CHEMISTRY

DINESH TUTORIAL
Creating excellence

Board – CBSE	Class – 10	Topic – Acids, Bases & Salts

Introduction

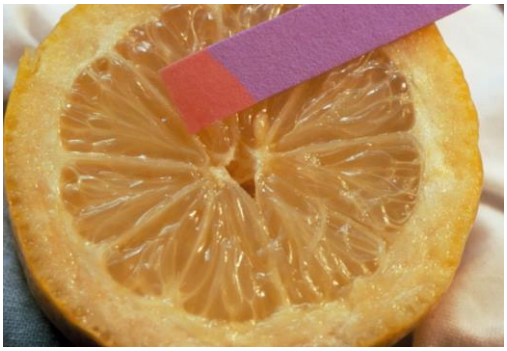
You all know that lemon, tomato, oranges tastes sour. You also know that all of them contains citric acid. This is the best natural example to prove that acids are sour in taste.

On the other hand, you all know that increased amount of baking soda makes the cake taste bitter. This is because baking soda is a base and hence tastes bitter.

When tested on a litmus paper acids turn the colour of the litmus to red whereas bases turns the colour of the litmus to blue.

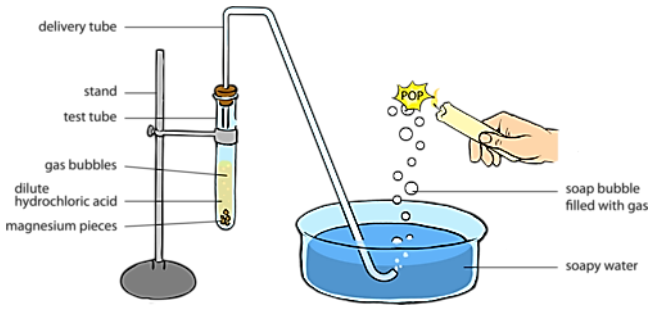
Litmus paper turns red when tested on acid & blue when tested on base.

Fig. lemon (acidic) and baking soda (basic)



Reaction of metals with acids

Metals react with acids and displaces hydrogen from the acids to produce hydrogen gas and metal salt. If a matchstick is brought near the mouth of the tube containing the product of the reaction then we hear a pop sound. It is this hydrogen gas that burns with a pop sound**.**



- For instance, Magnesium reacts with dilute hydrochloric acid to form magnesium chloride and hydrogen.

$$\underset{\text{Magnesium}}{Mg} + \underset{\text{Hydrochloric Acid}}{2\,HCl} \longrightarrow \underset{\text{Magnesium Chloride}}{MgCl_2} + H_2$$

- Electrochemical series is the development of a series of metals that are arranged as per their reactivity in a sequence from highest to lowest. Copper does not react with hydrochloric acid because it is below hydrogen in the electrochemical series due to which it does not react liberate hydrogen but reacts with sulphuric acid.

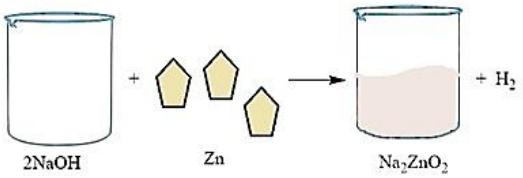
$$\underset{\text{Copper Oxide}}{CuO} + \underset{\text{Sulphuric Acid}}{H_2SO_4} \longrightarrow \underset{\text{Copper Sulphate}}{CuSO_4} + H_2O$$

Reaction of metals with bases

Metals react with base to give metal salt and hydrogen gas.

Metal like zinc reacts with sodium hydroxide to produce hydrogen gas. For instance, zinc reacts with sodium hydroxide to give sodium zincate.

$$\underset{\text{Zinc}}{Zn} + \underset{\text{Sodium Hydroxide}}{2NaOH} \longrightarrow \underset{\text{sodium zincate}}{Na_2ZnO_2} + H_2$$



Another example is when aluminium reacts with sodium hydroxide

$$\underset{\text{Aluminum}}{2\,Al} + \underset{\text{Sodium Hydroxide}}{2NaOH} + 6H_2O \longrightarrow 2Na^+ + \underset{\text{Aluminum Hydroxide}}{2[Al(OH)_4]^-} + 3H_2$$

Reaction of metal carbonates and metal hydrogen carbonates with acid

Metal carbonates are formed by reaction of metal salt with CO_2 or with a carbonate of a more reactive metal.

$$\underset{\text{Sodium Hydroxide}}{2NaOH} + CO_2 \longrightarrow \underset{\text{Sodium Carbonate}}{Na_2CO_3} + H_2O$$

Metal Hydrogencarbonates are formed by reaction of metal salt with HCO_3 or with a hydrogencarbonates of a more reactive metal.

Metal carbonates and Metal Hydrogencarbonates reacts with acids and produces corresponding metal salt, carbon dioxide and water.

Let us consider the reaction of sodium carbonate with dilute HCl. The reaction proceeds in the following manner.

$$\underset{\text{sodium carbonate}}{Na_2CO_3} + \underset{\text{Hydrochloric Acid}}{2HCl} \longrightarrow \underset{\text{Sodium Chloride}}{2NaCl} + H_2O + CO_2$$ Na_2CO_3 +

Secondly let us consider the reaction of sodium hydrogen carbonate with dilute HCl. The reaction proceeds as follows.

$$\underset{\text{Sodium hydrogencarbonate}}{NaHCO_3} + HCl \longrightarrow \underset{\text{Sodium Chloride}}{NaCl} + H_2O + CO_2$$

Both the reaction produces CO_2 which on passing through lime water makes lime water milky due to formation of calcium carbonate.

$$\underset{\text{Calcium Hydroxide}}{Ca(OH)_2} + CO_2 \longrightarrow \underset{\text{Calcium Carbonate}}{CaCO_3} + H_2O$$

On passing excess carbon dioxide following reaction occurs.

$$\underset{\text{Calcium Carbonate}}{CaCO_3} + H_2O + CO_2 \longrightarrow \underset{\text{Calcium Hydrogen Carbonate}}{Ca(HCO_3)_2}$$

- **Reaction of metallic oxides with acids**

Metallic oxides react with acids to give salts and water. Let us consider the reaction of copper oxide with dilute hydrochloric acid.

$$\underset{\text{Copper Oxide}}{CuO} + 2\,HCl \longrightarrow \underset{\text{Copper Chloride}}{CuCl_2} + H_2O$$

After the reaction takes place the colour of the solution becomes blue-green due to the formation of copper (II) chloride and the copper oxide dissolves. This proves that metallic oxides are basic oxides.

- **Reaction of non-metallic oxides with base**

Non-metallic oxides are formed by the reaction of non-metals with oxygen. They react with base to give salts and water. Let us consider the reaction of Calcium hydroxide (base) with carbon dioxide (non-metallic oxide) to produce salt and water.

$$\underset{\text{Calcium Hydroxide}}{Ca(OH)_2} + CO_2 \longrightarrow \underset{\text{Calcium Carbonate}}{CaCO_3} + H_2O$$

- **Reaction of non-metallic oxides with base**

Non-metallic oxides are formed by the reaction of non-metals with oxygen. They react with base to give salts and water. Let us consider the reaction of Calcium hydroxide (base) with carbon dioxide (non-metallic oxide) to produce salt and water.

$$Ca(OH)_2 + CO_2 \longrightarrow CaCO_3 + H_2O$$
Calcium Hydroxide — Calcium Carbonate

Reaction of acids and bases

Acids and bases react with each other to nullify the effect of each other. Let us consider a simple reaction. Take a sample of NaOH which is a base and add drops of dilute HCl.

The reaction will be as follows:

$$NaOH(aq) + HCl(aq) \longrightarrow NaCl(aq) + H_2O(l)$$
Sodium Hydroxide — Sodium Chloride

The reaction between an acid and a base to give a salt and water is known as a neutralisation reaction. Therefore, while suffering from acidity it is prescribed to take antacid which are bitter in taste i.e. they are base. And on entering the body they neutralise the acid and convert into salt and water.

What happens to acid and base in water?

Acids in water solution dissociates H^+ ions. Let us consider the reaction between water and hydrochloric acid (HCl). HCl in presence of water produces H^+ ion. This ion cannot exist alone and hence combines with water molecules and forms H_3O^+. The reaction is as follows:

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

Base when dissolved in water produces OH^- ion. Let us consider the reaction between water and sodium hydroxide NaOH. NaOH in presence of water produces OH^- ion.

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

Therefore the neutralisation stands out as follows:

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

$$HX + MOH \longrightarrow MX + HOH$$

$$H^+ + OH^- \longrightarrow H_2O$$

Cautions while adding acid to water

- Reaction of acid or base with water leads to the decrease in the concentration of ions (H_3O^+/OH^-) per unit volume. This process is known as dilution.
- The procedure of dissolving acid or base in water is highly exothermic reaction.
- The acid needs to be added slowly to water with constant stirring.

- Adding water to concentrated acid generates tremendous heat causing the mixture to splash out and can even cause burns.
- The beaker used for the reaction may also break due to the generation of excessive indigenous heating.

Acid and bases conduct electricity

Acids and Bases exhibit their conducting property only if they are in aqueous solution in which they could completely ionize in water. An acid in water solution dissociates H^+ ions. Let us consider the reaction between water and hydrochloric acid (HCl). HCl in presence of water produces H^+ ion. This ion cannot exist alone and hence combines with water molecules and forms H_3O^+. The reaction is as follows:

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

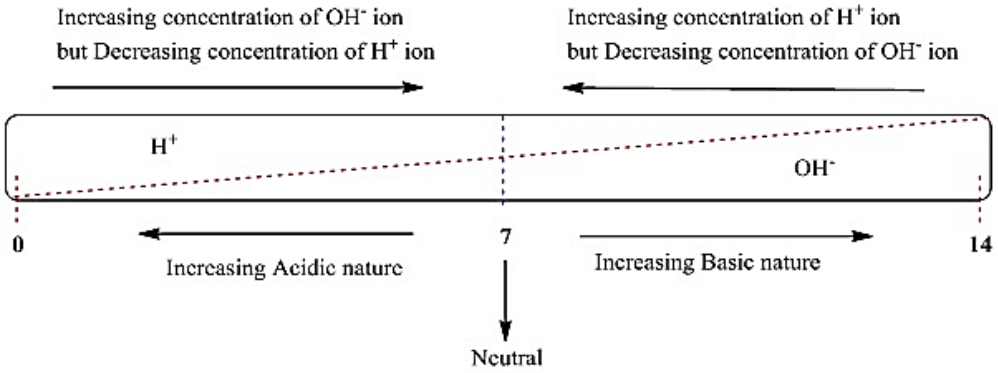
Base when dissolved in water produces OH^- ion. Let us consider the reaction between water and sodium hydroxide NaOH. NaOH in presence of water produces OH^-ion.

$$NaOH \xrightarrow{Heat} Na^+ + OH$$

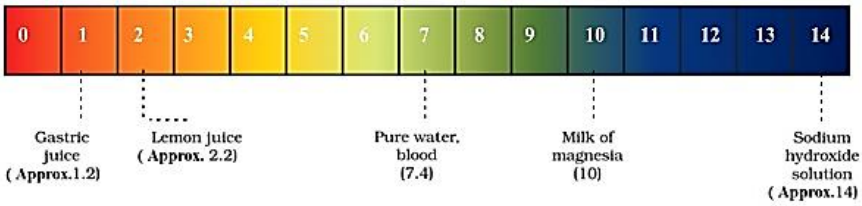
The H^+ and OH^- ions contain a free electron that carries the electric charge and thereby conducts electricity.

pH scale

- A scale developed to measure the concentration of hydrogen ion in a solution is known as pH scale where p in pH implies '*potenz*' in German.
- pH scale ranges from 0 (highly acidic) – 14 (highly alkaline).
- The pH of a neutral solution is 7.
- Acidic solution is represented by a value less than 7 on the pH scale.
- Whereas basic solution is represented by a value greater than 7 on the pH scale.
- An increase in OH^- ions concentration in the solution results in increase in the strength of alkali hence the value of pH increases.
- Acids giving rise to more H^+ ions are strong acids whereas those giving rise to less H+ ions are termed as weak acids.
- Similarly, bases giving rise to more OH^- ions are strong bases whereas those giving rise to less OH- ions are termed as weak bases.
- Salts of a strong acid and a strong base are neutral with pH value of 7.
- Salts of strong acid and weak base are acidic with pH value less than 7.
- Salts of a strong base and weak acid are basic in nature, with pH value more than 7.



pH scale in our day to day life



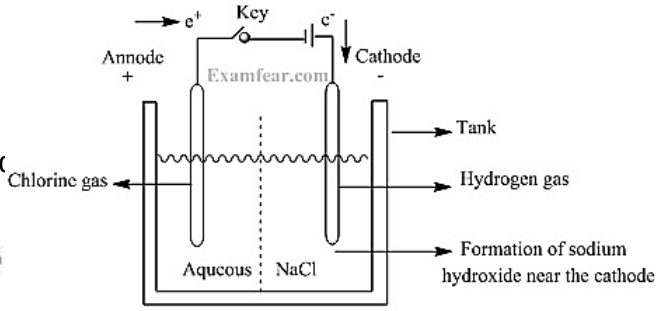
- Our body works within the pH range of 7.0 to 7.8. The pH of saliva ranges from 6.5-7.5.
- When pH of rain water is less than 5.6, it is called acid rain that lowers the pH of the river water and makes it difficult for marine creatures to survive.
- The pH of surface water is 6-8.5 and that of ground water is nearly 6.5-8.5
- Plants require a specific pH range for their healthy growth.
- pH of tomato juice ranges from 4.1 to 4.6 whereas the pH of carrot juice is 6.4.
- Our stomach produces hydrochloric acid during digestion of food causing no harm. But during indigestion an excess amount of acid is produced causing pain and irritation.
- Bacteria present in the mouth generates acids by decomposing the remaining sugar and food particles in the mouth that lowers the pH to 5.5 and corrodes calcium phosphate present in our teeth enamel.
- Ant sting injects formic acid and nettle stings and injects methanoic acid causing pain and irritation. Use of a mild base like baking soda on the stung area can provide relief to some extent due to neutralization reaction between acid and base.

Chemicals from salt

- Salts formed by the blend of hydrochloric acid and sodium hydroxide solution is called sodium chloride.
- The salt we commonly consume. It is neutral.
- This neutral common salt acts as a preliminary raw material for extracting several other materials of daily use, like sodium hydroxide, baking soda, washing soda, bleaching powder etc.

Sodium hydroxide

- Passing electricity through brine solution (an aqueous solution of sodium chloride), it decomposes to give chlorine and sodium hydroxide.
- The process is termed as the chlor-alkali process. The term chlor for chlorine and alkali for sodium hydroxide.
- Chlorine gas is given off at the anode,
- Hydrogen gas is given off at the cathode.
- Sodium hydroxide solution is formed near the cathoc
- The reaction that takes place is as follows:



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

Sodium Chloride — Sodium Hydroxide

Bleaching powder

- Chlorine produced on passing electricity through brine solution undergoes reaction with dry slaked lime [Ca $(OH)_2$] to produce Bleaching powder.
- The reaction is as follows:

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

Calcium Hydroxide — Calcium oxychloride

- It is used for several purposes:
- As a bleaching agent for bleaching cotton and linen in the textile industry,
- To bleach wood pulp in paper manufacturing industry.
- To bleach washed clothes in laundry.
- As an oxidising agent in many chemical industries.
- To disinfect drinking water and make it germfree.

Baking soda

- Chlorine produced on passing electricity through brine solution undergoes reaction with ammonia produces baking soda.
- The chemical name of baking soda is sodium hydrogencarbonate ($NaHCO_3$).
- It is a mild non-corrosive basic salt.
- The following reaction takes place.

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

Ammonium Chloride — Sodium Hydrogencarbonate

- On heating the reaction that takes place is as follows:

$$\underset{\text{Sodium hydrogencarbonate}}{2NaHCO_3} \longrightarrow \underset{\text{Sodium carbonate}}{Na_2CO_3} + H_2O + CO_2$$

- It is used for following purposes:
- Baking soda (sodium hydrogen carbonate) undergoes reaction with mild edible acid such as tartaric acid to manufacture baking powder. This baking powder on heating undergoes following reaction.

$$\underset{\text{Sodium Hydrogencarbonate}}{NaHCO_3} + H^+ \longrightarrow CO_2 + H_2O + \text{Sodium Salt of acid}$$

- This carbon-dioxide produced makes bread or cake rise thereby making them soft and spongy.
- Being alkaline it is also an active ingredient in antacids that acts by neutralising the excess acid produced in the stomach.
- It is also used in soda-acid fire extinguishers.

Washing soda

- This is another chemical derivative of sodium chloride. The heating of baking soda produces sodium carbonate.

$$\underset{\text{Sodium hydrogencarbonate}}{2NaHCO_3} \longrightarrow \underset{\text{Sodium carbonate}}{Na_2CO_3} + H_2O + CO_2$$

- This sodium carbonate undergoes recrystallization to give off washing soda.

$$\underset{\text{Sodium Carbonate}}{Na_2CO_3} + 10H_2O \longrightarrow Na_2CO_3.10H_2O$$

- It is also a basic salt.
- It is used for following purposes:
- It is used in glass, soap and paper manufacturing industries.
- It is also used in the manufacture of sodium compounds like borax.
- It is also used as a cleaning agent for domestic purposes.
- It also plays a pivotal role in removing permanent hardness of water.

Water of crystallisation

- The fixed number of water molecules present in one formula unit of a salt is called water of crystallisation.
- For instance, there are five molecules of water in one formula unit of copper sulphate and hence the chemical formula for hydrated copper sulphate is $CuSO_4.5H_2O$

Fig. Copper sulphate crystal

- Gypsum has two molecules of water as water of crystallisation and hence the chemical formula for hydrated gypsum stands out to be $CaSO_4.2H_2$
- This gypsum on getting heated loses water molecules and becomes calcium sulphate hemihydrate ($CaSO_4.1/2\ H_2O$). This is known as plaster of Paris.
- Uses of Plaster of Paris are as follows:
- Plaster for supporting fractured bones in their appropriate position.
- When mixed with water, it again changes to gypsum giving a hard solid mass. The reaction is as follows:

$$CaSO_4.\ 1/_2\ H_2O + 3/_2\ H_2O \longrightarrow CaSO_4.2H_2O$$

- It is also used for making toys, materials for decoration and for making smooth surfaces.

Acids, Bases and Salts

Arrhenius Concept :

Acids are defined as compounds which contain one or more hydrogen atoms and when dissolved in water, produces hydronium ions (H_3O^+) the only positively charged ions.

$HCl + H_2O \text{ ---------> } H_3O^+ + Cl^-$

- Hydronium ions are represented as H^+.
- Examples of acids: Acetic acid, hydrochloric acid, citric acid.
- The word 'acid' comes from the Latin word acidus, meaning 'sour'.

Base is a substance that produces hydroxyl (OH^-) ions when dissolved in water.

$NaOH\ [aq.] \text{ ---------> } Na^+ + OH^-$

- Examples of Bases : Potassium hydroxide, Ammonium hydroxide, Calcium hydroxide

Limitations of Arrhenius Concept :

1. It recognizes the dissociation of acids and bases and acid-base behavior in aqueous medium only.
2. It restricts acids to merely hydrogen containing compounds and bases to merely hydroxide containing compounds.
3. Substances such as CO_2, SO_2, NH_3, CaO are not taken into account although they show acidic and basic behavior and are not neutral.

Chemical Properties of Acid

Reaction with carbonates and bicarbonates (hydrogen carbonates)

Acids liberate carbon dioxide.

Carbonate / Bicarbonate +	Acid --->	Salt +	Water +	Carbon Dioxide
$CaCO_3$ +	2HCl --->	$CaCl_2$ +	H_2O +	CO_2 ↑
$Ca(HCO_3)_2$ +	2HCl --->	$CaCl_2$ +	$2H_2O$ +	$2CO_2$ ↑

Reaction with sulphites and bisulphites

Acids react with sulphites and bisulphites of metals to liberate sulphur dioxide.

Sulphite / Bicarbonate +	Acid --->	Salt +	Water +	Sulphite Dioxide
$CaSO_3$ +	2HCl --->	$CaCl_2$ +	H_2O +	SO_2 ↑
$NaHSO_3$ +	HCl --->	$NaCl_2$ +	H_2O +	SO_2 ↑

Reaction with sulphides

Acids react with metal sulphides to liberate hydrogen sulphide.

Metal sulphide +	Acid --->	Salt +	Hydrogen sulphide
ZnS +	2HCl --->	$ZnCl_2$ +	H_2S
FeS +	H_2SO_4 --->	$FeSO_4$ +	H_2S

Neutralization Reaction

Neutralization Reaction : Chemical reaction in which the hydrogen ions (H^+) or O^{2-} ions of an acid combine completely with the hydroxyl ions (OH^-) of a base to form the undissociated water molecules.

ACID + BASE ----------> SALT + WATER

HCl + KOH ----------> KCl + H_2O

Heat of neutralization: The amount of heat liberated when one mole of an acid or a base gets completely neutralized.

- Since all the neutralization reactions result in formation of water, the heat of neutralization of any neutralization reaction is same 57.3 kJ/mol.
- All neutralization reactions are exothermic.

Applications of neutralization reaction :

- The acidity of soil is reduced by adding slaked lime [$Ca(OH)_2$].
- Acidity in stomach is relieved by taking mild base like milk of magnesia.
- Stings of ants and bees contain formic acid, its neutralized by rubbing with soap solution.
- Harmful levels of CO_2 in submarines and spacecrafts are neutralized by lithium hydroxide.

Uses of Acids and Bases

Acids	Use	Bases	Use
Boric acid	Antiseptic	Sodium hydroxide	Manufacture of soap
Citric acid	Food preservation	Magnesium hydroxide	Antacid
Oxalic acid	Ink stain removal	Aluminium hydroxide	foaming agent in fire extinguishers
Carbonic acid	Soft-drink	Magnesia	In making refractory bricks.
Nitric acid	Explosives	Calcium oxide	Drying agent, basic reflux.

Strength of Acidic and Basic Solution

- Water ionizes to a very small extent. The concentration of H_3O^+(aq.) and OH^- (aq.) in pure water is found to be 1×10^{-7} mol litre^{-1}.
- The product of concentration of H_3O^+ and OH^- ions is known as ionic product of water (Kw).
- $Kw = (1 \times 10^{-7} \text{ mol litre}^{-1})(1 \times 10^{-7} \text{ mol litre}^{-1}) = 1 \times 10^{-14} \text{ mol}^2 \text{ litre}^{-2}$ at 25 °C.
- On adding acid to water, concentration of H_3O^+ ion increases and that of OH^- decreases so that Kw remains the same. It is vice versa for an alkali. The nature of solution depends on the concentration of H_3O^+ ion in solution.
- The pH of a solution is the negative logarithm to the base 10 of the hydrogen ion concentration expressed in moles per liter.

$$pH = \log_{10} \frac{1}{H^+} = -\log_{10} [H^+]$$

Example: Calculate the pH of a solution having

$[H^+] = 10^{-12}$ moles/L.

$$\text{Since pH} = \log_{10} \frac{1}{H^+} = \log_{10} \frac{1}{10^{-12} \text{ moles/L}}$$

$$= \log_{10} [10^{12}]$$

$$= 12 \log_{10} 10 = 12$$

- Number 7 on pH scale: Neutral
- Less than 7: Acidic
- More than 7: Basic
- Universal indicators are added to colorless solution to determine the pH of a solution.
- Universal indicators is a mixture of organic dyes or mixed indicators like pH paper or indicators.
- Universal indicator produces green color for neutral.
- From blue to violet for basic.
- From yellow to pink to red for acids.

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pH and its Applications

pH sensitivity in plants and animals : In gastric juices, if the pH goes below 1.4; acidity occurs leading to irritation and pain. Antacids such as milk of magnesia and other mild bases are used to reduce the acidity.

pH in tooth decay

- Carbohydrates and food particles present in our mouth after eating sweet tasting food decompose due to which HCl is produced. HCl causes tooth decay. It reacts with the enamel (calcium phosphate) to form soluble Calcium Chloride. In long run, this causes cavities.
  $Ca_3(PO_4)_2$ (s) + 6HCl (aq) ------> $2CaCl_2$ (aq) + $2H_3PO_4$ aq)
- Sodium flouride is added in the toothpaste to prevent decay. It reacts with calcium phosphate present in our teeth to form insoluble calcium flouride which gets coated on our teeth. Hence calcium phosphate is saved.
  $Ca_3(PO_4)_2$ (s) + 6NaF ------> $2CaF_2$ + $2Na_3PO_4$

Acids in joints and fatigued muscles :

- Accumulation of uric acid in joints leads to disease called **gout**. During strenuous exercises, the oxygen supply to muscles is less. This causes lactic acid accumulation causing pain.
- Calcium supplements containing calcium phosphate gives relief. It forms calcium lactate which is excreted through urine.

- Enzymes in our body works only at pH 7 - 7.5
- Some plants and insects use acids for self protection.

Solution	pH range
Human saliva	6.5-7.5
Blood	7.36-7.42
Gastric juices	1.0-2.0
Urine	5.5-7.5