bleaching fabric

BLEACHING POWDER (CALCIUM OXYCHLORIDE – $CaOCl_2$) It is prepared by passing chlorine gas over dry slaked lime –

$$\underset{\text{(slaked lime)}}{Ca(OH)_2} + Cl_2 \longrightarrow \underset{\text{(Bleaching powder)}}{CaOCl_2} + H_2O$$

Uses of bleaching powder – (i) It is used for bleaching cotton and linen in textile industry, wood pulp in paper factories and washed clothes in laundry.
(ii) It is used as an oxidizing agent in many chemical industries.
(iii) It is used for disinfecting drinking water to make it free of germs.

BAKING SODA (SODIUM HYDROGEN CARBONATE – $NaHCO_3$) – It is prepared on large scale by reacting a cold and concentrated solution of sodium chloride with ammonia and carbon dioxide –

$$NaCl + NH_3 + CO_2 + H_2O \longrightarrow NH_4Cl + NaHCO_3$$

- It is a mild non corrosive base. Its solution in water is mildly alkaline an can be used to neutralize an acid.

- When heated, it decomposes to give sodium carbonate with evolution of carbon dioxide gas -

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

Uses of baking soda - (i) It is used as an ingredient in antacids. Being alkaline, it neutralises excess acid in the stomach and provides relief.

(ii) It is used for making baking powder, which is a mixture of baking soda and a mild edible acid such as tartaric acid. When baking powder mixes with water (present in dough made for baking cake or bread) or heated, the following reaction takes place -

$$NaHCO_3 + H^+ \rightarrow CO_2 + H_2O + \text{Sodium salt of acid}$$

CO_2 produced during the reaction causes bread or cake to rise making them soft and spongy. Tartaric acid is added to neutralize the sodium carbonate formed on heating. If it is not added, the cake would taste bitter due to presence of sodium carbonate in it.

(iii) Used in soda-acid fire extinguisher - it contain a solution of $NaHCO_3$ and H_2SO_4 in separate containers. When the knob of fire extinguisher is pressed (or when it is inverted), then H_2SO_4 mixes with $NaHCO_3$ solution to produce lot of CO_2 gas. which forms a blanket around the burning substance and cut off the supply of air to burning substance.

WASHING SODA (SODIUM CARBONATE DECAHYDRATE - $Na_2CO_3 \cdot 10H_2O$) - It can be prepared from sodium chloride in the following three steps -

(i) $NaCl + NH_3 + H_2O + CO_2 \longrightarrow NaHCO_3 + NH_4Cl$

(ii) $2NaHCO_3 \xrightarrow{\Delta} Na_2CO_3 + CO_2 + H_2O$
(soda ash)

(iii) Anhydrous sodium carbonate is dissolved in water and recrystallised to get washing soda containing ten molecules of water of crystallisation -

$$Na_2CO_3 + 10H_2O \longrightarrow Na_2CO_3 \cdot 10H_2O$$
(washing soda).

- It is a basic salt as its aq. solution turns red litmus blue

Uses of washing soda - (i) It is used in glass, soap and paper industries.

(ii) It is used in manufacture of sodium compounds such as borax.

(iii) It is used as a cleaning agent for domestic purposes.

(iv) It is used for removing permanent hardness of water.

PLASTER OF PARIS (CALCIUM SULPHATE HEMIHYDRATE - $CaSO_4 \cdot \frac{1}{2}H_2O$ or $2CaSO_4 \cdot H_2O$) - It is obtained by heating gypsum at 373K, when it loses water molecules and form calcium sulphate hemihydrate -

$$CaSO_4 \cdot 2H_2O \xrightarrow{373K} CaSO_4 \cdot \tfrac{1}{2}H_2O + 1\tfrac{1}{2}H_2O$$

Gypsum → Plaster of Paris

Plaster of Paris is a white powder and on mixing with water, it changes to gypsum once again giving a hard solid mass –

$$CaSO_4 \cdot \tfrac{1}{2}H_2O + 1\tfrac{1}{2}H_2O \longrightarrow CaSO_4 \cdot 2H_2O$$

Gypsum

Uses of Plaster of Paris – (i) It is used in plasters for supporting fractured bones in the right position.
(ii) It is used for making toys, decorative materials, ornaments etc.
(iii) It is used for making surfaces (like the walls of a house) smooth before painting them.

WATER OF CRYSTALLISATION – The water molecules which form part of the structure of a crystal (of a salt) are called water of crystallisation.

- The salts which contain water of crystallisation are called HYDRATED SALTS. Each hydrated salt has a fixed number of molecules of water of crystallisation in its one formula unit e.g. $CuSO_4 \cdot 5H_2O$, $FeSO_4 \cdot 7H_2O$.
- Water of crystallisation is a part of "crystal structure" of a salt. Since water of crystallisation is not free water, it does not wet the salt.
- The water of crystallisation gives the crystals of salt their "shape" and in some cases imparts them colour e.g. $CuSO_4 \cdot 5H_2O$ is blue in colour and $FeSO_4 \cdot 7H_2O$ is green.
- When hydrated salts are heated strongly, they lose their water of crystallisation and lose their regular shape and become colourless powdery substance. The salts which have lost their water of crystallisation are called ANHYDROUS SALTS.

$$CuSO_4 \cdot 5H_2O \longrightarrow CuSO_4 + 5H_2O$$

Hydrated copper sulphate (blue) → anhydrous copper sulphate (white)

The dehydration of copper sulphate crystals is a reversible process. So when water is added to anhydrous copper sulphate, it gets hydrated and turns blue due to formation of hydrated copper sulphate. This property of anhydrous copper sulphate is used to detect the presence of moisture (water) in a liquid.

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