UNIT 14

ACIDS AND BASES

Learning Objectives

After the completion of this lesson, students will be able to:

- define acids and bases.
- understand the properties of acids and bases.
- distinguish between acids and bases.
- list out the uses of acids and bases.
- understand the neutralisation reaction between acids and bases.
- know about acid – base indicators.

Introduction

In our daily life we come across different food substances. Some substances like tamarind, grapes, curd and lemon are sour. They are said to be acidic. Some substances like sodium bicarbonate and soap are bitter in taste. They are said to be basic. This means that they contain either acid or base. But what are acids and bases? Acids and bases are one of the important classifications of chemical compounds, which play a significant role in every field of science. Acids and bases find applications in various products from the soap used for shower to the vinegar in the kitchen. Acids and bases are biologically, industrially and environmentally important compounds. For example, among the medicines we use, aspirin is acidic and antacids are basic. Similarly, many biological molecules are also either acids or bases. Dietary fats are acids and the chemical compounds in DNA are bases. In this lesson we will study about the properties and uses of acids and bases, neutralisation of acids and bases and acid-base indicators.

14.1 Acids

The term acid is derived from the Latin word 'acidus' which means sour. Thus, the chemical compounds which have sour taste are generally called as acids. All acids contain one or more replaceable hydrogen atoms in their molecules and when dissolved in water they release H^+ ions. For example, Hydrochloric acid (HCl), Sulphuric acid (H_2SO_4) and Nitric acid (HNO_3) release hydrogen ions (H^+) when dissolved in water.

Hydrochloric acid $\xrightarrow{\text{Water}}$ Hydrogen ion + Chloride ion

$HCl \xrightarrow{H_2O} H^+ + Cl^-$

Sulphuric acid $\xrightarrow{\text{Water}}$ Hydrogen ion + Sulphate ion

$H_2SO_4 \xrightarrow{H_2O} 2H^+ + SO_4^{2-}$

DO YOU KNOW?

Swedish chemist Svante Arrhenius proposed a theory on acids. According to him, an acid is a substance which furnishes H^+ ions or H_3O^+ ions in aqueous solution.

Thus, acids are defined as the chemical substances which release hydrogen ions when dissolved in water.

Acids can be classified into organic acids and inorganic acids depending on the sources. Some acids occur naturally in fruits and vegetables. These are called organic acids. Examples: Citric acid, tartaric acid etc.,

Table 14.1 Organic acids and their sources

Name of the Acid	Source
Citric acid	Lemon
Lactic acid	Sour milk
Oxalic acid	Tomato
Acetic acid	Vinegar
Malic acid	Apple
Tartaric acid	Tamarind

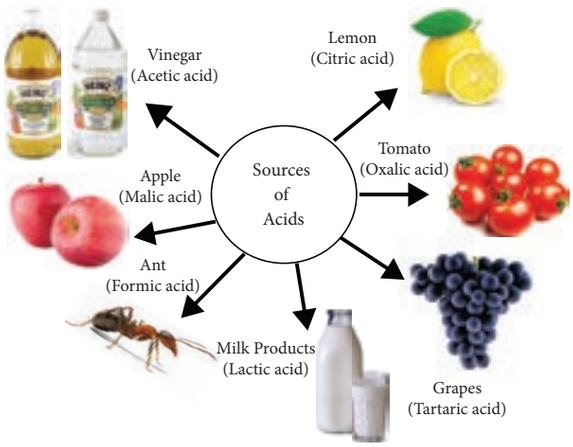

Figure 14.1 Acids and their sources

On the other hand, acids are produced artificially in industries. These acids are called mineral acids or inorganic acids. Examples: Hydrochloric acid (HCl), Sulphuric acid (H_2SO_4), Nitric acid (HNO_3) etc., There are many more classifications of acids. You will study about them in your higher classes.

14.1.1 Properties of Acids

a. Physical properties

- Acids are sour in taste.
- They are corrosive in nature. Strong acids can spoil substances like human skin, clothes and paper.
- Generally acids exist in liquid state but few acids exist in solid state as well. E.g. Benzoic acid
- Acids are colourless.
- Acids change the colour of the indicators. Blue litmus paper turns red and methyl orange turns pink when treated with acids.
- They are soluble in water.
- Solutions of acids conduct electricity due to ionisation in water.

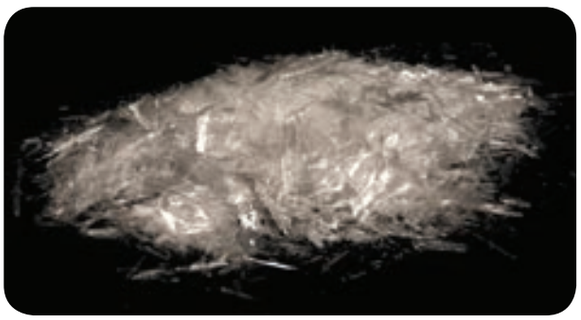

Figure 14.2 Benzoic acid crystals

DO YOU KNOW?

We feel hungry due to the corrosive action of hydrochloric acid on the inner lining of the stomach. When the level of hydrochloric acid goes higher, it causes ulcer.

b. Chemical properties

i. Reaction with metals

Metals like zinc, magnesium, aluminum, iron etc., react with acids like hydrochloric acid, sulphuric acid to form metal salts and release hydrogen gas.

Metal + Dilute acids → Metal salt + Hydrogen

Examples

Zinc + Hydrochloric acid → Zinc chloride + Hydrogen

$$Zn + 2HCl \rightarrow ZnCl_2 + H_2\uparrow$$

Iron + Sulphuric acid → Ferrous sulphate + Hydrogen

$$Fe + H_2SO_4 \rightarrow FeSO_4 + H_2\uparrow$$

Activity 1

Take a clean test tube with holder and pour some dilute hydrochloric acid. Add few pieces of magnesium ribbon slowly. What do you observe? Now show a burning match stick near the mouth of the test tube. Do you hear any sound? The gas burns with a pop sound. From this it is observed that hydrogen gas is formed due to the reaction between acid and metal (Do it under the supervision of the teacher).

DO YOU KNOW?

Copper or brass cooking vessels are coated with tin metal (eyam). If it is not coated the organic acids present in the food materials will react with copper and make the food poisonous. The tin isolates the vessel from the action of acids and prevents food poisoning.

ii. Reaction with metal carbonates and bicarbonates

When carbonates and bicarbonates come into contact with dilute acids carbon dioxide is given out along with water. For example, limestone (calcium carbonate) reacts with dilute sulphuric acid to form calcium sulphate, carbon dioxide and water.

Calcium carbonate + dil Sulphuric acid → Calcium sulphate + Carbon dioxide + Water

$$CaCO_3 + H_2SO_4 \rightarrow CaSO_4 + CO_2 + H_2O$$

Activity 2

Take some lemon juice in a tumbler and add baking soda slowly. What do you see? What do you infer from this?

iii. Reaction with metal oxide

Oxides of various metals react with dilute acids to form their metallic salts and water.

Metal oxides + dilute Acid → Metal salts + Water

Example:

Calcium oxide + Hydrochloric acid → Calcium chloride + Water

$$CaO + 2HCl \rightarrow CaCl_2 + H_2O$$

14.1.2 Uses of Acids

- Hydrochloric acid present in our stomach helps in the digestion of food materials.
- Vinegar (acetic acid) is used to preserve food materials.
- Benzoic acid is also used to preserve food materials like pickles.
- Sodium or potassium salts of higher fatty acids are used to make washing and bathing soaps.
- Sulphuric acid is called the king of chemicals. It is an effective dehydrating agent. It is used in various industries to make detergents, paints, fertilizers and many more chemicals.
- Hydrochloric acid, nitric acid and sulphuric acid are important laboratory reagents.
- Cells of all living organisms contain the fundamental nuclear material called nucleic acids. Animals have deoxy ribo nucleic acid (DNA) whereas plants contain ribo nucleic acid (RNA).

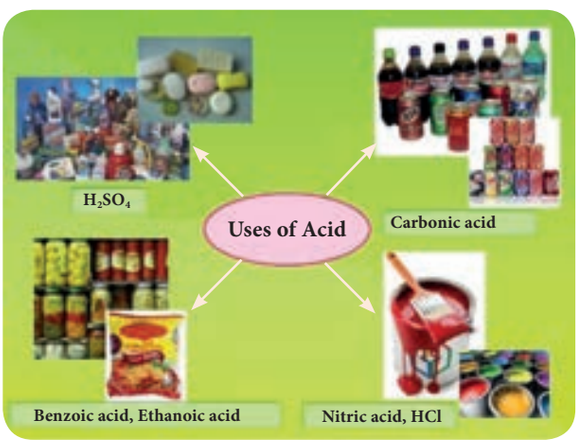

Figure 14.3 Uses of Acid

DO YOU KNOW?

Pickles remain in good condition for long time because they contain vinegar (acetic acid) or benzoic acid.

14.2 Bases

We use soaps for bathing as well as washing. Soaps are slippery in nature. Do you know why? Soaps are slippery due to the presence of 'base'. Bases are chemical substances that are corrosive and bitter in taste. A lot of bleaches, soaps, detergents, toothpaste, etc., contain bases. In contrast to acids which release hydrogen ions in water, bases release hydroxide ions in water.

Thus, the chemical substances that release hydroxide ions when dissolved in water are called as bases. Examples: Sodium hydroxide (NaOH) and Potassium hydroxide (KOH).

Sodium hydroxide $\xrightarrow{\text{Water}}$ Sodium ion + Hydroxide ion

$NaOH \xrightarrow{H_2O} Na^+ + OH^-$

Potassium hydroxide $\xrightarrow{\text{Water}}$ Potassium ion + Hydroxide ion

$KOH \xrightarrow{H_2O} K^+ + OH^-$

Water soluble bases are called Alkalis. Bases like sodium hydroxide, potassium hydroxide, calcium hydroxide and ammonium hydroxide are highly soluble in water and hence they are called alkalis. Certain chemical substances which do not release hydroxide ions when dissolved in water also behave as bases. Examples: Sodium carbonate, Sodium bicarbonate, Calcium carbonate etc.

Table 14.2 Common bases in some products

Base	Formula	Products
Magnesium hydroxide	$Mg(OH)_2$	Milk of magnesia
Sodium hydroxide	NaOH	Detergent
Ammonium hydroxide	NH_4OH	Solution for cleaning windows
Calcium hydroxide	$Ca(OH)_2$	Lime water
Potassium hydroxide	KOH	Soap

DO YOU KNOW?

Sodium carbonate (Na_2CO_3) is commercially called as washing soda. Similarly sodium bicarbonate ($NaHCO_3$) is commercially called as baking soda. Caustic soda is sodium hydroxide (NaOH) and caustic potash is potassium hydroxide (KOH).

Activity 3

Classify the following substances.

Sodium oxide, Potassium hydroxide, Calcium oxide, Copper oxide, Calcium hydroxide, Ammonium hydroxide, Ferric hydroxide, Zinc oxide

Base	Alkali	Oxide

14.2.1 Properties of Bases

a. Physical properties

- Bases generally exist in solid state but some bases exist in liquid state also. E.g. Ammonium hydroxide, calcium hydroxide
- Bases give soapy touch only in aqueous medium not in dry nature.
- Bases are bitter in taste.
- Bases are corrosive in nature. When come in contact with the skin frequently they form painful blisters.
- Bases are generally colourless.
- Bases also change the colour of the indicators. Red litmus paper turns blue when treated with bases. Similarly, they turn methyl orange to yellow and phenolphthalein to pink colour.
- Bases also conduct electricity in aqueous solution.

b. Chemical properties

i. Reaction with metals

Generally metals do not react with bases. Metals like aluminium and zinc react with bases like sodium hydroxide forming aluminates and release hydrogen.

Aluminum + Sodium hydroxide + Water → Sodium aluminate + Hydrogen

$$2Al + 2NaOH + 2H_2O \rightarrow 2NaAlO_2 + 3H_2\uparrow$$

ii. Reaction with non-metal oxides

All bases react with non metallic oxides to form salt and water. For example, sodium hydroxide reacts with carbon dioxide to form sodium carbonate.

Sodium hydroxide + Carbon dioxide → Sodium carbonate + Water

$$2NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O$$

iii. Reaction with ammonium salts

Bases react with ammonium salts to form metal salts, ammonia gas and water.

Sodium hydroxide + Ammonium chloride → Sodium chloride + Ammonia + Water

$$NH_4Cl + NaOH \rightarrow NaCl + NH_3\uparrow + H_2O$$

Though acids and bases have some unique properties there are certain similarities between them. Some of them are given below.

- They are corrosive in nature.
- They undergo ionization in aqueous solution.
- They conduct electricity in aqueous solution.
- They undergo neutralization reaction.

Some of the differences between acids and bases are given in Table 14.3.

Table 14.3 Difference between acids and bases

Acids	Bases
They produce H^+ ions in water.	They produce OH^- ions in water.
They are sour in taste.	They are bitter in taste.
Few acids are in solid state.	Most of the bases are in solid state.
Acids turn blue litmus paper red.	Bases turn red litmus paper blue.

14.2.2 Uses of Bases

i) Potassium hydroxide is used to make bathing soaps.
ii) Sodium hydroxide is used to make washing soaps.
iii) Sodium hydroxide is also used in paper industries, textile industries and in the preparation of medicines.
iv) Calcium hydroxide is used for white washing.
v) Aluminum hydroxide and magnesium hydroxides are used in antacids to cure acidity problems.
vi) Ammonium hydroxide is used to manufacture fertilizers, nylon, plastics and rubber.

Figure 14.4 Uses of bases in daily life

14.3 Neutralisation Reaction

When neutrality is achieved between two different chemical substances with different chemical properties through a reaction then it is called neutralization in chemistry. Thus neutralization is a chemical reaction in which

an acid and a base react with each other to form salt and water. Neutralization reaction between an acid and a base can be written as:

Acid + Base → Salt + Water

In this reaction, H^+ and Cl^- ions are produced by the hydrochloric acid and Na^+ and OH^- ions are produced by sodium hydroxide (base). When these ions combine together sodium chloride (NaCl) salt and water are produced.

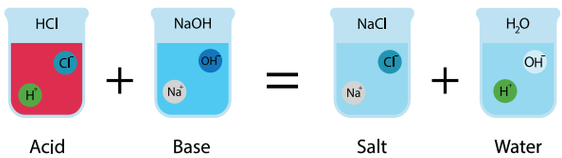

Figure 14.5 Acid – Base reaction

Similarly other acids also produce their salts when they react with bases. Some of the salts produced by neutralization reaction are given below in Table 14.4.

Table 14.4 Salts produced by neutralisation

Acid	Base	Salt
Hydrochloric acid HCl	Sodium hydroxide NaOH	Sodium chloride NaCl
Sulphuric acid H_2SO_4	Sodium hydroxide NaOH	Sodium sulphate Na_2SO_4
Nitric acid HNO_3	Sodium hydroxide NaOH	Sodium nitrate $NaNO_3$
Acetic acid CH_3COOH	Sodium hydroxide NaOH	Sodium acetate CH_3COONa

14.3.1 Neutralisation reactions in our daily life

Balancing acids and bases is important for our health and for our environment. We come across various neutralization reactions in our daily life. Let us study about the importance of some of those reactions.

Bee bite

Whenever bees or red ants bite us they inject an acid called formic acid into our body. This acid cause burning sensation and pain. To suppress the pain a suitable base in the form of calcium hydroxide (lime paste available at home) is applied so as to neutralise the formic acid.

Figure 14.6 Bee bite

Wasp bite

When we are bitten by wasp, we feel the burning sensation and pain. It is due to an alkaline substance injected by the insect. To neutralise the alkalinity we use vinegar which is an acid.

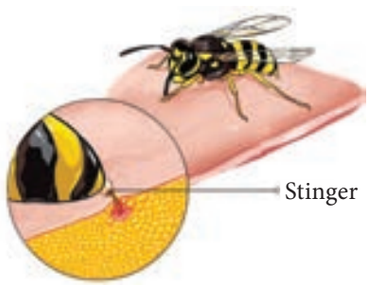

Figure 14.7 Wasp bite

Tooth decay

Generally it is advised by the doctors that we should brush our teeth twice a day. This is because the bacteria present in our mouth decompose the food particles stuck in the gaps between our teeth thereby causing acid formation which leads to tooth decay. To prevent this we have to neutralize the acid. When we brush with tooth powder or tooth paste containing weak bases, the acid gets neutralized. So our teeth will be strong and healthy.

Acidity

As we know, hydrochloric acid present in our stomach helps the digestion of food material along with the enzymes secreted by liver, gallbladder and pancreas. Sometimes due

to excessive production of hydrochloric acid in our stomach we feel burning sensation in food pipe and in chest area. If this happens again and again ulcer will be formed in stomach and food pipe, which further aggravates the conditions. In order to neutralize, antacids which are nothing but weak bases like aluminum and magnesium hydroxides are used. As a result the acidity is removed.

Agriculture

Acidic soil is not suitable for plant growth. So farmers add lime fertilisers such as powdered lime (CaO), limestone ($CaCO_3$) or ashes of burnt wood to the soil to neutralise the acidity.

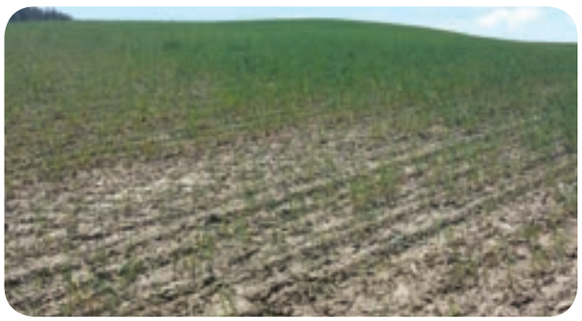

Figure 14.8 Acidic soil

Industries

Effluents from the industries contain acids such as sulphuric acid. It is treated by adding lime to neutralise it before it is discharged into rivers and streams. Similarly, in power stations fossil fuels such as coal are burnt to produce electricity. Burning fossil fuels will liberate sulphur dioxide gas as an acidic pollutant in the air. Hence, power stations treat this acidic gas using powdered lime (CaO) or limestone ($CaCO_3$) to neutralise it so that air pollutant can be prevented.

Figure 14.9 Industrial Effluents

14.4 Indicators

An indicator or acid–base indicator is a chemical substance which indicates the acidic or basic nature of a solution by suitable colour change. These may be natural or synthetic.

14.4.1 Natural indicators

Natural indicators are chemical substances which are obtained from the natural resources. Litmus, turmeric juice, China rose petals, red cabbage, grape juice and beetroot juice are the indicators obtained from natural resources.

Turmeric indicator

By adding small amount of water to turmeric powder a paste is prepared. This is applied on a blotting paper or filter paper and dried. These strips are used as indicators to find the nature of the solution. In acidic solution turmeric indicator paper has no change in colour. That means it remains yellow. In basic solution the colour changes from yellow to red.

Figure 14.10 Turmeric indicator

Activity 4

Take a white cloth with turmeric powder stain. Wash the cloth with washing soap. Do you observe any change in the colour? Why?

Hibiscus flower indicator

Some hibiscus flowers soaked in warm water for about 5 to 10 minutes forms a solution. This solution can be used as indicator. In acidic solution, the colour will be changed to deep pink or deep red. In basic solution, the colour will be changed into green.

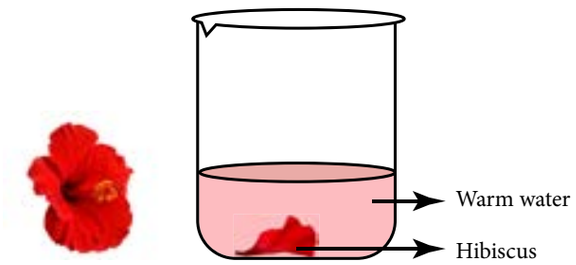

Figure 14.11 Hibiscus solutions as indicator

Beet root juice indicator

Extracts of beet root are also used as an indicator for identifying the acidic or basic nature of a solution.

Activity 5

Take a small beet root vegetable and cut it into pieces. Boil them in hot water and filter the extract. Take two test tubes. Take sodium hydroxide solution in one test tube and vinegar or lemon juice in another test tube. Add beet root extract slowly. Observe the colour change. What do you infer?

Litmus

Litmus is the most common indicators used in the laboratories. Litmus is a natural indicator which is extracted from lichens. It is available in the form of solution or in the form of strips prepared by absorbing litmus solution on filter paper. It is either red or blue in colour. Blue litmus paper turns red in acidic solution and red litmus paper turns blue in the basic solution.

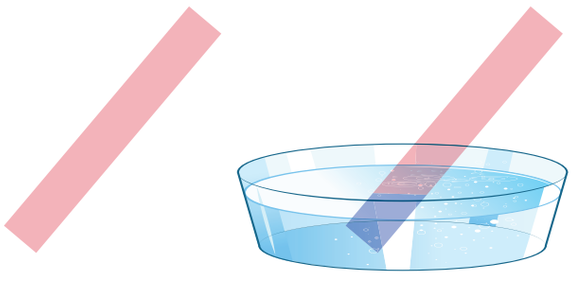

Figure 14.12 Litmus paper

Activity 6

Find out the nature of the solution.

Sample solution	Change of colour in litmus paper		Acid / Base
	Red litmus	Blue litmus	
Lemon juice			
Vinegar			
Calcium hydroxide solution			
Bathing Soap solution			
Orange juice			

14.4.2 Synthetic indicators

An indicator prepared from artificial substances is known as synthetic indicators. Phenolphthalein and methyl orange are the examples for synthetic indicators.

Phenolphthalein

Phenolphthalein is a colourless compound. Its alcoholic form is used as an indicator. It is colourless in acidic solution but turns pink in basic solution.

Methyl orange

Solid methyl orange is dissolved in hot water and its filtrate is used as an indicator. It turns red in acidic solution and yellow in basic solution.

The following table gives the colour changes of different indicators in acidic and basic medium.

Table 14.5 Colour change in Indicators

Indicator	Acidic solution	Basic solution
Blue litmus	Red	No change in colour
Red litmus	No change in colour	Blue
Phenolphthalein	Colourless	Pink
Methyl orange	Red	Yellow

Points to Remember

- Acids produce H^+ ions when they are dissolved in water.
- Acids are generally corrosive in nature and sour in taste
- All dilute acids react with metallic oxides to form respective metallic salts and water.
- Natural acids (organic acids) and mineral acids are the two types of acids.
- Acetic acid and benzoic acid are used as food preservatives.
- Sulphuric acid is known as king of chemicals.
- Bases are the substances that give hydroxide ions (OH^-) on dissolving in water.
- Bases which are soluble in water are called alkalis. All alkalis are bases but all bases are not alkalis.
- Bases are generally corrosive in nature. They give soapy touch only in aqueous medium not in dry nature.
- Bases are used in paper industries, textile industries and in the preparation of medicines. They are used to manufacture fertilizers, nylon, plastics and rubber.
- When acids and bases are mixed together in aqueous solution, they react chemically to produce salt and water. This is known as neutralisation reaction.
- An indicator is a chemical substance (either natural or artificial) which indicates the end of a chemical reaction by a suitable colour change.
- Extracts of turmeric powder, hibiscus, beet root and vegetables are used as natural indicators. Phenolphthalein and methyl orange are artificial indicators.

A-Z GLOSSARY

Acid	A substance which contains one or more replaceable hydrogen atoms.
Alkali	Water soluble bases.
Base	A substance that releases hydroxide ions when dissolved in water.
Indicator	Chemical substance which indicates the acidic or basic nature of a solution by suitable colour change.
Inorganic acid	Acids produced artificially in industries.
Natural indicators	Substances obtained from plants and used as indicators.
Neutralisation reaction	Reaction between an acid and a base which produces water and salt.
Organic acid	Acids which occur naturally in fruits and vegetables.
Synthetic indicators	Artificially produced indicators .

TEXTBOOK EXERCISES

I. Choose the best answer.

1. Acids are _____ in taste.
   a) sour b) sweet
   c) bitter d) salty
2. Aqueous solutions of _____ conduct electricity.
   a) acid b) base
   c) salt d) All of these
3. In acidic solutions blue litmus changes into _____ colour.
   a) blue b) green
   c) red d) white
4. Base is a substance that gives _____ on dissolving in water.
   a) OH^- b) H^+ c) OH d) H
5. Sodium hydroxide is a _____
   a) acid b) base
   c) oxide d) alkali
6. Red ant sting contains _____
   a) acetic acid b) sulphuric acid
   c) oxalic acid d) formic acid
7. Magnesium hydroxides are used for treating_____
   a) acidity b) head pain
   c) teeth decay d) None of these
8. Acid mixed with base forms _____
   a) salt and water b) salt
   c) water d) No reaction
9. We brush our teeth with tooth paste because it is _____ in nature.
   a) basic b) acidic
   c) Both a and b d) None of these
10. In basic solution turmeric indicator paper changes from yellow to _____
    a) blue b) green c) yellow d) red

II. Fill in the blanks.

1. Benzoic acids are used for _____
2. The word sour refers to _____ in Latin.
3. Bases are _____ in taste.
4. Chemical formula of calcium oxide is _____
5. Wasp sting contains _____
6. Turmeric is used as a_____
7. In acidic solution the colour of the hibiscus indicator paper will change to _____

III. State true or false. If false, correct the statement.

1. Most of the acids are not soluble in water.
2. Acids are bitter in taste.
3. Bases are soapy to touch when they are dry.
4. Acids are corrosive in nature.
5. All bases are alkalis.
6. Hibiscus flower is an example for natural indicator.

IV. Answer briefly.

1. Acid - Define.
2. Write any four physical properties of acids.
3. What are the similarities between acids and bases?
4. State the difference between acids and bases.
5. What is an indicator?

6. What is a neutralization reaction?
7. Write any four physical properties of base.

V. Answer in detail

1. What are the uses of acids?
2. What are the uses of bases?
3. Explain the neutralization reactions in our daily life.
4. How will you prepare natural indicator from turmeric powder.

VI. Higher Order Thinking Questions.

1. Vinu and Priyan take their lunch at school. Vinu eats lemon rice and Priyan eats curd rice. Both lemon rice and curd rice are sour in taste. What is the reason?
2. Heshna and Keerthi are friends. Keerthi's teeth are white without caries, but Heshna has teeth with caries. Why? How is it formed?

REFERENCE BOOKS

1. Petrucci, Palph Het.al. General Chemistry: Principles & Modern Applications (9th Edition). Upper Saddle River, NJ: Person Prentice Hall, 2007. Prinit.
2. P.L.Soni, Text book of Inorganic chemistry, S.Chand publication, New Delhi.
3. Complete Chemistry (IGCSE), Oxford university press, New York.
4. Raymond Chang. (2010). Chemistry, New York, NY: The Tata McGraw Hill Companies. Inc.
5. Frank New Certificate Chemistry. McMillan Publishers.

INTERNET RESOURCES

1. https://www.chem4kids.com
2. https:// www.khanacademy.org/science/chemistry/acids-and-bases-topic
3. https:// www.khanacademy.org/science/chemistry/neutralization
4. https://courses.chemistry/chapter/acids-and-bases

Concept Map