Chapter 2 - Acids, Bases and Salts

Introduction

Electrolytes: The substances which when dissolved in water conduct electricity.

Acids, bases and salts are three main categories of chemical compounds. The sour taste of many fruits and vegetables, lemon for instance, is due to various types of acids present in them. The digestive fluids of most animals and humans also contain acids.
The word 'acid' is derived from a Latin word, which means "sour". The acids we use in the laboratory are stronger acids like hydrochloric acid and sulphuric acid. Strong acids are corrosive and can burn your skin. Bases on the other hand are the chemical opposites of acids. They are bitter in taste and soapy to touch. Sea water and detergents are some examples of substances that are basic. Many bases are oxide or hydroxide compounds of metals. Strong bases can also burn ones skin.

- Acids present in plant materials & animals are called **Organic acids.**
  Some naturally occurring acids,

Vinegar	Acetic acid
Sour milk (curd)	Lactic acid
Oranges	Citric acid
Lemons	Citric acid
Tamarind	Tartaric acid
Ant sting	Formic acid
Apples	Malic acid
Tomatoes	Oxalic acid.

Inorganic or Minerals acids are derived from minerals occurring in nature.
Some common acids that are found in laboratories are
Hydrochloric acid (HCl),
Sulphuric acid (H_2SO_4) and
Nitric acid (HNO_3).
Some of the lesser used acids are
Acetic acid (CH_3COOH),
Hydrofluoric acid (HF), Hydrofluoric acid is a highly corrosive acid and is used to etch glass.
Carbonic acid (H_2CO_3).

General properties of Acids:
- Tastes sour
- Reacts with metals such as zinc, magnesium etc. liberating hydrogen gas.

- Changes the colour of litmus from blue to red.
- Conducts electricity.

General properties of Bases

- Have a soapy feel,
- May also burn the skin
- Common examples are soaps & detergents.
- Commonly found bases in laboratories and in our daily life are: Caustic soda, $NaOH$; Caustic potash, KOH; Milk of magnesia, $Mg(OH)_2$; Liquor ammonia, NH_3; Washing powder, Tooth paste.

ACIDS

Concentrated & Dilute acids - A concentrated acid is one which contains the minimum amount of water in it. A dilute acid is obtained by mixing the concentrated acid with water.

Addition of Acids or Bases to Water - The process of dissolving an acid or a base in water is a highly exothermic one. As this reaction generates lot of heat care must be taken while mixing concentrated acids with water, specially nitric acid or sulphuric acid with water. As a rule:

Always add Acid to Water and Never the Other Way! The acid must be added slowly to water with constant stirring. If one mixes the other way by adding water to a concentrated acid, the heat generated causes the mixture to splash out and cause burns. The glass container may also break due to excessive local heating and cause damages! Mixing an acid or base with water results in dilution. It decreases the concentration of ions (H_3O^+/OH^-) per unit volume thereby dissipating the heat effect easily.

What Happens to an Acid in a Water Solution? Acids - Since all acids contain hydrogen ions, the more hydrogen ions they contain, the stronger the acids are. **A good definition of an acid is a compound that produces H^+ ions when it dissolved in water.** Hydrogen ions cannot exist alone, but they exist after combining with water molecules. H^+ ions in association with a water molecule form H_3O^+ ions or hydronium ion.

$$H^+ + H_2O \longrightarrow H_3O^+$$

For example, when hydrogen chloride gas is dissolved in water, the hydrogen chloride molecules immediately dissociate or split into hydrogen ions and chloride ions. The solution becomes a very strong acid solution called hydrochloric acid.

$$HCl(aq) \rightarrow H^+(aq) + Cl^-(aq)$$

The separation of H^+ ion from HCl molecules cannot occur in the absence of water. Thus hydrogen ions must always be shown as $H^+(aq)$ or (H_3O^+).

The strength of an acid depends on the concentration of the hydronium ions (H_3O^+) present in a solution. We know that greater the number of hydronium ions present, greater is the strength of acid. However, some acids do not dissociate to any appreciable extent in water such as carbonic acid. Therefore, these acids will have a low concentration of hydronium ions

How Strong are Acid Solutions? Strong Acid - An acid, which dissociates completely or almost completely in water, is classified as a strong acid. An aqueous solution of a strong acid contains only ions along with water.

It must be noted that in these acids all the hydrogen ions (H^+) combine with water molecule and exist as hydronium ions (H_3O^+). Examples of strong acids are: Hydrochloric acid, Sulphuric acid, Nitric acid etc.

$$\underset{\text{Hydrochloric acid}}{HCl\,(aq)} \longrightarrow H^+\,(aq) + Cl^-\,(aq)$$

$$\underset{\text{Nitric acid}}{HNO_3\,(aq)} \longrightarrow H^+\,(aq) + NO_3^-\,(aq)$$

$$H_2SO_4\,(aq) \rightarrow 2H^+(aq) + SO_4^{2-}\,(aq)$$

Weak Acid – An acid that dissociates only partially when dissolved in water, is classified as a weak acid. An Aqueous solution of a weak acid contains ions and molecules. Examples are: acetic acid, formic acid, carbonic acid etc.

$$\underset{\text{Acetic acid}}{CH_3COOH\,(aq)} \longrightarrow CH_3COO^-\,(aq) + H^+\,(aq)$$

$$\underset{\text{Formic acid}}{HCOOH\,(aq)} \longrightarrow HCOO^-\,(aq) + H^+\,(aq)$$

$$\underset{\text{Carbonic acid}}{H_2CO_3\,(aq)} \longrightarrow H^+\,(aq) + HCO_3^-\,(aq)$$

$$\underset{\text{Carbonic acid}}{H_2CO_3\,(aq)} \longrightarrow 2H^+\,(aq) + CO_3^{2-}\,(aq)$$

Reaction of Acids with Metals

(a) All metals above hydrogen in the metal reactivity series generally react with dilute acids to form their respective salt and liberate hydrogen.

Metal + Acid $\rightarrow$ Salt + Hydrogen

$$\underset{\text{Magnesium}}{Mg(s)} + \underset{\text{Dil.Hydrochloric acid}}{2HCl(aq)} \rightarrow \underset{\text{Magnesium chloride}}{MgCl_2\,(aq)} + \underset{\text{Hydrogen}}{H_2\,(g)}$$

$$\underset{\text{Zinc}}{Zn(s)} + \underset{\text{Dil. Hydrochloric acid}}{2HCl(aq)} \rightarrow \underset{\text{Zinc chloride}}{ZnCl_2(aq)} + \underset{\text{Hydrogen}}{H_2(g)}$$

$$\underset{\text{Iron}}{Fe(s)} + \underset{\text{Dil.Sulphuric acid}}{H_2SO_4\,(aq)} \rightarrow \underset{\text{Iron(II) sulphate}}{Fe_2SO_4(aq)} + \underset{\text{Hydrogen}}{H_2(g)}$$

(b) Very active metals like potassium, sodium and calcium also react similarly, but tend to explode when combining with acids.

$$2Na(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2(g)$$

Sodium	Dil. hydrochloric acid	Sodium chloride	Hydrogen

(c) Nitric acid (of various concentrations) usually exhibits oxidizing property, rather than acidic properties. Metals such as magnesium combine with extremely dilute (1%) nitric acid to liberate hydrogen.

(d) Reaction of Metal Carbonates and Metal Hydrogen Carbonates with Acids?

Acids react with carbonates and hydrogen carbonates (bicarbonates) to form their respective salt, water and carbon dioxide.

Carbonate/Bicarbonate + Acid $\rightarrow$ Salt + Water + Carbon dioxide

$$Na_2CO_3(aq) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$$

Sodium carbonate	Hydrochloric acid	Sodium chloride	Water	Carbon dioxide

$$ZnCO_3(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2O(l) + CO_2(g)$$

Zinc carbonate	Sulphuric acid	Zinc sulphate	Water	Carbon dioxide

$$2NaHCO_3(s) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l) + 2CO_2(g)$$

Sodium hydrogen carbonate	Sulphuric acid	Sodium sulphate	Water	Carbon dioxide

Neutralization

The reaction between the hydrogen ions of an acid and the hydroxyl ions of a base is called neutralization. In general, a neutralization reaction can be written as:

Acid + Base $\longrightarrow$ Salt + Water

Examples:

1.

$$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$$

Sodium hydroxide	Hydrochloric acid	Sodium chloride	Water

2.

$$3NH_4OH(aq) + H_3PO_4(aq) \rightarrow (NH_4)_3PO_4(aq) + 3H_2O(l)$$

Ammonium hydroxide	Phosphoric acid	Ammonium phosphate	Water

3.

$$PbO(s) + 2HNO_3(aq) \rightarrow Pb(NO_3)_2(aq) + H_2O(l)$$

Lead oxde	Nitric acid	Lead nitrate	Water

The acidic property of an acid is due to the presence of hydrogen ions (H^+) while that of a base or alkali, is due to the presence of hydroxyl (OH^-) ions in them. When an acid and base (alkali) combine, the positively charged hydrogen ion of the acid combines with the negatively charged hydroxyl ion of the base to form a molecule of water. Hence, the water molecule formed does not have any charge because the positive and negative charges of the hydrogen ions and hydroxyl ions get neutralized.

$$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$$

Neutralization can be viewed as a reaction in which an acid combine with a base, neutralizing the positively charged hydrogen ion and the negatively charged hydroxyl ion, to form a molecule of water and the respective salt.

Reaction of Metallic Oxides with Acids

Action with Basic Oxides

Oxides that react with an acid to form salt and water are called basic oxides. These oxides get neutralized when they react with acids.

Basic oxide + Acid $\longrightarrow$ Salt + Water

1.

$Na_2O(s)$	+	$2HCl(aq)$	$\rightarrow$	$2NaCl(aq)$	+	$H_2O(l)$
Sodium oxide		Hydrochloric acid		Sodium chloride		Water

2.

$PbO(s)$	+	$2HNO_3(aq)$	$\rightarrow$	$Pb(NO_3)_2(aq)$	+	$H_2O(l)$
Lead oxide		Nitric acid		Lead nitrate		Water

3.

$CuO(s)$	+	$H_2SO_4(aq)$	$\rightarrow$	$CUSO_4(aq)$	+	$H_2O(l)$
Copper oxide		Sulphuric acid		Copper sulphate		Water

Action with Basic Hydroxides

Acids undergo neutralization reaction with basic hydroxides to form salt and water.

Basic hydroxide + Acid $\longrightarrow$ Salt + Water

1.

$2KOH(aq)$	+	$H_2CO_3(aq)$	$\rightarrow$	$K_2CO_3(aq)$	+	$2H_2O(l)$
Potassium hydroxide		Carbonic acid		Potassium carbonate		Water

2.

$$3NaOH(aq) + H_3PO_4(aq) \rightarrow Na_3PO_4(aq) + 3H_2O(l)$$

Sodium hydroxide	Phosphoric acid	Tri sodium phosphate	Water

3.

$$NH_4OH(aq) + H_2SO_4(aq) \rightarrow (NH_4)_2SO_4(aq) + 2H_2O(l)$$

Ammonium hyroxide	Sulphuric acid	Ammonium sulphate	Water

Reaction of Non-metallic Salts with Base

Calcium hydroxide, which is a base, reacts with carbon dioxide to produce salt and water. Since this is similar to the reaction between a base and an acid, we can conclude that nonmetallic oxides are acidic in nature.

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

Calcium hydroxide	Carbon dioxide	Calcium carbonate	Water

This reaction occurs during white washing.

Bases

The oxides and hydroxides of metals are called bases. Examples of bases- sodium hydroxide, magnesium oxide, calcium oxide, copper oxide, potassium hydroxide, magnesium hydroxide etc. Some bases are water soluble and dissolve in water to produce hydroxyl ions. A base that is soluble in water is an **alkali.** For example, when sodium hydroxide is dissolved in water it readily dissociates to produce a lot of hydroxide ions.

$$NaOH(aq) \rightarrow Na^+(aq) + OH^-(aq)$$

All alkalis are bases that dissociate in water to yield hydroxyl ion (OH^-) as the only negative ions. Sodium hydroxide, potassium hydroxide, calcium hydroxide and ammonium hydroxide are the common alkalis.

$NaOH(aq) \longrightarrow Na^+(aq) + OH^-(aq)$

$KOH(aq) \longrightarrow K^+(aq) + OH^-(aq)$

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

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

Strong Base /Alkali - The strength of a base depends on the concentration of the hydroxyl ions when it is dissolved in water. A base that dissociates completely or almost completely in water to give a high concentration of hydroxyl ions is classified as a strong base. The greater the number

of hydroxyl ions the base produces, the stronger is the base. NaOH, KOH, & LiOH are strong alkalis.
Example:

$$NaOH \longrightarrow Na^+ + OH^-$$

Weak Base / Alkali - A base that dissociates in water only partially to give a low concentration of hydroxyl ions is known as a weak base. Calcium hydroxide & ammonium hydroxide are weak alkalis.
Example:

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

Reactions of Bases/alkalis
Neutralization Reaction – Already done
Action of Alkalis/Base with Ammonium Salts
Alkalis combine with ammonium salts to liberate ammonia.
Alkali + Ammonium salt $\longrightarrow$ Salt + Water + Ammonia

$Ca(OH)_2(aq)$	+ $2NH_4Cl(s)$	$\rightarrow$ $CaCl_2(s)$	+ $2H_2O(l)$	+ $2NH_3(g)$
Calcium hydroxide	Ammonium chloride	Calcium Chloride	Water	Ammonia

$2NaOH(aq)$	+ $(NH_4)_2SO_4(aq)$	$\rightarrow$ $Na_2SO_4(aq)$	+ $2H_2O(l)$	+ $2NH_3(g)$
Sodium hydroxide	Ammonium sulphate	Sodium sulphite	Water	Ammonia

pH scale: The pH of a solution is defined as the negative logarithm of hydrogen ion concentration in moles per litre.

pH = - log [H$^+$(aq)]

The pH scale is a continuous scale and the value of pH varies between 0 to 14.

The pH of pure or neutral water is 7. Solutions having pH less than 7 are acidic in nature and the solutions with pH more than 7 are basic in nature.

Indicators
Acids and bases can be better distinguished with the help of indicators. Indicators are substances that undergo a change of color with a change of acidic, neutral or basic medium.
Litmus, a purple dye extracted from the lichen plant, is commonly used as an indicator in laboratories. Acids change the color of litmus solution to red, and bases change the color of litmus solution to blue.

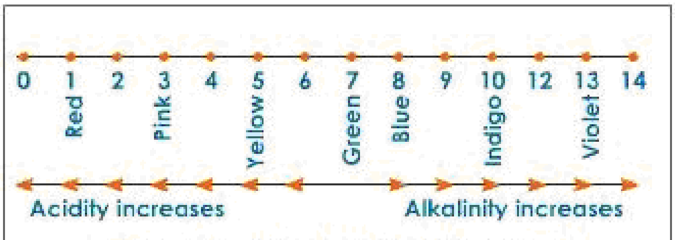
Turmeric is another common household indicator. A stain of turmeric based food spill on a white cloth becomes reddish-brown when soap is scrubbed on it. Soap is basic in nature and changes the color of the turmeric stain. It turns yellow again when the cloth is washed with plenty of water. Other indicators—

- Red cabbage extract gives red color in acidic solutions & yellow color in basic solutions.
- Onion has a characteristic smell. In basic solutions like NaOH, there is no smell. Acids however, do not destroy the smell of onions.
- Vanilla extract has a pleasant smell in acidic solutions, in basic solutions there is no smell.

The common indicators used and the color changes observed are mentioned below:

Indicator	**Acid**	**Alkali**
Litmus	Red	Blue
Methyl orange	Pink	Yellow
Phenolphthalein	Colorless	Deep pink
Methyl red	Yellow	Red

Universal Indicator: It is a mixture of indicators which give a gradual change of various colors over a wide range of pH.



Colour changes of universal indicator at different pH values

Approximate pH Values of Some Common Substances

Substance	**pH Value**
Hydrochloric acid	1.0
Sulphuric acid	1.2
Gastric juice	2.0
Rain water	6.2
Lemon	2.3
Milk	6.5
Vinegar (Acetic acid)	2.8
Pure water	7.0
Soft drink	3.0
Apple	3.1
Sea water	8.5

Grape	3.1
Ammonium hydroxide	11.1
Tomato	4.2
Sodium hydroxide	13.0

Importance of pH in our daily life:

(a) pH and Plants: Proper pH of soil is required for healthy growth of plants. It should not be too acidic or too basic.

(b) pH in the digestive system: Human body secrets hydrochloric acid which aids in digestion. **Hyperacidity**: The Condition of excess acid in the stomach. Hyperacidity can be cured by taking ant-acid tablets or suspensions.

(c) pH and tooth decay: Tooth enamel which is the hardest substance in our body is corroded when the pH of the mouth is below 5.5. Cleaning of teeth using toothpaste helps in preventing tooth decay. Toothpastes are basic in nature, therefore neutralize the excess acid in the mouth and thus prevent tooth decay.

Salts & pH of Salts

Salts are obtained by treating an acid with a base. Salts consist of both positive ions or 'cations', and negative ions or 'anions'. The cations are called basic radicals and are mostly obtained from metallic ions (ammonium ion being one exception), while the anions are called acidic radicals and are obtained from acids.

$$\underset{\substack{\text{Sodium hydroxide}\\\text{(Base)}}}{Na^+OH^-(aq)} + \underset{\substack{\text{Hydrochloric acid}\\\text{(Acid)}}}{H^+Cl^-(aq)} \rightarrow \underset{\substack{\text{Sodium chloride}\\\text{(Salt)}}}{NaCl(aq)} + \underset{\text{Water}}{H_2O(l)}$$

Salt is a compound, which on dissociation in water yields positive ions other than a hydrogen ion or hydronium ion, and a negative ion other than hydroxyl ion.

$$NaCl(aq) \rightarrow Na^+(aq) + Cl^-(aq)$$

Family of Salts: Salts can be classified into the following types:

Normal or Neutral Salts - A salt that is formed by the complete replacement of the replaceable hydrogen ions of an acid by a metal ion or ammonium ion is called a normal salt.

Examples: $NaCl$, Na_2SO_4, Na_3PO_4, NH_4Cl, K_2CO_3 etc.

A neutral salt arises due to the neutralization reaction. Here, salts of strong acid and strong base combine to form such salts that show a neutral pH of 7.

Sodium Chloride

Sodium chloride is the commonly available salt and so is called common salt. Seawater is the main source of sodium chloride. Seawater contains about 3.5% of soluble salts, the most common of which is sodium chloride (2.7 to 2.9%). Saline water of inland lakes is also a good source of this salt. Sodium chloride is also found as rock salt.

Common salt is generally obtained by evaporation of seawater. Crude sodium chloride is obtained by crystallization of 'brine' that contains sodium sulphate, calcium sulphate, calcium chloride and magnesium chloride as impurities.

Pure sodium chloride is obtained from the crude salt by dissolving it in minimum amount of water and filtering it to remove insoluble impurities. The solution is then saturated with hydrogen chloride gas, when crystals of pure sodium chloride separate out. Calcium and magnesium chlorides, being more soluble than sodium chloride, remain in solution.

Properties

- Sodium chloride is a white crystalline solid having a density of 2.17 g/ml.
- It melts at 1080 K (807°C) and boils at 1713 K (1440°C).
- It is soluble in water and its solubility is 36 g per 100 g of water at 273 K. (0°C). The solubility in water remains constant with temperature.
- Pure sodium chloride is non-hygroscopic, but behaves as hygroscopic due to the impurities of $CaCl_2$ and $MgCl_2$ in it.
- Solid Sodium chloride does not conduct electricity at room temperature but molten sodium chloride is a very good ionic conductor.

Uses

- As table salt, an essential constituent of our food.
- In the manufacture of Na_2CO_3, NaOH, Cl_2, etc.
- For salting out soap, and organic dyes.
- In freezing mixtures.
- In tanning and textile industries.
- As a preservative for fish, meat, butter etc.

Sodium Carbonate (Na_2CO_3)

Sodium carbonate exists as anhydrous (Na_2CO_3) and also as hydrated salt. The dehydrated salt ($Na_2CO_3.10H_2O$) is known as washing soda while the anhydrous salt is called soda ash.

Manufacture of Sodium Carbonate

Sodium carbonate is usually made by the Ammonia-soda process or Solvay process. The raw materials for this process are common salt, ammonia and limestone (for supplying CO_2 and quicklime).

When carbon dioxide is passed into a concentrated solution of brine saturated with ammonia, ammonium bicarbonate is produced. The ammonium bicarbonate then reacts with common salt forming sodium bicarbonate.

$$NH_4OH + H_2CO_3 \longrightarrow \underset{\text{Ammonium bicarbonate}}{NH_4HCO_3} + H_2O$$

$$NH_4HCO_3 + NaCl \longrightarrow \underset{\text{Sodium Bicarbonate}}{NaHCO_3} + NH_4Cl$$

Sodium bicarbonate being slightly soluble (in presence of sodium ions) gets precipitated. Precipitated sodium bicarbonate is removed by filtration and changed into sodium carbonate by heating.

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

Steps in the Solvay process

Step 1. Ammoniacal brine reacts with carbon dioxide to produce sodium hydrogen carbonate.

$NaCl + NH_3 + H_2O + CO_2 \rightarrow NH_4Cl + NaHCO_3$.

Step 2. Sodium hydrogen carbonate is heated to get sodium carbonate.

$2\ NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2$.

Step 3. Sodium carbonate is recrystallized by dissolving in water to get washing soda.

$Na_2CO_3 + 10\ H_2O \rightarrow Na_2CO_3 .10H_2O$

Limestone is heated to obtain CO_2. $CaCO_3 \rightarrow CaO + CO_2$.

The quicklime is dissolved in water to obtain slaked lime which is made to react with ammonium chloride to obtain ammonia which is used in step 1.

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

$Ca(OH)_2 + NH_4Cl \rightarrow CaCl_2 + 2\ NH_3 + 2H_2O$

Properties

Sodium carbonate is a white crystalline solid, which can exist as anhydrous salt (Na_2CO_3), monohydrate salt ($Na_2CO_3.H_2O$), heptahydrate salt ($Na_2CO_3.7H_2O$) and decahydrate ($Na_2CO_3.10H_2O$ - washing soda). Sodium carbonate is readily soluble in water. On heating, the decahydrate salt gradually loses water to, finally give anhydrous salt (Na_2CO_3 - soda ash).

$$\underset{\text{(washing soda)}}{Na_2CO_3.10H_2O} \xrightarrow[-\,9H_2O]{373\text{ K}} Na_2CO_3.H_2O \xrightarrow[-\,H_2O]{\text{above }373\text{ K}} \underset{\text{(soda ash)}}{Na_2CO_3}$$

Uses

- For the manufacture of glass.

- For washing purposes in laundries.
- For the manufacture of other sodium compounds like sodium silicates, sodium hydroxide, borax, hypo etc.
- As a household cleansing agent.
- In paper and soap/detergent industries.
- For the softening of water.
- A mixture of $NaCO_3$ and KCO_3 is used as a fusion mixture.
- In textile industry and petroleum refining.

Sodium Hydrogen Carbonate, ($NaHCO_3$)

Sodium hydrogen carbonate is also known as sodium bicarbonate or baking soda because it decomposes on heating to generate bubbles of carbon dioxide (leaving pores in cakes or pastries and making them light and fluffy).

Preparation

$NaHCO_3$ is made by saturating a solution of sodium carbonate with carbon dioxide. The white crystalline powder of sodium hydrogen carbonate being less soluble gets separated.

$$Na_2CO_3 + H_2O + CO_2 \longrightarrow NaHCO_3$$

On an industrial scale, sodium hydrogen carbonate ($NaHCO_3$) is obtained as an intermediate product in Solvay process for the manufacture of sodium carbonate.

Properties

- Sodium hydrogen carbonate is a white crystalline solid having a density of about 2.2 g/ml.
- It has alkaline taste and is sparingly soluble in water. The solubility of sodium hydrogen carbonate increases with the rise of temperature.

Uses

- As a component of baking powder.
- In fire extinguishers.
- In medicines as a mild antiseptic for skin diseases and to neutralize the acidity of stomach.
- As a reagent in laboratory.

Sodium Hydroxide (NaOH)

Sodium hydroxide is commonly called caustic soda because of its corrosive action on animal and vegetable tissues. Large quantity of sodium hydroxide is prepared by electrolytic process called the 'Chlor-alkali process'. Here, chlorine gas is given of at the anode and hydrogen gas at the cathode. Sodium hydroxide solution is formed near the cathode.

Properties

- Sodium hydroxide is a white deliquescent solid having melting point at 591 K (318°C).
- It is stable towards heat.
- It is highly soluble in water and considerable amount of heat is evolved due to the formation of a number of hydrates e.g., $NaOH.H_2O$, $NaOH.2H_2O$. It is also soluble in alcohol.
- Aqueous solution of sodium hydroxide is strongly alkaline due to its complete dissociation into Na^+ and OH^-.

$$NaOH + H_2O \longrightarrow Na^+(aq) + OH^-(aq)$$

- Solution of sodium hydroxide is soapy to touch. It has a bitter taste. When a concentrated solution of sodium hydroxide comes in contact with skin, it breaks down the skin and flesh to a pasty mass.

Uses

- In the manufacture of soap, paper, viscose rayon (artificial silk), organic dyestuffs, and many other chemicals.
- In the refining of petroleum and vegetable oils.
- In the purification of bauxite for the extraction of aluminum.
- As a cleansing agent and in washing powder for machines, metal sheets etc. It is too caustic to be used in washing clothes or hands.
- For mercerizing cotton.
- As a reagent in the laboratory.
- In reclaiming rubber.
- In the preparation of soda lime.

Plaster of Paris, [$CaSO_4$. ½ H_2O]

Calcium sulphate with half a molecule of water per molecule of the salt (hemi-hydrate) is called plaster of paris (plaster of paris).

Water of Crystallization

When crystals of certain salts are formed, they do so with a definite number of molecules of water, chemically combined in a definite proportion. Water of crystallization is the number of water molecules, chemically combined in a definite molecular proportion, with the salt in its crystalline state. This water is responsible for the geometric shape and color of the crystals.

Remember

A substance containing water of crystallization is called a hydrous substance or a hydrate. This water can be expelled, by heating, and then the salt is said to have become anhydrous.

Preparation

Plaster of Paris is prepared by heating gypsum ($CaSO_4.2H_2O$) at 120°C in rotary kilns, where it gets partially dehydrated.

$$2\,(CaSO_4.2H_2O) \xrightarrow{120^{\circ}C} 2(CaSO_4).H_2O + 2H_2O$$

The temperature should be kept below 140°C otherwise further dehydration will take place and the setting property of the plaster will be partially reduced.

Properties

It is a white powder. When mixed with water (1/3 of its mass), it evolves heat and quickly sets to a hard porous mass within 5 to 15 minutes. During setting, a slight expansion (about 1%) in volume occurs so that it fills the mould completely and takes a sharp impression. The process of setting occurs as follows:

$$\underset{\text{plaster of paris}}{CaSO_4.1/2H_2O} \xrightarrow[\text{setting}]{H_2O} \underset{\substack{\text{gypsum}\\ \text{orthorhombic}\\ \text{dihydrate}}}{CaSO_4.2H_2O} \xrightarrow[\text{hardening}]{} \underset{\substack{\text{gypsum}\\ \text{monoclinic dihydrate}}}{CaSO_4.2H_2O}$$

The first step is called the setting stage, and the second, the hardening stage. The setting of plaster of Paris is catalyzed by sodium chloride, while it is reduced by borax, or alum.

Uses

- In surgery for setting broken or fractured bones.
- For making casts for statues, in dentistry, for surgical instruments, and toys etc.
- In making black board chalks, and statues.
- In construction industry.