Acids, Bases and Salts

Acids, Bases and Salts

Acids – Acids are compounds which give hydrogen ion in water solution. For example, Hydrochloric acid (HCl), Sulphuric acid(H_2SO_4), Nitric acid(HNO_3).

$$HCl(aq) \longrightarrow \underset{\text{(Hydrogen ion)}}{\underset{\Downarrow}{H^+}} + Cl^-$$

$$H^+ + H_2O \longrightarrow \underset{\text{(Hydronium ion)}}{\underset{\Downarrow}{H_3^+O}}$$

$$HNO_3(aq) \longrightarrow H^+ + NO_3$$

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

Bases – Bases are compounds which give hydroxide ion in water solution. For example, Sodium hydroxide(NaOH), Potassium hydroxide(KOH), Calcium hydroxide($Ca(OH)_2$).

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

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

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

Salts – Salts are compounds obtained by replacement of H from acid by a metal. For example, Sodium chloride (NaCl), Copper sulphate ($CuSO_4$), Potassium nitrate (KNO_3).

$$\underset{NaCl}{\underset{\Downarrow}{HCl}}, \quad \underset{CuSO_4}{\underset{\Downarrow}{H_2SO_4}}, \quad \underset{KNO_3}{\underset{\Downarrow}{HNO_3}}$$

Strong and Weak –

- **Strong acids** ionize fully in water to produce large number of H^+ ions. For example, Hydrochloric acid (HCl), Sulphuric acid(H_2SO_4), Nitric acid(HNO_3), hydrobromic acid(HBr).

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

- **Weak acids** ionize partially in water to produce small number of H+ ions. For example, carbonic acid(H_2CO_3), phosphoric acid(H_3PO_4), sulphurous acid(H_2SO_3), acetic acid(CH_3COOH).

$$CH_3COOH(aq) \rightleftharpoons CH_3COO^- + H^+$$

- **Strong bases** ionize fully in water to produce large number of OH^- ions. For example, sodium hydroxide (NaOH), potassium hydroxide (KOH), lithium hydroxide (LiOH), calcium hydroxide ($Ca(OH)_2$).

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

- **Weak bases** ionize partially in water to produce small number of OH^- ions. For example magnesium hydroxide ($Mg(OH)_2$), ammonium hydroxide (NH_4OH).

$$Mg(OH)_2 \rightleftharpoons Mg^{2+} + 2OH^-$$

Concentrated and Dilute –

A concentrated solution is a solution in which large amount of solute is dissolved in less amount of water (solvent).

A dilute solution is a solution in which small amount of solute is dissolved in large amount of water (solvent).

For example, concentrated hydrochloric acid have more amount of HCl and less amount of water. On the other side, dilute hydrochloric acid have less amount of HCl and more amount of water.

For more examples, concentrated H_2SO_4, dilute H_2SO_4, concentrated CH_3COOH, dilute CH_3COOH, concentrated NaOH, dilute NaOH etc.

Diluting Acids and Bases –

- If concentrated acid (or base) is mixed with water, concentration of hydronium ions () decreases. So the acid or base becomes dilute.
- The phenomena of changing concentrated acid / base into dilute acid / base (respectively) is an exothermic reaction.
- Always add concentrated acid/base to water; not water to concentrated acid/base.
- When concentrated acid is added to water, heat is released gradually. This heat is absorbed by large amount of water to increase its temperature.
- When water is added to concentrated acid, heat is released suddenly. This heat vaporizes small amount of water to steam. This steam is splits out with drops of concentrated acid which can damage our body. So always add concentrated acid to water, not water to concentrated acid.
- Same is true with base also.

Presence and Taste –

Acids –

The word 'Acid' came from Latin word 'Acidus or Acere' which means sour. Sour taste is the most common characteristic of acid. There are many substances which contain acid and hence taste sour, such as curd, grapes, tamarind, lemon, tomato etc.

Types of Acids –

Acids can be divided into two types on the basis of their occurrence –

(i) Natural acids

(ii) Mineral acids.

Natural Acid – Acids which are obtained from natural sources (plants and animals) are called natural acid or organic acid.

Commonly found organic acids	Their natural sources
• Citric acid	Orange, lemon
• Tartaric acid	Tamarinds, grapes
• Lactic acid	Curd/ sour milk
• Oxalic acid	Tomatoes
• Acetic acid	Ketchup, vinegar (sirka)
• Formic acid (Methanoic acid)	Ant sting, nettle leaf sting

Mineral Acids – Acids that prepare from mineral are known as mineral acids/ inorganic acids/man-made acids or synthetic acid, such as hydrochloric acid (HCl), sulphuric acid (H_2SO_4) , nitric acid (HNO_3), etc.

Note:

- Organic acids are always weak but minerals acids can be strong as well as weak.
- We can take dilute weak acids (like organic acid) in our body. But strong acids (like strong mineral acids) are very harmful for us.

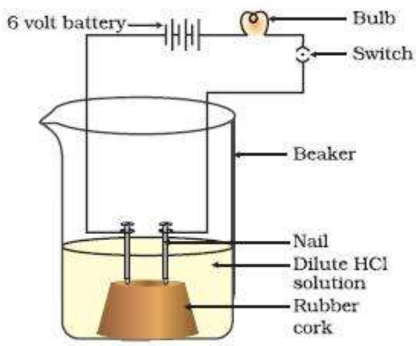
Bases –

Bases are bitter in taste and feels soapy on touch. There are many substances which contain bases such as soap, detergents, white wash etc.

Some common bases	Presence
• Sodium hydroxide (NaOH)	Soap, detergents, caustic soda
• potassium hydroxide(KOH)	Caustic potash
• sodium carbonate(Na_2CO_3)	Washing soda
• Calcium hydroxide($Ca(OH)_2$)	White wash

Conduction of Electricity in Acids/Bases –

- Take solution of hydrochloric acid (HCl).
- Fix two nails on a cork, and place the cork in a beaker.
- Connect the nails to the two terminals of a 6 volt battery through a bulb and a switch.
- Now pour some dilute HCl in the beaker and switch on the current.
- What do you observe?



- Bulb will start glowing.
- It indicates that there is flow of electricity in HCl solutions.
- When we pour some dilute HCl in beaker, it gets ionized and produces hydrogen ions(H^+) and chloride ions(Cl^-).

$$\underset{}{HCl(aq)} \longrightarrow \underbrace{H^+}_{\text{(Hydrogen ion)}} + \overbrace{Cl^-}^{\text{(Chloride ion)}}$$

- Hydrogen ions react with water and make hydronium ions.

$$H^+ + H_2O \longrightarrow \underbrace{H_3^+O}_{\text{(Hydronium ion)}}$$

- These chloride and hydronium ions can move in solution to conduct electricity.
- You can repeat the same activity with other acids and bases.
- Acid and base solution can conduct electricity due to formation of mobile ions. Therefore, acid and base solutions are called electrolytes.

Reactions of Acids and Bases –

Neutralization Reaction –

An acid neutralizes a base when they react with each other and respective salt and water are formed.

$$Acid + Base \longrightarrow Salt + Water$$

Since in the reaction between acid and base both neutralize each other, hence it is also known as neutralization reaction.

Example:

- Sodium chloride and water are formed when hydrochloric acid reacts with sodium hydroxide (a strong base).

$$\underset{\text{Hydrochloric Acid}}{HCl(aq)} + \underset{\text{Sodium Hydroxide}}{NaOH(aq)} \xrightarrow{\text{Neutralisation reaction}} \underset{\text{Sodium Chloride}}{NaCl(aq)} + \underset{\text{Water}}{H_2O(l)}$$

- In similar way, calcium chloride is formed along with water when hydrochloric acid reacts with calcium hydroxide (a base).

$$\underset{\text{Hydrochloric Acid}}{2HCl(aq)} + \underset{\text{Calcium Hydroxide}}{Ca(OH)_2(aq)} \longrightarrow \underset{\text{Calcium Chloride}}{CaCl_2(aq)} + \underset{\text{Water}}{2H_2O(l)}$$

- Sodium sulphate and water are formed when sulphuric acid reacts with sodium hydroxide (a base).

$$\underset{\text{Sulphuric Acid}}{H_2SO_4(aq)} + \underset{\text{Sodium Hydroxide}}{NaOH(aq)} \longrightarrow \underset{\text{Sodium Sulphate}}{Na_2SO_4(aq)} + \underset{\text{Water}}{H_2O(l)}$$

- In similar way, when nitric acid reacts with sodium hydroxide, sodium nitrate and water are formed.

$$\underset{\text{Nitric Acid}}{HNO_3(aq)} + \underset{\text{Sodium Hydroxide}}{NaOH(aq)} \longrightarrow \underset{\text{Sodium nitrate}}{NaNO_3} + \underset{\text{Water}}{H_2O(l)}$$

Note: The most important thing in whole process is that H^+ and OH^- ions combine to form H_2O.

$$H^+(aq) + OH^-(aq) \xrightarrow{\text{Neutrilisation}} H_2O$$

Reaction of acids with metal Oxides –

Metal oxide is a chemical compound that contains oxygen and one metal in its chemical formula. For example, copper oxide (CuO), sodium oxide (Na_2O), magnesium oxide (MgO).

Acids give water along with respective salt when they react with a metal oxide.

$$\text{Metal} + \text{acid} \longrightarrow \text{Respective salt} + \text{Water}$$

Example:

- Water and sodium chloride are formed when hydrochloric acid reacts with sodium oxide.

$$Na_2O + 2HCl\ (aq)\ 2NaCl + H_2O$$

- Water and magnesium chloride are formed when hydrochloric acid reacts with magnesium oxide.

$$MgO + 2HCl\ MgCl_2 + H2O$$

- Water and copper sulphate are formed when copper oxide reacts with sulphuric acid.

$$CuO + H_2SO_4\ (aq)\ CuSO_4 + H_2O$$

- Water and copper chloride are formed when copper oxide reacts with hydrochloric acid.

$$CuO + 2HCl\ (aq)\ CuCl_2 + H_2O$$

Reaction of bases with non–metal Oxides –

Non – metal oxide is a chemical compound that contains oxygen and one non – metal in its chemical formula. For example, carbon dioxide (CO_2), sulphur dioxide (SO_2).

When a base reacts with non-metal oxide both neutralize each other resulting respective salt and water are produced.

$$\text{Base + non – metal oxide} \longrightarrow \text{Respective salt + water}$$

Example :

- Sodium hydroxide gives sodium carbonate and water when it reacts with carbon dioxide.

$$\underset{\text{Sodium hydroxide}}{2NaOH(aq)} + \underset{\text{Carbon dioxide}}{CO_2(g)} \longrightarrow \underset{\text{Sodium carbonate}}{Na_2CO_3} + \underset{\text{Water}}{H_2O}$$

- Calcium hydroxide gives calcium carbonate and water when it reacts with carbon dioxide.

$$\underset{\text{Calcium hydroxide}}{Ca(OH)_2(aq)} + \underset{\text{Carbon dioxide}}{CO_2(g)} \longrightarrow \underset{\text{Calcium carbonate}}{CaCO_3(s)} + \underset{\text{Water}}{H_2O(l)}$$

Note :

- When an **acid** reacts with a **metal oxide,** both neutralize each other. In this reaction, respective salt and water are formed as we saw in neutralization reaction. So it can be said that metal oxide are basic in nature.

- Similarly when a **base** reacts with a **non – metal oxide**, both neutralize each other. In this reaction, respective salt and water are formed. So it can be said that non – metal oxide are acidic in nature.

Reaction of acids with metal –

Acids give hydrogen gas along with respective salt when they react with a metal.

$$Metal + Acid \longrightarrow Salt + Hydrogen\ gas$$

Example:

- Hydrogen gas and zinc chloride are formed when hydrochloric acid reacts with zinc metal.

$$\underset{\text{Zinc}}{Zn} + \underset{\text{Hydrochloric acid}}{2HCl(l)} \longrightarrow \underset{\text{Zinc chloride}}{ZnCl_2(s)} + \underset{\text{Hydrogen}}{H_2}$$

- Hydrogen gas and sodium chloride are formed when hydrochloric acid reacts with sodium metal.

$$\underset{\text{Sodium}}{2Na(s)} + \underset{\text{Hydrochloric acid}}{2HCl(l)} \longrightarrow \underset{\text{Sodium chloride}}{2NaCl(aq)} + \underset{\text{Hydrogen}}{H_2(g)}$$

- Hydrogen gas and iron chloride are formed when hydrochloric acid reacts with iron.

$$\underset{\text{Iron}}{Fe(s)} + \underset{\text{Hydrochloric acid}}{2HCl(aq)} \longrightarrow \underset{\text{Ferrous chloride}}{FeCl_2(aq)} + \underset{\text{Hydrogen}}{H_2(g)}$$

- Hydrogen gas and zinc sulphate are formed when zinc metal reacts with sulphuric acid

$$\underset{\text{Zinc}}{Zn(s)} + \underset{\text{Sulphuric acid}}{H_2SO_4(l)} \longrightarrow \underset{\text{Zinc sulphate}}{ZnSO_4(aq)} + \underset{\text{Hydrogen}}{H_2(g)}$$

Note: Acid is not stored in metallic containers as acids and metals can easily react.

Reaction of Base with Metals –

When base reacts with metal, it produces salt and hydrogen gas.

$$Alkali + metal \longrightarrow Respective\ salt + hdyrogen\ gas$$

Example:

- Sodium hydroxide gives hydrogen gas and sodium zincate when reacts with zinc metal.

$$\underset{\text{Sodium hydroxide}}{2NaOH(aq)} + \underset{\text{Zinc}}{Zn(s)} \longrightarrow \underset{\text{Sodium zincate}}{Na_2ZNO_2(aq)} + \underset{\text{Hydrogen}}{H_{2(g)}}$$

- Sodium aluminate and hydrogen gas are formed when sodium hydroxide reacts with aluminium metal.

$$\underset{\text{Sodium hydroxide}}{2NaOH(s)} + 2\underset{\text{Aluminium}}{Al(s)} + \underset{\text{Water}}{2H_2O} \longrightarrow \underset{\text{Sodium aluminate}}{2NaAlO_2(aq)} + \underset{\text{Hydrogen}}{2H_{2(g)}}$$

Note : Not all metals do this type of reaction.

Reaction of Carbonates and Bicarbonates with Acids –

Acids give carbon dioxide gas and respective salts along with water when they react with carbonates.

Carbonate + acid $\longrightarrow$ Salt + carbon dioxide + water

Examples:

- Hydrochloric acid gives carbon dioxide gas, sodium chloride along with water when reacts with sodium carbonate.

$$\underset{\text{Sodium Carbonate}}{Na_2CO_3} + \underset{\text{Hydrochloric acid}}{2HCl} \longrightarrow \underset{\text{Sodium Chloride}}{2NaCl} + \underset{\text{Carbon dixoide}}{CO_2} + \underset{\text{Water}}{H_2O}$$

- Hydrochloric acid gives carbon dioxide, magnesium chloride and water when it reacts with magnesium carbonate.

$$\underset{\text{Magnesium Carbonate}}{MgCO_3} + \underset{\text{Hydrochloric acid}}{2HCl} \longrightarrow \underset{\text{Magnesium Chloride}}{MgCl_2} + \underset{\text{Carbon dixoide}}{CO_2} + \underset{\text{Water}}{H_2O}$$

- Hydrochloric acid gives carbon dioxide gas, calcium chloride and water when it reacts with calcium carbonate.

$$\underset{\text{Calcium Carbonate}}{CaCO_3} + \underset{\text{Hydrochloric acid}}{2HCl} \longrightarrow \underset{\text{Calcium Chloride}}{CaCl_2} + \underset{\text{Carbon dixoide}}{CO_2} + \underset{\text{Water}}{H_2O}$$

- Sulphuric acid gives calcium sulphate, carbon dioxide gas, calcium sulphate and water when it reacts with calcium carbonate.

$$\underset{\text{Calcium Carbonate}}{CaCO_3} + \underset{\text{Sulphuric acid}}{H_2SO_4} \longrightarrow \underset{\text{Calcium sulphate}}{CaSO_4} + \underset{\text{Carbon dixoide}}{CO_2} + \underset{\text{Water}}{H_2O}$$

- Sulphuric acid gives sodium sulphate, carbon dioxide gas and water when it reacts with sodium carbonate.

$$\underset{\text{Sodium Carbonate}}{Na_2CO_3} + \underset{\text{Sulphuric acid}}{H_2SO_4} \longrightarrow \underset{\text{Sodium sulphate}}{Na_2SO_4} + \underset{\text{Carbon dixoide}}{CO_2} + \underset{\text{Water}}{H_2O}$$

- Nitric acid gives sodium nitrate, water and carbon dioxide gas when it reacts with sodium carbonate.

$$\underset{\text{Nitric Acid}}{2HNO_3} + \underset{\text{Sodium carbonate}}{Na_2CO_3} \longrightarrow \underset{\text{Sodium nitrate}}{NaNO_3} + \underset{\text{Water}}{2H_2O} + \underset{\text{Carbon dixoide}}{CO_2}$$

Reaction of Acid with Bicarbonates –

Acids give carbon dioxide gas, respective salt and water when they react with bicarbonate.

Acid + bicarbonate $\longrightarrow$ Salt + carbon dioxide + water

Examples:

- Hydrochloric acid gives carbon dioxide, sodium chloride and water when it reacts with sodium bicarbonate.

$$\underset{\text{Sodium bicarbonate}}{NaHCO_3} + \underset{\text{Hydrochloric acid}}{HCl} \longrightarrow \underset{\text{Sodium Chloride}}{NaCl} + \underset{\text{Carbon dixoide}}{CO_2} + \underset{\text{Water}}{H_2O}$$

- Sulphuric acid gives sodium sulphate, carbon dioxide gas and water when it reacts with sodium bicarbonate.

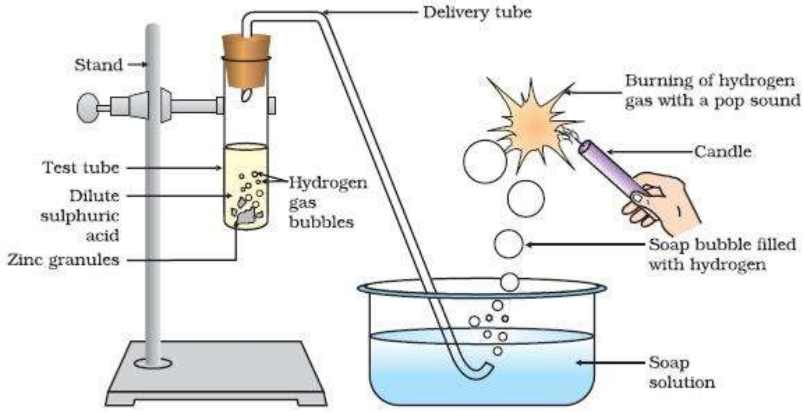
$$\underset{\text{Sodium bicarbonate}}{2NaHCO_3} + \underset{\text{Sulphuric acid}}{H_2SO_4} \longrightarrow \underset{\text{Sodium sulphate}}{Na_2SO_4} + \underset{\text{Carbon dixoide}}{2CO_2} + \underset{\text{Water}}{2H_2O}$$

Sodium bicarbonate is also known as sodium hydrogen carbonate / baking soda / baking powder / bread soda or bicarbonate of soda.

Note:

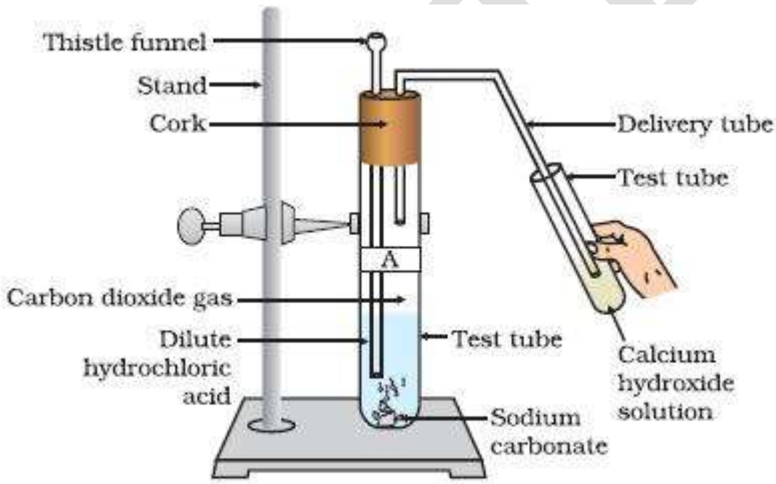
- In general, if we use weak acids, reactions will be slow and if we use strong acids, reactions will be fast.
- Generally bases do not react with carbonates and bicarbonates. So here we are not interested to see the reactions of bases with carbonates and bicarbonates.

Experiment to Show how do Acid and Base react with Metal –



- Set apparatus as above.
- Take zinc granules in a test tube and put dilute suphuric acid in it.
- You will see small bubbles of hydrogen gas in test tube.
- Pass the gas through soap solution.
- Soap bubble will be formed with the gas inside.
- Take a burning candle near bubbles.
- If the candle burns with pop sound, then it confirms the evolution of hydrogen gas. Burning with pop sound is the characteristic test for hydrogen gas.

Experiment to Show how do Carbonate and Bicarbonate react with Acid –



- Set apparatus as above with 0.5 gm of Na_2CO_3 in test tube.
- Pour 2mL of dilute HCl in test tube through thistle funnel.
- Brisk effervescence of gas is observed in test tube.
- Pass the gas produce through lime water.
- Lime water turns milky which shows that the gas was CO_2. This is the characteristic test for carbon dioxide gas.
- This happens because of formation of white precipitate of calcium carbonate.

$$\underset{\text{Calcium hydroxide(lime water)}}{Ca(OH)_2} + \underset{\text{Carbon dixoide}}{CO_2} \longrightarrow \underset{\text{Calcium carbonate(white ppt)}}{CaCO_3} + \underset{\text{Water}}{H_2O}$$

$$\underset{\text{Calcium carbonate(white ppt)}}{CaCO_3(s)} + \underset{\text{Carbon dixoide}}{CO_2(g)} + \underset{\text{Water}}{H_2O(l)} \longrightarrow \underset{\text{Calcium hydrogen carbonate}}{Ca(HCO_3)_2(aq)}$$

- On passing the gas continuously, milkyness disappears.
- This happens because of formation of calcium hydrogen carbonate. As calcium hydrogen carbonate is soluble in water, thus the milky colour of solution mixture disappears.

$$\underset{\text{Calcium hydroxide(lime water)}}{Ca(OH)_2} + \underset{\text{Carbon dixoide}}{CO_2} \longrightarrow \underset{\text{Calcium carbonate(white ppt)}}{CaCO_3} + \underset{\text{Water}}{H_2O}$$

$$\underset{\text{Calcium carbonate(white ppt)}}{CaCO_3(s)} + \underset{\text{Carbon dixoide}}{CO_2(g)} + \underset{\text{Water}}{H_2O(l)} \longrightarrow \underset{\text{Calcium hydrogen carbonate}}{Ca(HCO_3)_2(aq)}$$

Reaction of acid with marble and egg shell –
Since, marble and egg shell are made of calcium carbonate, hence when acid is poured over marble or egg shell, bubbles of carbon dioxide are formed.

Experiment to Show how does Metal Oxide react with Acid –

- Take small amount of black copper oxide in a test tube.
- Pour some dilute HCl slowly in test tube.
- Keep stirring.
- We observe a bluish – green solution due to formation of copper chloride.

Corrosive Nature of Acids and Bases –
- Acids and bases are corrosive in nature. They damage / destroy the substances with which they come into contact.
- **Strong acids and bases** are more corrosive while **weak acids and bases** are less corrosive.
- Specially **concentrated** acids and bases are more corrosive.
- Generally **dilute weak** acids and bases are not corrosive. Dilute weak acids are found in fruits and vegetable and we eat them in our meal because they are not corrosive. But concentrated **weak acids and bases** are corrosive in nature.

This symbol is used to warn us from corrosive substances.

Acid Rain:
- Due to air pollution, many harmful gases like nitrogen dioxide (NO_2) and sulphur dioxide (SO_2) come into atmosphere.
- Nitrogen dioxide and sulphur dioxide form nitric acid and sulphurous acid on reaction with water.
- When rain droplets mix with these gases; present in atmosphere; they form acid rain.
- Acid rain causes damage to the historical monuments and other buildings. For example Taj Mahal, which is made of marble, is getting damaged because of reaction with acid rain. Marble is calcium carbonate which reacts with the acid and thus gets corroded.

Uses of Acids and Bases –
- **Sulphuric acid** is used to make fertilizers, dyes, chemicals, plastics, fibres, detergent, explosives, car batteries.
- **Nitric acids** is used to make fertilizers, explosives (TNT – Tri Nitro Toluene), dyes, plastics.

- **Hydrochloric acid** is used to form dye, in textile industry, food and leather industry, removing metal oxide films from steel objects.
- **Sodium hydroxide** (base) is used to form soap, paper, fibre.
- **Calcium hydroxide** (base) is used in bleaching powder.

pH Scale –

When an acid is dissolved in water, it dissociates hydrogen. Because of this dissociation of hydrogen ion in aqueous solution, number of hydrogen ions(H^+) increases and number of hydroxide ions (OH^-) decreases.

Example:

- Hydrochloric acid (HCl) gives hydrogen ion (H^+) and chloride ion (Cl^-) when it is dissolved in water.
$$HCl(aq) \longrightarrow H^+(aq) + Cl^-(aq)$$
- Sulphuric acid (H_2SO_4) gives hydrogen ion (H^+) and sulphate ion (SO_4^-) in water.
$$H_2SO_4(aq) \longrightarrow H^+(aq) + SO_4^{-2}(aq)$$
- Nitric acid (HNO_3) gives hydrogen ion (H^+) and nitrate ion (NO_3^-) in water.
$$HNO_3(aq) \longrightarrow H^+(aq) + NO_3^-(aq)$$
- Acetic acid (CH_3COOH) gives acetate ion (CH_3COO^-) and hydrogen ion (H^+).
$$CH_3COOH(aq) \longrightarrow CH_3COO^-(aq) + H^+(aq)$$

Similarly a base dissociates hydroxide ion in water. Because of this dissociation of hydroxide ion (OH^-) in aqueous solution, number of hydroxide ions(OH^-) increases and number of hydrogen ions(H^+) decreases.

Example:

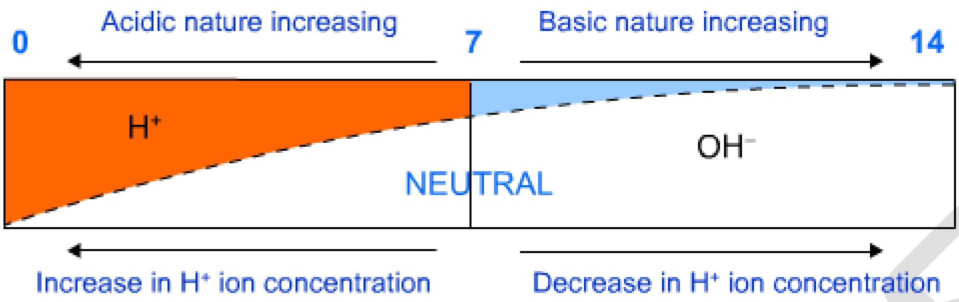
- When sodium hydroxide is dissolved in water, it dissociates hydroxide ion and sodium ion.
$$\underset{\text{Sodium hydroxide}}{NaOH(s)} \xrightarrow{Water} \underset{\text{Sodium ion}}{Na^+(aq)} + \underset{\text{Hydroxide ion}}{OH^-(aq)}$$
$$\underset{\text{Potassium hydroxide}}{KOH(s)} \xrightarrow{Water} \underset{\text{Sodium ion}}{K^+(aq)} + \underset{\text{Hydroxide ion}}{OH^-(aq)}$$
- When potassium hydroxide is dissolved in water, it dissociates hydroxide ion and potassium ion.
$$\underset{\text{Sodium hydroxide}}{NaOH(s)} \xrightarrow{Water} \underset{\text{Sodium ion}}{Na^+(aq)} + \underset{\text{Hydroxide ion}}{OH^-(aq)}$$
$$\underset{\text{Potassium hydroxide}}{KOH(s)} \xrightarrow{Water} \underset{\text{Sodium ion}}{K^+(aq)} + \underset{\text{Hydroxide ion}}{OH^-(aq)}$$
- If the concentration of hydrogen ion(H^+) is greater than hydroxide ion(OH^-), the solution is called acidic.
- If the concentration of hydrogen ion(H^+) is smaller than the hydroxide ion(OH^-), the solution is called basic.
- If the concentration of hydrogen ion(H^+) is equal to the concentration of hydroxide ion(OH^-), the solution is called neutral solution.
- If the concentration of hydrogen ion(H^+) is much greater than hydroxide ion(OH^-), the solution is called highly acidic.
- If the concentration of hydrogen ion(H^+) is much less than the hydroxide ion(OH^-), the solution is called highly basic.

pH is a scale which quantifies the concentration of hydrogen ion in a solution. The range of pH scale is between 0 to 14. The pH value increases with decrease in hydrogen ion concentration.

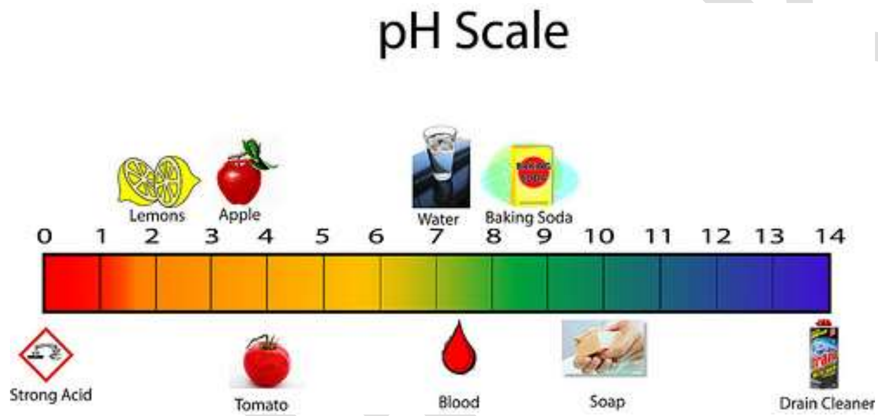
- If the value of pH is 0, this shows maximum hydrogen ion concentration.
- pH value equal to 14 shows lowest hydrogen ion concentration.
- pH value equal to 7 shows that hydrogen ion concentration is equal to hydroxide ion concentration.
- A neutral solution, such as distilled water has value of hydrogen ion concentration equal to 7 on pH scale.

- The acidic solution has value of hydrogen ion concentration less than 7 on pH scale.
- The basic solution has value of hydrogen ion concentration greater than 7 on pH scale.
- Thus we can say that pH is inversely proportional to concentration of H^+ ion.

$$pH \propto \frac{1}{[H^+]}$$



pH value of different substances –



Substances	pH value
Saliva (before meal)	7.4
Saliva (after meal)	5.8
Lemon juice	2.5
Colourless aerated drink	6
Carrot juice	6
Coffee	5
Tomato juice	4.1
Tap water	6.8
1 M NaOH Conc.	14
1M HCl Conc.	0

Acid Base Indicator –
Substances which identify/show the acidic or basic behavior of other substance by change in colour are known as indicator.

Type of Indicator: There are many types of indicators. Some common types of indicators are
- Natural Indicator
- Synthetic Indicator.
- Olfactory Indicator.
- Universal Indicator.

Natural Indicator –
Indicators obtained from natural sources are called natural indicators. Litmus, turmeric, etc. are some common natural indicators used widely to show the acidic or basic character of substances.

Litmus: It is obtained from lichens. The solution of litmus is purple in colour. When we add acid to litmus solution, it turns to red. And when we add base to litmus solution, it turns to blue.
Litmus paper comes in two colour – blue and red.
- An acid turns; blue litmus paper; red.
- A base turns; red litmus paper; blue.

Turmeric: Turmeric is yellow in colour. Turmeric solution or paper turns reddish brown with base. It does not change colour with acid.

Synthetic Indicator –
Indicators that are synthesized in laboratory are known as synthetic indicators. For example; phenolphthalein, methyl orange, etc.

Methyl Orange: It is used to show acidic and basic behavior of substance. It is originally orange in colour. It turns to red with acid and turns to yellow with base.

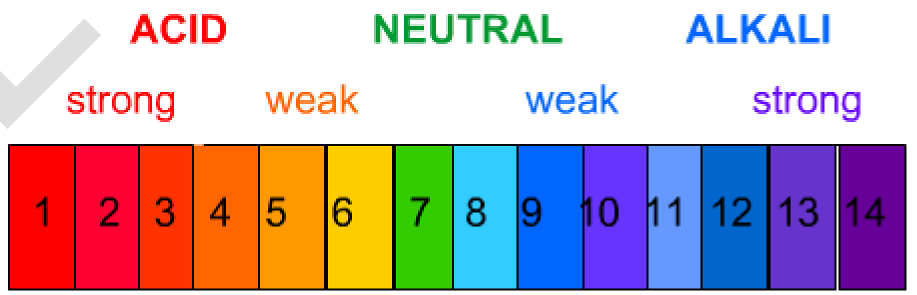
Phenolphthalein: It is also an indicator. It is a colourless liquid. Phenolphthalein remains colourless with acid but turns to pink with base.

Olfactory Indicators –
Substances which change their smell when mixed with acid or base are known as olfactory indicators. For example onion, vanilla, clove, etc.

Onion: Paste or juice of onion loses its smell when added with base. It does not change its smell with acid.

Vanilla: The smell of vanilla vanishes with base, but it's smell does not vanishes with an acid.

Universal Indicator –
Using a litmus paper, phenolphthalein, methyl orange, etc. only the acidic or basic character of a solution can be determined, but use of these indicators does not give the idea about the strength(pH value) of acid or base. So, to get the strength as well as acidic and basic nature of a given solution, universal indicator is used.
- Universal indicator shows different colour over the range of pH value from 1 to 14 for a given solution.
- Universal indicator is available both in the form of strips and solution.
- Universal indicator is the combination of many indicators, such as water, propanol, phenolphthalein, sodium salt, sodium hydroxide, methyl red, bromothymol blue monosodium salt, and thymol blue monosodium salt.
- The colour matching chart is supplied with universal indicator which shows the different colours for different values of pH.



pH value as shown by different colour in universal indicator

Colour	Dark Red	Red	Red	Orange Red	Orange	Orange yellow	Greenish yellow	Green	Greenish blue	Blue	Navy blue	Purple	Dark purple	Violet	Violet
pH	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14

Colour of Universal Indicator for different values of pH scale

Red cabbage: Red cabbage is a simple universal indicator.
When we add cabbage juice in different substances of different pH value, their colour get change.

If substance is highly acidic, its colour turns to red. If substance is highly basic, its colour turns to yellow. If substance is neutral in nature, solution remain bluish in colour.

Importance of pH in Everyday Life

pH in Digestive System –

When we start eating, our body produces strong dilute hydrochloric acid (HCl) to begin the process of digestion. Normally, your body produces just the amount of HCl and other chemicals it needs for digestion.
But, under certain conditions, our stomach starts producing more HCl acid. Too much stomach acid can cause pain and irritation. This problem is called acidity. At that point, we may have to take medicines called **antacids** that decrease the amount of active HCl in your stomach.
Antacids are actually anti acids or we can say basic in nature which neutralize acids in stomach and we feels good.

Tooth Decay –

Our mouth is full of bacteria. Some bacteria are helpful. But some can be harmful such as those that play a role in the tooth decay process.
Tooth decay is the result of an infection with certain types of bacteria. These bacteria use sugars in food to make acids. Over time, these acids can make a cavity in the tooth.
Toothpaste is used to protect our teeth from those acids. Toothpaste is basic in nature which neutralizes the acids and thus protects our teeth.

pH of Soil –

- Take soil and dissolve it in water.
- You will get a muddy solution.
- Now filter this solution and do a test either using universal indicator or using litmus paper or using any other acid base indicator.
- If soil is more acidic, you can use basic substance such as chalk, quick lime, and slacked lime to neutralize it.
- If soil is more basic in nature, you can use manure and compost (organic matters obtained by the decomposition of dead plants and animals) etc. to neutralize it.

Effects of pH on Animals and Plants –

pH of acid rain is around 5 – 6. This is highly acidic. Due to acid rain, acid reaches into oceans, lakes and affects the life of aquatic animals and plants. Some aquatic animals and plants are died due to acid rain and some plants lose lots of their leaves.
To neutralize this acidic behavior of lakes and oceans, calcium carbonate($CaCO_3$) is added into it.

Acids and Bases in absence of Water –

A dry acid does not dissociate in hydrogen ions. When we dissolve it with water, then it shows the acidic behavior.

For example, dry hydrochloric acid (gas) does not change the colour of blue litmus paper to red because a dry acid does not dissociate hydrogen ion. This is the cause that a moist litmus paper is used to check the acidic or basic character of a gas.

Similarly at room temperature, sodium hydroxide is in the form of solid. So as a solid, NaOH does not dissociate into hydroxide ion. When we dissolve it with water, then it shows its basic behavior.

Salt –

Salts are the ionic compounds which are produced after the neutralization reaction between acid and base.

Family of Salt –

Salts having common acidic or basic radicals are said to belong to same family.

Example:

- Sodium chloride (NaCl) and Calcium chloride ($CaCl_2$) belong to chloride family.
- Sodium sulphate (Na_2SO_4), Potassium sulphate (K_2SO_4) and Aluminium sulphate ($Al_2(SO4)_3$) belong to sulphate family.
- Calcium chloride ($CaCl_2$) and calcium sulphate ($CaSO_4$) belong to calcium family.
- Zinc chloride ($ZnCl_2$) and Zinc sulphate ($ZnSO_4$) belong to zinc family.

Conduction of Electricity –

As we saw that acid and base solution can conduct electricity due to formation of mobile ions.
Similarly when salt is dissolved in water, it ionizes to form ions. And these ions are responsible to conduct electricity same as in the case of acids and bases.
For example, if sodium chloride (NaCl) is dissolved in water, it ionizes to form Na^+ and Cl^- ions.

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

Hence salts can also conduct electricity.

pH Value of Acidic, Basic and Neutral Salt –

Neutral Salt –

Salts produced because of reaction between strong acid and strong base are neutral in nature. The pH value of such salts is equal to 7, i.e. neutral.
Examples of such type of salts are sodium chloride, sodium sulphate, potassium chloride, etc.

- **Sodium chloride (NaCl)** is formed after the reaction between hydrochloric acid (a strong acid) and sodium hydroxide (a strong base).

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

- **Sodium sulphate (Na_2SO_4)** is formed after the reaction between sodium hydroxide (a strong base) and sulphuric acid (a strong acid).

- **Potassium chloride (KCl)** is formed after the reaction between potassium hydroxide (a strong base) and hydrochloric acid (a strong acid).

$$\underset{\text{Sodium hydroxide}}{NaOH} + \underset{\text{Sulphuric acid}}{H_2SO_4} \longrightarrow \underset{\text{Sodium sulphate}}{Na_2SO_4} + \underset{\text{Water}}{H_2O}$$

$$\underset{\text{Potassium hydroxide}}{KOH} + \underset{\text{Hydrochloric acid}}{HCl} \longrightarrow \underset{\text{Potassium chloride}}{KCl} + \underset{\text{Water}}{H_2O}$$

Basic Salt –

Salts which are formed after the reaction between weak acid and strong base are called basic salt. The pH value of acidic salt is greater than 7.
Examples of such type of salts are sodium carbonate, sodium acetate, etc.

- **Sodium carbonate (Na_2CO_3)** is formed after the reaction between sodium hydroxide (a strong base) and carbonic acid (a weak base).
- **Sodium acetate (CH_3COONa)** is formed after the reaction between a strong base, sodium hydroxide and a weak acid, acetic acid.

$$\underset{\text{Carbonic acid}}{H_2CO_3} + \underset{\text{Sodium hydroxide}}{NaOH} \rightleftharpoons \underset{\text{Sodium carbonate}}{Na_2CO_3} + \underset{\text{Water}}{H_2O}$$

$$\underset{\text{Acetic acid}}{CH_3COOH} + \underset{\text{Sodium hydroxie}}{NaOH} \rightleftharpoons \underset{\text{Sodium acetate}}{CH_3COONa} + \underset{\text{Water}}{H_2O}$$

Acidic salt –

Salts which are formed after the reaction between a strong acid and weak base are called acidic salt. The pH value of acidic salt is lower than 7.
Examples of such type of salts are ammonium sulphate, ammonium chloride, etc.

- **Ammonium chloride(NH_4Cl)** is formed after reaction between hydrochloric acid (a strong acid) and ammonium hydroxide (a weak base).

- **Ammonium sulphate ($(NH_4)_2SO_4$)** is formed after reaction between ammonium hydroxide (weak base) and sulphuric acid (a strong acid).

$$\underset{\text{Ammonium hydroxide}}{NH_4OH} + \underset{\text{Hydrochloric acid}}{HCl} \rightleftharpoons \underset{\text{Ammonium chloride}}{NH_4Cl} + \underset{\text{Water}}{H_2O}$$

$$\underset{\text{Ammonium hydroxide}}{NH_4OH} + \underset{\text{Sulphuric acid}}{H_2SO_4} \rightleftharpoons \underset{\text{Ammonium sulphate}}{(NH_4)_2SO_4} + \underset{\text{Water}}{H_2O}$$

Cause of formation of acidic, basic and neutral salt –

- When equally strong acid and base react they fully neutralize each other. Due to this a neutral salt is formed in this case.
- When a strong acid reacts with a weak base, the base is unable to fully neutralize the acid. Due to this an acidic salt is formed in this case.
- When a strong base reacts with a weak acid, the acid is unable to fully neutralize the base. Due to this a basic salt is formed in this case.

Characteristics of salt:

- Most of the salts are crystalline solid.
- Salts may be transparent or opaque.
- Most of the salts are soluble in water.
- Solution of salts conducts electricity. Salts conduct electricity in their molten state also.
- The salt may be salty, sour, sweet, bitter and savory.
- Neutral salts are odourless.
- Salts can be colourless or of coloured.

Water of crystallization

Many salts contain water molecule and are known as hydrated salts. The water molecules present in salt is known as water of crystallization. For example; copper sulphate pentahydrate ($CuSO_4.5H_2O$), ferrous Sulphate heptahydrate ($FeSO_4.7H_2O$), Plaster of Paris etc.

Copper sulphate pentahydrate ($CuSO_4.5H_2O$):

- Blue colour of copper sulphate pentahydrate is due to presence of 5 molecules of water.
- When copper sulphate pentahydrate is heated, it loses water molecules and turns into grey-white colour, which is known as anhydrous copper sulphate.

$$\underset{\substack{\text{Copper sulpahte pentahydrate}\\ \text{Blue in colour}}}{CuSO_4.5H_2O} \xrightarrow{Heat} \underset{\substack{\text{Copper sulpahte}\\ \text{Anhydrous}}}{CuSO_4}$$

- After adding water; anhydrous copper sulphate becomes blue again.

Ferrous Sulphate heptahydrate ($FeSO_4.7H_2O$):

The green colour of ferrous sulphate heptahydrate; commonly known as ferrous sulphate; is due to the presence of 7 molecules of water in it.

Effect of heating on Water of Crystallization –

- Take crystal of $CuSO_4.5H_2O$ in dry boiling tube.
- Heat it over flame strongly.
- White powdery ($CuSO_4$) substance is formed.

$$\underset{\text{(Hydrated)}}{CuSO_4.5H_2O} \xrightarrow{\text{Heat}} \underset{\text{(Anhydrous)}}{CuSO_4} + 5H_2O\ (g)$$

- Water droplets are also seen in tube in the upper part.
- Allow the white powder to cool down and then add few drops of water.
- Colour of solid again changes to blue.

Plaster of Paris:

Plaster of Paris is obtained by heating of gypsum, a hydrated salt of calcium.

$$\underset{Gypsum}{CaSO_4.2H_2O} \xrightarrow{\text{Heat upto } 150°C} \underset{Plaster\ of\ Paris}{CaSO_4.\frac{1}{2}H_2O} + \underset{Water}{1\frac{1}{2}H_2O}$$

$$\underset{Plaster\ of\ Paris}{CaSO_4.\frac{1}{2}H_2O} + \underset{Water}{1\frac{1}{2}H_2O} \longrightarrow \underset{Gypsum}{CaSO_4.2H_2O}$$

After addition of water, Plaster of Paris is again converted into gypsum.
Plaster of Paris is used in making of toys, designer false ceiling, etc. Doctors use Plaster of Paris to set the fractured bone.

Common Salt (Sodium Chloride) –

Sodium chloride (NaCl) is also known as common salt or table salt. It is formed after the reaction between sodium hydroxide and hydrochloric acid.

$$NaOH + HCl \longrightarrow NaCl$$

- It is a neutral salt.
- The pH value of sodium chloride is about 7.
- Sodium chloride is used in cooking as well as to prepare many other important chemicals such as chemicals used in manufacturing industries.

Methods of obtaining Sodium Chloride –

1. From sea water by evaporation: Spread sea water in open. In summer season, water of seawater evaporates in atmosphere and we get sodium chloride.

2. From rock salts found in mines: Sodium chloride is mined from deposits which form underground. Deposits of rock salt are usually the remains of inland seas which evaporated thousands or millions of years ago.

Rock Salts (NaCl with impurities)

Making Other Chemical from Common Salt –
Sodium Hydroxide –
- Sodium hydroxide is a strong base. It is also known as caustic soda or Iye.
- It is obtained by the electrolytic decomposition of solution of sodium chloride (brine).
- In the process of electrolytic decomposition of brine (aqueous solution of sodium chloride), brine decomposes to form sodium hydroxide.
- In this process, chlorine is obtained at anode and hydrogen gas is obtained at cathode as byproducts. This whole process is known as Chlor-Alkali process.

$$\underset{\text{Sodium chloride}}{2NaCl} + \underset{\text{Water}}{H_2O} \xrightarrow{\text{Electrolysis}} \underset{\text{Sodium hydroxide}}{2NaOH(aq)} + \underset{\text{Chlorine}}{Cl_2(g)} + \underset{\text{Hydrogen}}{H_2(g)}$$

Use of products after the electrolysis of brine:

Hydrogen gas is used as fuel, margarine, in making of ammonia for fertilizer, etc.

Chlorine gas is used in water treatment, manufacturing of PVC, disinfectants, CFC, pesticides. It is also used in manufacturing of bleaching powder and hydrochloric acid.

Sodium hydroxide is used in de-greasing of metals, manufacturing of paper, soap, detergents, artificial fibres, bleach, etc.

Bleaching Powder ($CaOCl_2$) –
Bleaching powder is also known as chloride of lime. It is a solid and yellowish white in colour. Bleaching powder can be easily identified by the strong smell of chlorine.

When calcium hydroxide (slaked lime) reacts with chlorine, it gives calcium oxychloride (bleaching powder) and water is formed.

$$\underset{\text{Calcium hydroxide}}{Ca(OH)_2} + \underset{\text{Chlorine}}{Cl_2} \longrightarrow \underset{\text{Calcium oxychloride}}{CaOCl_2} + \underset{\text{Water}}{H_2O}$$

Water solution of bleaching powder is basic in nature.
The term bleach means removal of colour. Bleaching powder is often used as bleaching agent. It works because of oxidation. Chlorine in the bleaching powder is responsible for bleaching effect.

Use of bleaching powder:
- Bleaching powder is used as disinfectant to clean water, moss remover, weed killers, etc.
- Bleaching powder is used for bleaching of cotton in textile industry, bleaching of wood pulp in paper industry.
- Bleaching powder is used as oxidizing agent in many industries, such as textiles industry, paper industry, etc.

Baking Soda ($NaHCO_3$) –
Baking soda is another important product which can be obtained using byproducts of chlor-alkali process. The chemical name of baking soda is sodium hydrogen carbonate ($NaHCO_3$) or sodium bicarbonate. Bread soda, cooking soda, bicarbonate of soda, sodium bicarb, bicarb of soda or simply bicarb, etc. are some other names of baking soda.

Baking soda is obtained by the reaction of brine with carbon dioxide and ammonia. This is known as Solvay process.

$$\underset{\text{Sodium chloride}}{NaCl} + \underset{\text{Carbon dioxide}}{CO_2} + \underset{\text{Ammonia}}{NH_3} + \underset{\text{Water}}{H_2O} \longrightarrow \underset{\text{Ammonium chloride}}{NH_4Cl} + \underset{\text{Sodium bicarbonate}}{NaHCO_3}$$

In this process, calcium carbonate is used as the source of CO_2 and the resultant calcium oxide is used to recover ammonia from ammonium chloride.

Properties of sodium bicarbonate:
- Sodium bicarbonate is white crystalline solid, but it appears as fine powder
- Sodium hydrogen carbonate is amphoteric in nature
- Sodium hydrogen carbonate is sparingly soluble in water
- Thermal decomposition of sodium hydrogen carbonate (baking soda)
- When baking soda is heated, it decomposes into sodium carbonate, carbon dioxide and water

$$\underset{\text{Sodium bicarbonate}}{NaHCO_3} \xrightarrow{\text{Heat}} \underset{\text{Sodium carbonate}}{Na_2CO_3} + \underset{\text{Carbon dioxide}}{CO_2} + \underset{\text{Water}}{H_2O}$$

Sodium carbonate formed after thermal decomposition of sodium hydrogen carbonate; decomposes into sodium oxide and carbon dioxide on further heating.

$$\underset{\text{Sodium carbonate}}{Na_2CO_3} \xrightarrow{\text{Dehydration Reaction}} \underset{\text{Sodium oxide}}{Na_2O} + \underset{\text{Carbon dioxide}}{CO_2}$$

This reaction is known as dehydration reaction.

Use of Baking Soda:

- Baking soda is used in making of baking powder, which is used in cooking as it produces carbon dioxide which makes the batter soft and spongy.
- Baking soda is used as antacid.
- Baking soda is used in toothpaste which makes the teeth white and plaque free.
- Baking soda is used in cleansing of ornaments made of sliver.
- Since, sodium hydrogen carbonate gives carbon dioxide and sodium oxide on strong heating, thus it is used as fire extinguisher.

Baking powder –

Baking powder produces carbon dioxide on heating, so it is used in cooking to make the batter spongy. Although baking soda also produces carbon dioxide on heating, but it is not used in cooking because on heating; baking soda produces sodium carbonate along with carbon dioxide. The sodium carbonate; thus produced; makes the taste bitter.

$$\underset{\text{Sodium bicarbonate}}{NaHCO_3} \xrightarrow{\text{Heat}} \underset{\text{Sodium carbonate}}{Na_2CO_3} + \underset{\text{Carbon dioxide}}{CO_2} + \underset{\text{Water}}{H_2O}$$

Baking powder is the mixture of baking soda and a mild edible acid. Generally, tartaric acid is mixed with baking soda to make baking powder.

$$\underset{\substack{\text{Sodium bicarbonate}\\ \text{(Baking soda)}}}{NaHCO_3} + \underset{\text{Tartaric acid}}{C_4H_6O_6} \longrightarrow \underset{\text{Carbon dioxide}}{CO_2} + \underset{\text{Water}}{H_2O} + \underset{\text{Sodium tartarate}}{Na_2C_4H_4O_6}$$

$$\underset{\substack{\text{Sodium bicarbonate}\\ \text{(Baking soda)}}}{NaHCO_3} + \underset{\substack{\text{Hydrogen ion}\\ \text{(From tartaric acid)}}}{H^+(aq)} \longrightarrow \underset{\substack{\text{Sodium ion}\\ \text{(From sodium tartrate)}}}{Na^+} + \underset{\text{Carbon dioxide}}{CO_2} + \underset{\text{Water}}{H_2O}$$

When baking powder (mixture of baking soda and an edible acid) is heated, the sodium carbonate formed because of heating of baking soda neutralizes after reacting with tartaric acid and sodium tartarate salt is formed. The smell of sodium tartarate is pleasant and taste is good. This makes the cake or any other food tasty.

Washing Soda (Sodium carbonate) –

Sodium carbonate is manufactured by the thermal decomposition of sodium hydrogen carbonate obtained by Solvay process.

$$\underset{\text{Sodium chloride}}{NaCl} + \underset{\text{Carbon dioxide}}{CO_2} + \underset{\text{Ammonia}}{NH_3} + \underset{\text{Water}}{H_2O} \longrightarrow \underset{\text{Ammonium chloride}}{NH_4Cl} + \underset{\text{Sodium bicarbonate}}{NaHCO_3}$$

$$\underset{\text{Sodium bicarbonate}}{NaHCO_3} \xrightarrow{\text{Heat}} \underset{\text{Sodium carbonate}}{Na_2CO_3} + \underset{\text{Carbon dioxide}}{CO_2} + \underset{\text{Water}}{H_2O}$$

The sodium carbonate obtained in this process is dry. It is called soda ash or anhydrous sodium carbonate. Washing soda is obtained by rehydration of anhydrous sodium carbonate.

$$\underset{\text{Sodium carbonate}}{Na_2CO_3} + \underset{\text{Water}}{H_2O} \longrightarrow \underset{\text{Washing soda (Sodium bicarbonate decahydrate)}}{Na_2CO_3.10H_2O}$$

Since there are 10 water molecules in washing soda, hence it is known as Sodium bicarbonate decahydrate. Sodium carbonate is a crystalline solid and it is soluble in water when most of the carbonates are insoluble in water.

Use of sodium carbonate:

- It is used in cleaning of cloths; especially in rural areas.
- In making of detergent cake and powder.
- In removing permanent hardness of water.
- It is used in glass and paper industries.

Base & Alkali – Alkalis are water soluble bases.

Bases in which complete dissociation of hydroxide ion takes place are called strong base. In alkali; complete dissociation of hydroxide ions takes place so they are considered as strong base.

But it is not perfectly well defined that which substance is consider in category of Alkali and which is not.