

UNIT

14

ACIDS, BASES AND SALTS



Learning Objectives

After completing this lesson, students will be able to

- know about formation, properties and uses of acids, bases and salts.
- know the importance of acids, bases and salts in daily life.
- understand how to identify the nature of a solution by using indicators and pH paper.
- know the strength of acid or base solutions.
- define pH scale and explain the significance of pH in everyday life.
- know aquaregia and its properties.

Introduction

We know that the physical world around us is made of large number of chemicals. Soil, air, water, all the life forms and the materials that they use are all consist of chemicals. Out of such chemicals, acids, bases and salts are mostly used in everyday life. Let it be a fruit juice or a detergent or a medicine, they play a key role in our day-to-day activities. Our body metabolism is carried out by means of hydrochloric acid secreted in our stomach. An acid is a the compound which is capable of forming hydrogen ions (H^+) in aqueous solution whereas a base is a compound

that forms hydroxyl ions (OH^-) in solution. When an acid and a base react with each other, a neutral product is formed which is called salt. In this lesson let us discuss about them in detail.

14.1 Acids

Look at the pictures of some of the materials used in our daily life, given below:

All these edible items taste similar i.e. sour. What causes them to taste sour? A certain type of chemical compounds present in them gives sour taste. These are called acids. The word 'acid' is derived from the Latin name "acidus"

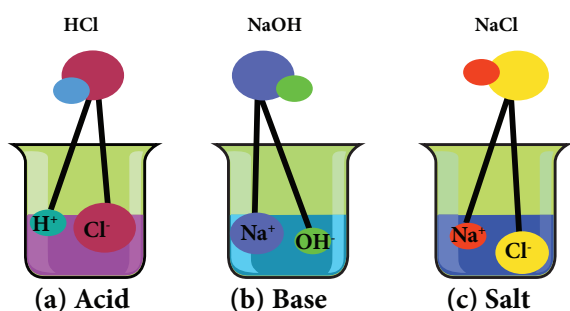


Figure 14.1 Acid, base and salt



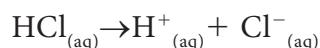
Figure 14.2 Acid, base and salt in food

which means sour taste. Substances with sour taste are called acids.

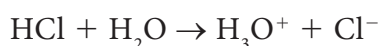
Table 14.1 Acid and its source

Source	Acid Present
Apple	Malic acid
Lemon	Citric acid
Grape	Tartaric acid
Tomato	Oxalic acid
Vinegar	Acetic acid
Curd	Lactic acid
Orange	Ascorbic acid
Tea	Tannic acid
Stomach juice	Hydrochloric acid
Stings of Ant, Bee	Formic acid

In 1884, a Swedish chemist Svante Arrhenius proposed a theory on acids and bases. According to Arrhenius theory, an acid is a substance which furnishes H^+ ions or H_3O^+ ions in aqueous solution. They contain one or more replaceable hydrogen atoms. For example, when hydrogen chloride is dissolved in water, it gives H^+ and Cl^- ions in water.



What happens to an acid or a base in water? Do acids produce ions only in aqueous solution? Hydrogen ions in HCl are produced in the presence of water. The separation of H^+ ion from HCl molecules cannot occur in the absence of water.



Hydrogen ions cannot exist alone, but they exist in combined state with water molecules. Thus, hydrogen ions must always be H^+ (or) Hydronium (H_3O^+).



All acids essentially contain one or more hydrogens. But all the hydrogen containing substances are not acids. For example, methane (CH_4) and ammonia (NH_3) also contain hydrogen. But they do not produce H^+ ions in aqueous solution.

The following table enlists various acids and the ions formed by them in water.

Table 14.2 Ions formed by acids

Acid	Molecular Formula	Ions formed		No. of replaceable hydrogen
Acetic Acid	CH_3COOH	H^+	CH_3COO^-	1
Formic Acid	$HCOOH$	H^+	$HCOO^-$	1
Nitric Acid	HNO_3	H^+	NO_3^-	1
Sulphuric Acid	H_2SO_4	$2H^+$	SO_4^{2-}	2
Phosphoric Acid	H_3PO_4	$3H^+$	PO_4^{3-}	3

14.1.1 Classification of Acids

Acids are classified in different ways as given below:

(a) Based on their sources:

Organic Acids: Acids present in plants and animals (living things) are organic acids. Example: $HCOOH$, CH_3COOH

Inorganic Acids: Acids prepared from rocks and minerals are inorganic acids or mineral acids. Example: HCl , HNO_3 , H_2SO_4

(b) Based on their Basicity

Monobasic Acid: Acid that contain only one replaceable hydrogen atom per molecule is called monobasic acid. It gives one hydrogen ion per molecule of the acid in solution. Example: HCl , HNO_3



For acids, we use the term basicity that refers to the number of replaceable hydrogen atoms present in one molecule of an acid. For example, acetic acid (CH_3COOH) has four hydrogen atoms but only one can be replaced. Hence it is monobasic.

Dibasic Acid: An acid which gives two hydrogen ions per molecule of the acid in solution. Example: H_2SO_4 , H_2CO_3

Tribasic Acid: An acid which gives three hydrogen ions per molecule of the acid in solution. Example: H_3PO_4

(c) Based on Ionisation

Acids get ionised in water (produce H^+ ions) completely or partially. Based on the extent of ionisation acids are classified as below.

Strong Acids: These are acids that ionise completely in water. Example: HCl

Weak Acids: These are acids that ionise partially in water. Example: CH_3COOH .



Ionisation is the condition of being dissociated into ions by heat or radiation or chemical reactions or electrical discharge.

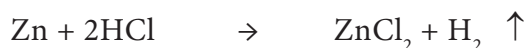
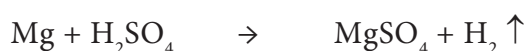
(d) Based on Concentration

Concentrated Acid: It has relatively large amount of acid dissolved in a solvent.

Dilute Acid: It has relatively smaller amount of acid dissolved in solvent.

14.1.2 Properties of Acids

- They have sour taste.
- Their aqueous solutions conduct electricity since they contain ions.
- Acids turn blue litmus red.
- Acids react with active metals to give hydrogen gas.

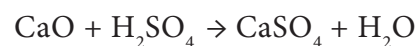


Few metals do not react with acid and liberate hydrogen gas. For example: Ag , Cu .

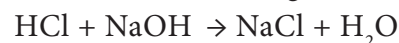
- Acids react with metal carbonate and metal hydrogen carbonate to give carbon dioxide.



- Acids react with metallic oxides to give salt and water.



- Acids react with bases to give salt and water.



The reaction is known as neutralisation reaction.

Activity 1

Take about 10 ml of dilute hydrochloric acid in a test tube and add a few pieces of zinc granules into it. What do you observe? Why are bubbles formed in the solution? Take a burning candle near a bubble containing hydrogen gas, the flame goes off with a 'Popping' sound. This confirms that metal displaces hydrogen gas from the dilute acid.

Caution: Care must be taken while mixing any concentrated inorganic acid with water. The acid must be added slowly and carefully with constant stirring to water since it generates large amount of heat. If water is added to acid, the mixture splashes out of the container and it may cause burns.

14.1.3 Uses of Acids

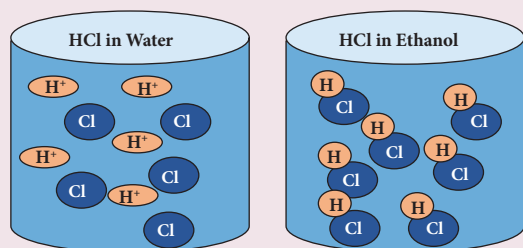
- Sulphuric acid is called King of Chemicals because it is used in the preparation of many other compounds. It is used in car batteries also.
- Hydrochloric acid is used as a cleansing agent in toilets.
- Citric acid is used in the preparation of effervescent salts and as a food preservative.
- Nitric acid is used in the manufacture of fertilizers, dyes, paints and drugs.
- Oxalic acid is used to clean iron and manganese deposits from quartz crystals. It is also used as bleach for wood and removing black stains.
- Carbonic acid is used in aerated drinks.
- Tartaric acid is a constituent of baking powder.



Role of water in acid solution

Acids show their properties only when dissolved in water.

In water, they ionise to form H^+ ions which determine the properties of acids. They do not ionise in organic solvents. For example, when HCl is dissolved in water it produces H^+ ions and Cl^- ions whereas in organic solvents like ethanol they do not ionise and remain as molecule.



14.1.4 Aquaregia

We know that metals like gold and silver are not reactive with either HCl or HNO_3 . But the mixture of these two acids can dissolve gold. This mixture is called Aquaregia. It is a mixture of hydrochloric acid and nitric acid prepared optimally in a molar ratio of 3:1. It is a yellow-orange fuming liquid. It is a highly corrosive liquid, able to attack gold and other substances.

Chemical formula : $3 HCl + HNO_3$

Solubility in Water : Miscible in water

Melting point : $-42^\circ C (-44^\circ F, 231K)$

Boiling point : $108^\circ C (226^\circ F, 381K)$

Table 14.3 Ions formed by bases in water.

Base	Molecular Formula	Ions formed		No. of replaceable hydroxyl ion
Calcium oxide	CaO	Ca^{2+}	O^{2-}	1
Sodium oxide	Na_2O	Na^+	O^{2-}	1
Potassium hydroxide	KOH	K^+	OH^-	1
Calcium hydroxide	$Ca(OH)_2$	Ca^{2+}	OH^-	2
Aluminium hydroxide	$Al(OH)_3$	Al^{3+}	OH^-	3

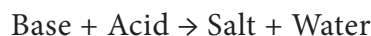
The term aquaregia is a Latin phrase meaning 'King's Water'. The name reflects the ability of aquaregia to dissolve the noble metals such as gold, platinum and palladium.

Uses of Aquaregia

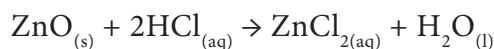
1. It is used chiefly to dissolve metals such as gold and platinum.
2. It is used for cleaning and refining gold.

14.2 Bases

According to Arrhenius theory, bases are substances that ionise in water to form hydroxyl ions (OH^-). There are some metal oxides which give salt and water on reaction with acids. These are also called bases. Bases that are soluble in water are called alkalis. A base reacts with an acid to give salt and water only.



For example, zinc oxide (ZnO) reacts with HCl to give the salt zinc chloride and water.



Similarly, sodium hydroxide ionises in water to give hydroxyl ions and thus get dissolved in water. So it is an alkali.



Bases contain one or more replaceable oxide or hydroxyl ions in solution. Table 14.3 enlists various bases and ions formed by them in water.



All alkalis are bases but not all bases are alkalis. For example: NaOH and KOH are alkalis whereas $Al(OH)_3$ and $Zn(OH)_2$ are bases.

14.2.1 Classification of Bases

(a) Based on their Acidity

Monoacidic Base: It is a base that ionises in water to give one hydroxide ion per molecule.
Example: NaOH, KOH

Diacidic Base: It is a base that ionises in water to give two hydroxide ions per molecule.
Example: $\text{Ca}(\text{OH})_2$, $\text{Mg}(\text{OH})_2$

Triacidic Base: It is a base that ionises in water to give three hydroxide ions per molecule.
Example: $\text{Al}(\text{OH})_3$, $\text{Fe}(\text{OH})_3$

(b) Based on concentration

Concentrated Alkali: It is an alkali having a relatively high percentage of alkali in its aqueous solution.

Dilute Alkali: It is an alkali having a relatively low percentage of alkali in its aqueous solution.

(c) Based on Ionisation

Strong Bases: These are bases which ionise completely in aqueous solution.

Example: NaOH, KOH

Weak Bases: These are bases that ionise partially in aqueous solution.

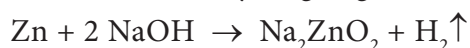
Example: NH_4OH , $\text{Ca}(\text{OH})_2$



The term acidity is used for base, which means the number of replaceable hydroxyl groups present in one molecule of a base.

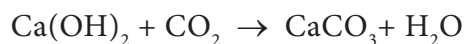
14.2.2 Properties of Bases

- They have bitter taste.
- Their aqueous solutions have soapy touch.
- They turn red litmus blue.
- Their aqueous solutions conduct electricity.
- Bases react with metals to form salt with the liberation of hydrogen gas.

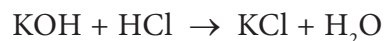


- Bases react with non-metallic oxides to produce salt and water. Since this is similar to the reaction between a base

and an acid, we can conclude that non-metallic oxides are acidic in nature.

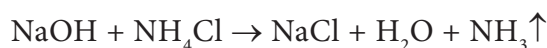


- Bases react with acids to form salt and water.



The above reaction between a base and an acid is known as Neutralisation reaction.

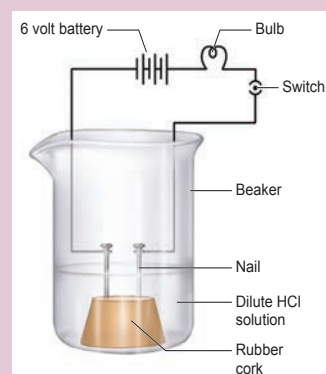
- On heating with ammonium salts, bases give ammonia gas.



Few metals do not react with sodium hydroxide.
Example: Cu, Ag, Cr

Activity 2

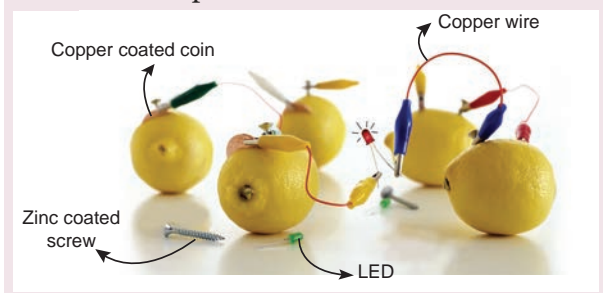
Take solutions of hydrochloric acid or sulphuric acid. Fix two nails on a cork and place the cork in a 100 ml beaker. Connect the nails to the two terminals



of a 6V battery through a bulb and a switch as shown in Figure. Now pour some dilute HCl in the beaker and switch on the current. Repeat the activity with dilute sulphuric acid, glucose and alcohol solutions. What do you observe now? Does the bulb glow in all cases?

In the above activity you can observe that the bulb will start glowing only in the case of acids. But, you will observe that glucose and alcohol solution do not conduct electricity. Glowing of the bulb indicates that there is a flow of electric current through the solution. The electric current is carried through the solution by ions. Repeat the same activity using alkalis such as sodium hydroxide and calcium hydroxide.

Try Yourself: Construct a Lemon cell as shown in picture.



14.2.3 Uses of Bases

- Sodium hydroxide is used in the manufacture of soap.
- Calcium hydroxide is used in white washing of building.
- Magnesium hydroxide is used as a medicine for stomach disorder.
- Ammonium hydroxide is used to remove grease stains from cloths.

14.3 Tests for Acids and Bases

a) Test with a litmus paper:

An acid turns blue litmus paper into red. A base turns red litmus paper into blue.

b) Test with an indicator Phenolphthalein:

In acid medium, phenolphthalein is colourless. In basic medium, phenolphthalein is pink in colour.

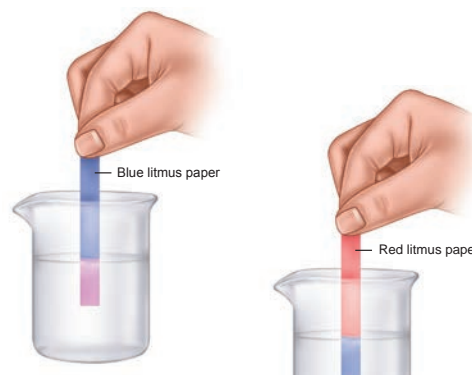


Figure 14.3 Test for acid and base using litmus paper

c) Test with an indicator Methyl orange:

In acid medium, methyl orange is pink in colour. In basic medium, methyl orange is yellow in colour.

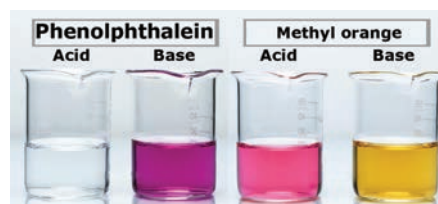


Figure 14.4 Test for acid and base using indicator

Table 14.4 Acid base indicator

Indicator	Colour in acid	Colour in base
Litmus	Blue to Red	Red to Blue
Phenolphthalein	Colourless	Pink
Methyl orange	Pink	Yellow

Activity 3

Collect the following samples from the science laboratory – Hydrochloric acid, Sulphuric acid and Nitric acid, Sodium hydroxide, Potassium hydroxide. Take 2 ml of each solution in a test tube and test with a litmus paper and indicators phenolphthalein and Methyl orange. Tabulate your observations.

Sample Solutions	Litmus Paper		Indicators	
	Blue	Red	Phenolphthalein	Methyl Orange
Hydrochloric acid				
Sulphuric acid				
Nitric acid				
Sodium hydroxide				
Potassium hydroxide				

14.4 Strength of Acidic or Basic solutions

pH Scale

A scale for measuring hydrogen ion concentration in a solution is called pH scale. The 'p' in pH stands for 'potenz' in German meaning power. pH scale is a set of numbers from 0 to 14 which is used to indicate whether a solution is acidic, basic or neutral.

- ✓ Acids have pH less than 7
- ✓ Bases have pH greater than 7
- ✓ A neutral solution has pH equal to 7

14.5 Salts

When you say salt, you may think of the common salt. Sea water contains many salts dissolved in it. Sodium chloride is separated from these salts.

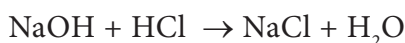


There are many other salts used in other fields. Salts are the products of the reaction between acids and bases. Salts produce positive ions and negative ions when dissolved in water.

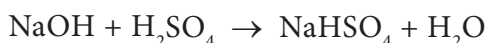


14.5.1 Types of Salts

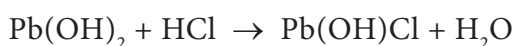
Normal Salts: A normal salt is obtained by complete neutralization of an acid by a base.



Acid Salts: It is derived from the partial replacement of hydrogen ions of an acid by a metal. When a calculated amount of a base is added to a polybasic acid, acid salt is obtained.



Basic Salts: Basic salts are formed by the partial replacement of hydroxide ions of a diacidic or triacidic base with an acid radical.



Double Salts: Double salts are formed by the combination of the saturated solution of two simple salts in equimolar ratio followed by crystallization. For example, potash alum is a mixture of potassium sulphate and aluminium sulphate. $\text{KAl(SO}_4)_2 \cdot 12\text{H}_2\text{O}$

14.5.2 Properties of Salts

- ✓ Salts are mostly solids which melt as well as boil at high temperature.
- ✓ Most of the salts are soluble in water. For example, chloride salts of potassium and sodium are soluble in water. But, silver chloride is insoluble in water
- ✓ They are odourless, mostly white, cubic crystals or crystalline powder with salty taste.
- ✓ Salt is hygroscopic in nature.

14.5.3 Water of Crystallisation

Many salts are found as crystals with water molecules. These water molecules are known as water of crystallisation. Salts that contain water of crystallisation are called hydrated salts. The number of molecules of water hydrated to a salt is indicated after a dot in its chemical formula. For example, copper sulphate crystal have five molecules of water for each molecule of copper sulphate. It is written as $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ and named as copper sulphate pentahydrate. This water of crystallisation makes the copper sulphate blue. When it is heated, it loses its water molecules and becomes white.



Figure 6.7 Hydrated Salt

Salts that do not contain water of crystallisation are called anhydrous salt. They are generally found as powders. Fill in the blanks in the following table based on the concept of water of crystallisation.

Activity 4

Fill in the blanks in the following table based on the concept of water of crystallisation.

Salt	Formula of anhydrous salt	Formula of hydrated salt	Name of hydrated salt
Zinc sulphate	ZnSO ₄	ZnSO ₄ ·7H ₂ O	
Magnesium chloride	MgCl ₂		Magnesium chloride hexahydrate
Iron (II) sulphate		FeSO ₄ ·7H ₂ O	Iron (II) sulphate heptahydrate
Calcium chloride	CaCl ₂	CaCl ₂ ·2H ₂ O	
Sodium thiosulphate	Na ₂ S ₂ O ₃		Sodium thiosulphate pentahydrate

14.5.4 Identification of Salts

(i) Physical examination of the salt.

The physical examination of the unknown salt involves the study of colour, smell and density. This test is not much reliable.

(ii) Dry heating Test.

This test is performed by heating a small amount of salt in a dry test tube. After all the water get evaporated, the dissolved salts are sedimented in the container.

(iii) Flame Test.

Certain salts on reacting with concentrated hydrochloric acid (HCl) form their chlorides. The paste of the mixture with con. HCl is introduced into the flame with the help of platinum wire.

Colour of the flame	Inference
Brick red	Ca ²⁺
Golden Yellow	Na ⁺
Pink Violet	K ⁺
Green Fleshes	Zn ²⁺

(iv) When HCl is added with a carbonate salt, it gives off CO₂ gas with brisk effervescence.

14.5.5 Uses of Salts

Common Salt (Sodium Chloride - NaCl)

It is used in our daily food and used as a preservative.

Washing Soda (Sodium Carbonate-Na₂CO₃)

- It is used in softening hard water.
- It is used in glass, soap and paper industries.

Baking Soda (Sodium bicarbonate -NaHCO₃)

- It is used in making of baking powder which is a mixture of baking soda and tartaric acid.
- It is used in soda-acid fire extinguishers.
- Baking powder is used to make cakes and bread, soft and spongy.
- It neutralizes excess acid in the stomach and provides relief.

Bleaching powder

(Calcium Oxychloride - CaOCl₂)

- It is used as disinfectant.
- It is used in textile industry for bleaching cotton and linen.

Plaster of Paris (Calcium Sulphate Hemihydrate - CaSO₄·½ H₂O)

- It is used for plastering bones.
- It is used for making casts for statues.

Activity 5

Boil about 100 ml of ground water in a vessel to dryness. After all the water get evaporated observe the inner wall of the vessel. Can you observe any deposits? This is the deposit of dissolved salts present in water.

Points to Remember

- ❖ Acid is a substance which furnishes H^+ ions or H_3O^+ ions when dissolved in water.
- ❖ Base is a substance which releases OH^- ions when dissolved in water.
- ❖ Salt is the product of reaction between acids and bases.
- ❖ Acids and bases neutralize each other to form corresponding salts and water.
- ❖ Salts have various uses in everyday life.
- ❖ Acidic and basic solutions in water conduct electricity because they produce hydrogen and hydroxide ions respectively.
- ❖ When an acid reacts with a metal, hydrogen gas is evolved and a corresponding salt is formed.
- ❖ Phenolphthalein and Methyl orange are used as indicators to find out whether the given solution is acid or base.
- ❖ Litmus paper is also used to find out whether the given solution is acid or base.
- ❖ pH paper is used to find out the given solution whether acidic or basic in nature.
- ❖ Aquaregia is a mixture of hydrochloric acid and nitric acid optimally in a molar ratio of 3:1.
- ❖ pH Scale is used to find out the power of hydrogen ion concentration in a solution.

A-Z GLOSSARY

Acids	Substance which furnishes H^+ ions H_3O^+ ions when dissolved in water.
Bases	Substance which furnishes OH^- ions when dissolved in water.
Salts	Product of reaction between acids and bases.
Indicators	Chemical substances used to find out whether the given solution is acid or base.
pH Scale	Scale used to find out Hydrogen ion concentration in a solution.
pH Paper	Paper used to find out whether the given solution is acidic or basic or neutral in nature.
Aquaregia	Mixture of hydrochloric acid and nitric acid prepared optimally in a molar ratio of 3 : 1.
Hygroscopic substance	Substance which absorbs water from the surroundings.



TEXTBOOK EXERCISES

I. Choose the correct answer.

1. $Zn + 2 HCl \rightarrow ZnCl_2 + \dots \uparrow (H_2, O_2, CO_2)$
2. Apple contains malic acid. Orange contains _____ (citric acid, ascorbic acid).
3. Acids in plants and animals are organic acids. Whereas Acids in rocks and minerals are _____ (Inorganic acids, Weak acids).
4. Acids turn blue litmus paper to _____ (green, red, orange).
5. Since metal carbonate and metal bicarbonate are basic, they react with acids to give salt and water with the liberation of _____ (NO_2, SO_2, CO_2).

6. The hydrated salt of copper sulphate has _____ colour (red, white, blue).

II. Answer briefly.

1. Classify the various types of Acids based on their sources.
2. Write any four uses of acids.
3. Give the significance of pH of soil in agriculture.
4. What are the various uses of Aquaregia.
5. What are the uses of Plaster of Paris?
6. Two acids 'A' and 'B' are given. Acid A gives one hydrogen ion per molecule of the acid in solution. Acid B gives two hydrogen ions per molecule of the acid in solution.

- (i) Find out acid A and acid B. (ii) Which acid is called the King of Chemicals?
- Define aquaregia.
 - Correct the mistakes:
 - Washing soda is used for making cakes and bread soft, spongy.
 - Calcium sulphate hemihydrate is used in textile industry for bleaching cloths.
 - What is neutralization reaction? Give an example.

III. Answer in detail.

- Differentiate hydrate and anhydrous salts with examples.
 - Give the tests to identify Acids and Bases.
- Write any four uses of bases.
 - Write any five uses of salts.
 - Sulphuric acid is called King of Chemicals. Why is it called so?



REFERENCE BOOKS

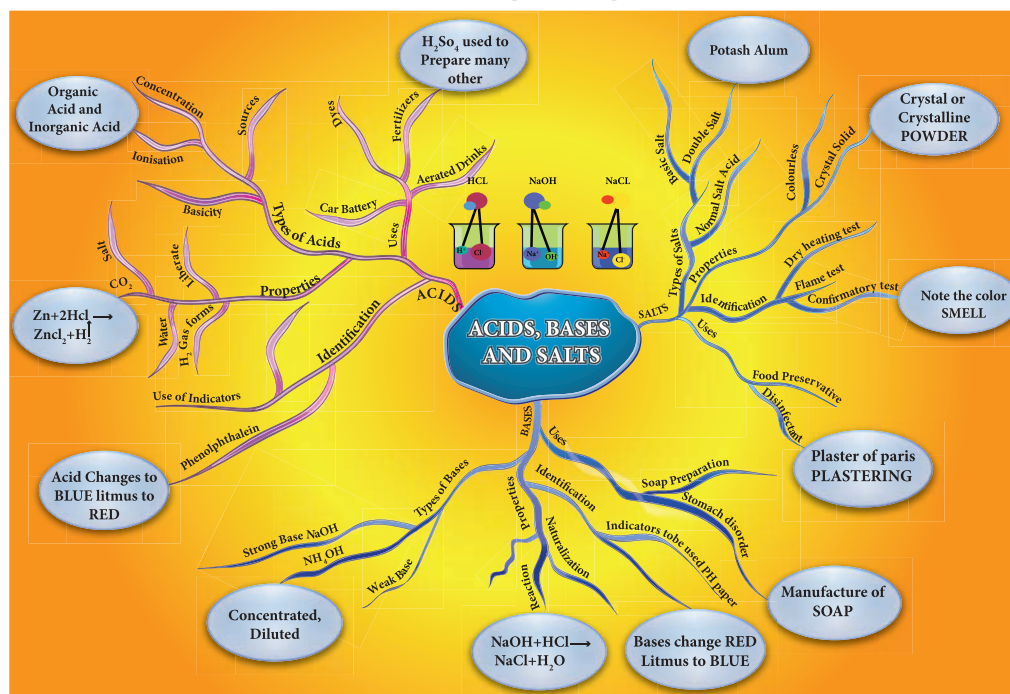
- Chemistry-Lakhmir Singh & Manjit Kaur
- Practical Chemistry-Dr. N.K. Verma



INTERNET RESOURCES

- <https://www.thoughtco.com>
- Aquaregia Wikipedia
- <https://scienceing.com>>Chemistry

Concept Map



ICT CORNER

Steps

- Type the URL link given below in the browser or scan the QR code. You can view "Acids and bases".
- Click the 'pH meter' to explore the properties based on the pH value.
- Click the 'pH paper' to explore the properties based on the colour of pH paper.
- Also you can see the nature of the acids, bases using the conductivity.

Browse in the link:

URL: <https://phet.colorado.edu/en/simulation/acid-base-solutions>

