212en08

8

# ACIDS, BASES AND SALTS

From generations, our parents have been using tamarind or lemon juice to give shiny look to the copper vessels. Our mothers never store pickles in metal containers. Common salt and sugar has often been used as an effective preservative. How did our ancestors know that tamarind, lemon, vinegar, sugar etc. works effectively? This was common collective wisdom which was passed from generation to generation. These days, bleaching powder, baking soda etc. are commonly used in our homes. You must have used various cleaners to open drains and pipes and window pane cleaners for sparkling glass. How do these chemicals work? In this lesson we will try to find answers to these questions. Most of these examples can be classified as acids, bases or salts. In this unit we shall categorize these substances. We shall study about their characteristic properties. We will also be learning about pH – a measure of acidity and its importance in our life.

## OBJECTIVES

After completing this lesson you will be able to:

- *define the terms acid, base, salt and indicator;*
- *give examples of some common household acids, bases, salts and suggest suitable indicators;*
- *describe the properties of acids and bases;*
- *differentiate between strong and weak acids and bases;*
- *explain the role of water in dissociation of acids and bases;*
- *explain the term ionic product constant of water;*
- *define pH;*
- *correlate the concentration of hydrogen ions and pH with neutral, acidic and basic nature of aqueous solutions;*

- *recognize the importance of pH in everyday life,;*
- *define salts and describe their methods of preparation;*
- *correlate the nature of salt and the pH of its aqueous solution;*
- *describe the manufacture and use of baking soda, washing soda, plaster of paris and bleaching powder.*

## 8.1 ACIDS AND BASES

For thousands of years, people have known that vinegar, lemon juice, Amla, tamarind and many other food items taste sour. However, only a few hundred years ago it was proposed that these things taste sour because they contain 'acids'. The term **acid** comes from Latin term 'accre' which means sour. It was first used in the seventeenth century by Robert Boyle to label substances as acids and bases according to the following characteristics:

| Acids | Bases |
|---|---|
| (i) taste sour | (i) taste bitter |
| (ii) are corrosive to metals | (ii) feel slippery or soapy |
| (iii) change blue litmus red | (iii) change red litmus blue |
| (iv) become less acidic on mixing with bases | (iv) become less basic on mixing with acids |

While Robert Boyle was successful in characterising acids and bases he could not explain their behaviour on the basis of their chemical structure. This was accomplished by Swedish scientist Svante Arrhenius in the late nineteenth century. He proposed that on dissolving in water, many compounds dissociate and form ions and their properties are mainly the properties of the ions they form. Governed by this, he identified the ions furnished by acids and bases responsible for their characteristic behaviour and gave their definitions.

### 8.1.1 Acids

An acid is a substance which furnishes hydrogen ions ($H^+$) when dissolved in water. For example, in its aqueous solution hydrochloric HCl (aq) dissociates as:

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

Some examples of acids are:

$H^+$

ACIDS

(i) Hydrochloric acid (HCl) in gastric juice

(ii) Carbonic acid ($H_2CO_3$) in soft drinks

(iii) Ascorbic acid (vitamin C) in lemon and many fruits

(iv) Citric acid in oranges and lemons
(v) Acetic acid in vinegar
(vi) Tannic acid in tea
(vii) Nitric acid ($HNO_3$) used in laboratories
(viii) Sulphuric acid ($H_2SO_4$) used in laboratories

### 8.1.2 Bases

A base is a substance which furnishes hydroxide ions ($OH^-$) when dissolved in water.

For example, sodium hydroxide NaOH (aq), in its aqueous solutions, dissociates as:

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

$OH^-$
BASE

The term '**alkali**' is often used for water soluble bases.

Some examples of bases are:

(i) Sodium hydroxide (NaOH) or caustic soda used in washing soaps.
(ii) Potassium hydroxide (KOH) or potash used in bathing soaps.
(iii) Calcium hydroxide ($Ca(OH)_2$) or lime water used in white wash.
(iv) Magnesium hydroxide ($Mg(OH)_2$) or milk of magnesia used to control acidity.
(v) Ammonium hydroxide ($NH_4OH$) used in hair dyes.

### 8.1.3 Indicators

You might have seen that the spot of turmeric or gravy on cloth becomes red when soap is applied on it. What do you think has happened? Turmeric has acted as an indicator of base present in soap. There are many substances that show one colour in an acidic medium and another colour in a basic medium. Such substances are called acid-base indicators.

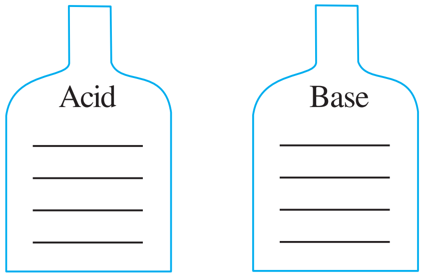
Litmus is a natural dye found in certain lichens. It was the earliest indicator to be used. It shows red colour in acidic solutions and blue colour in basic solutions. Phenolphthalein and methyl orange are some other indicators. The colours of these indicators in acidic, neutral and basic solutions are given below in table 8.1.

**Table 8.1 Colours of some indicators in acidic and basic solutions**

| Indicator | Colour in acidic solutions | | Colour in neutral solutions | | Colour in basic solutions | |
|---|---|---|---|---|---|---|
| Litmus | | red | | purple | | blue |
| Phenolphthalein | | colourless | | colourless | | pink |
| Methyl orange | | red | | orange | | yellow |
| | | | | | | |

## INTEXT QUESTION 8.1

1. Put the following substances in acid or base bottle.
   (a) Milk of magnesia
   (b) gastric juice in humans
   (c) soft drinks
   (d) lime water
   (e) vinegar
   (f) soap




2. What will happen if you add a drop of the following on a cut unripe apple, curd, causting soda solution and soap soluton.
   (i) phenolphthalein
   (ii) litmus

## 8.2 PROPERTIES OF ACIDS AND BASES

Each substance shows some typical or characteristics properties. We can categorize a substance as an acid or a base according to the properties displayed. Let us learn the characteristic properties of acids and bases.

### 8.2.1 Properties of Acids

The following are the characteristic properties of acids:

#### 1. Taste

You must have noticed that some of the food items we eat have sour taste. The sour taste of many unripe fruits, lemon, vinegar and sour milk is caused by the acids present in them. Hence, we can say that acids have a sour taste. This is particularly true of dilute acids (see table 8.2).

**Table 8.2 Acids present in some common substances**

| Substance | Acid present |
|---|---|
| 1. Lemon juice | Citric acid and ascorbic acid (vitamin C) |
| 2. Vinegar | Ethanoic acid (commonly called acetic acid) |
| 3. Tamarind | Tartaric acid |
| 4. Sour milk | Lactic acid |

## ACTIVITY 8.1

Go to your neighbourhood shop and procure.

1. Packaged Curd
2. Juices in tetra packs

Test these with a litmus paper to find out if these are acidic in nature.

### 2. Action on Indicators

We have learnt earlier (section 8.1.3) that indicators show different colours in presence of acids and bases. Let us recall the colours of the three commonly used indicators in presence of acids.

**Table 8.3 Colours of some indicators in presence of acids.**

| Indicator | Colour in acidic medium |
|---|---|
| 1. Litmus | Red |
| 2. Phenolphthalein | Colourless |
| 3. Methyl orange | Red |

### 3. Conduction of electricity and dissociation of acids

Do you know that solutions of acids in water (aqueous solutions) conduct electricity? Such solutions are commonly used in car and inverter batteries. When acids are dissolved in water they produce ions which help in conducting the electricity. This process is known as *dissociation*. More specifically, acids produce hydrogen ions ($H^+$) which are responsible for all their characteristic properties. These ions do not exist as $H^+$ in the solution but combine with water molecules as shown below:

$$\underset{\text{hydrogen ion}}{H^+} + H_2O \longrightarrow \underset{\text{hydronium ion}}{H_3O^+}$$

The $H_3O^+$ ions are called **hydronium ions**. These ions are also represented as $H^+(aq)$.

On the basis of the extent of dissociation occurring in their aqueous solutions, acids are classified as strong and weak acids.

**Points to ponder**

All hydrogen containing compounds are not acids

Although Ethyl alcohol ($C_2H_5OH$) and glucose ($C_6H_{12}O_6$) contain hydrogen but do not produce $H^+$ ion on dissolving in water. Their solutions do not conduct electricity and are not acidic.

#### A. Strong and Weak acids

Acids are classified as strong and weak acids and their characteristics are as follow :

| Strong Acids | Weak Acids |
|---|---|
| The acids which completely dissociate in water are called strong acids<br><br>Nitric acid completely dissociates in water<br><br>$HNO_3(aq) \longrightarrow H^+(aq) + NO_3^-(aq)$<br><br>There are only seven strong acids<br><br>1. HCl   Hydrochloric Acid<br>2. HBr   Hydrobromic Acid<br>3. HI   Hydroiodic Acid<br>4. $HClO_4$   Perchloric Acid<br>5. $HClO_3$   Chloric Acid<br>6. $H_2SO_4$   Sulphuric Acid<br>7. $HNO_3$   Nitric Acid | The acids which dissociate partially in water are called weak acids. All organic acids like acetic acid and some inorganic acids are weak acids. Since their dissociation is only partial, it is depicted by double half arrows.<br><br>$HF(aq) \rightleftharpoons H^+(aq) + F^-(aq)$<br><br>The double arrows indicates here that<br><br>(i) the aqueous solution of hydrofluoric acid not only contains $H^+$ (aq) and $F^-$(aq) ions but also the undissociated acid HF(aq).<br><br>(ii) there is an equilibrium between the undissociated acid HF(aq) and the ions furnished by it, $H^+$(aq) and $F^-$ (aq)<br><br>**Examples:**<br><br>(a) $CH_3COOH$ Ethanoic (acetic) acid,<br>(b) HF Hydrofluoric acid<br>(c) HCN Hydrocynic acid<br>(d) $C_6H_5COOH$ Benzoic acid |

## 4. Reaction of Acids with Metals

The reaction of acids with metals can be studied with the help of the following acitivity.

### ACTIVITY 8.2

This activity may be carried out in the chemistry laboratory of your study centre.

**Aim:** To study the reaction of acids with metals.

### What is required?

A test tube, zinc granules, dilute $H_2SO_4$, match box and a test tube holder.

### What to do?

- Add a few zinc granules in a test tube.
- Add dil. sulphuric acid carefully along the sides of the test tube.
- Set the apparatus as shown in the Fig. 8.1.
- Bring a burning match stick near the mouth of the test tube, (Fig. 8.1.

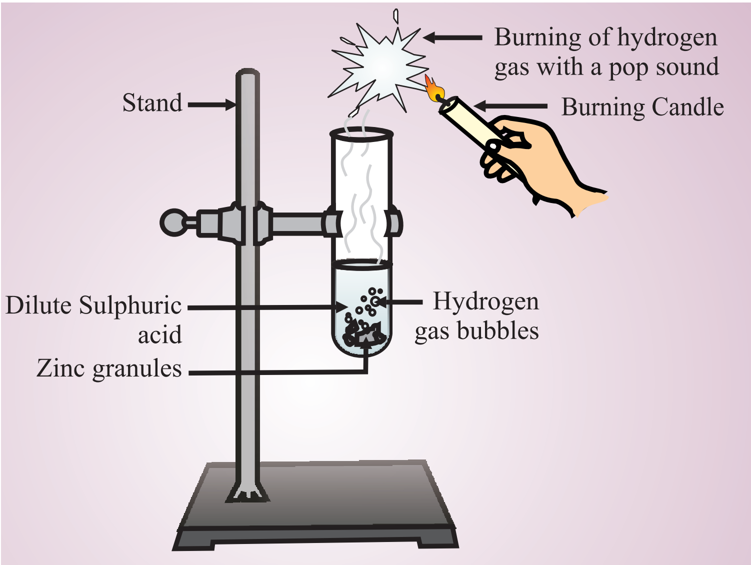



**Fig. 8.1:** *Experiment to study the reaction of dil. $H_2SO_4$ with zinc. The gas burns with a 'pop' sound when a burning match stick is brought near the mouth of the test tube.*

### What to observe?

- When dilute sulphuric acid is added to zinc granules, hydrogen gas is formed. The gas bubbles rise through the solution.
- When the burning match stick is brought near the mouth of the test tube the gas in the test tube burns with a 'pop' sound. This confirms that the gas evolved is hydrogen gas.

From this experiment it can be said that dilute sulphuric acid reacts with zinc to produce hydrogen gas. A similar reaction is observed when we use other metals like iron. In general, it can be said that in such reactions metal displaces hydrogen from acids and hydrogen gas is released. The metal combines with the remaining part of the acid and forms a compound called a salt, thus,

$$\text{Acid} + \text{Metal} \longrightarrow \text{Salt} + \text{Hydrogen gas}$$

For example, the reaction between zinc and dil. sulphuric acid can be written as:

| $Zn$ | + | $H_2SO_4$ | $\longrightarrow$ | $ZnSO_4$ | + | $H_2 \uparrow$ |
|---|---|---|---|---|---|---|
| zinc metal | | dil sulphuric acid acid | | zinc sulphate salt | | hydrogen gas |

### 5. Reaction of acids with metal carbonates and hydrogen carbonates

Reaction of acids with metal carbonates and hydrogen carbonates can be studied with the help of activity 8.2.

## ACTIVITY 8.3

This experiment may be carried out in the chemistry laboratory of your study centre.

**Aim:** To study the reaction of acids with metal carbonates and hydrogen carbonates.

### What is required?

One test tube, one boiling tube fitted with a cork, thistle funnel and delivery tube, sodium carbonate, sodium hydrogen carbonate, dilute HCl and freshly prepared lime water.

### What to do?

- Take the boiling tube and add about 0.5 g sodium carbonate to it.
- Take about 2 mL of freshly prepared lime water in a test tube.

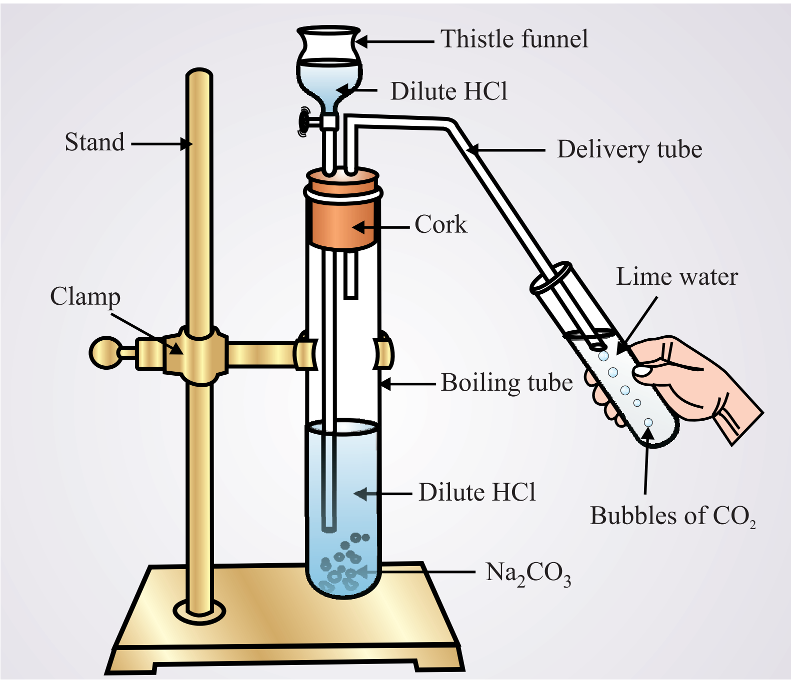



**Fig. 8.2:** *Experimental set up to study the reaction of acids with metal carbonates and hydrogen carbonates*

- Add about 3 mL dilute HCl to the boiling tube containing sodium carbonate and immediately fix the cork filled with a delivery tube and set the apparatus as shown in the Fig. 8.2.
- Dip the other end of the delivery tube in the lime water as shown in Fig. 8.2.
- Observe the lime water carefully.
- Repeat the activity with sodium hydrogen carbonate.

### What to observe?

- When dilute HCl is added to sodium carbonate or sodium hydrogen carbonate, carbon dioxide gas is evolved.
- On passing $CO_2$ gas, lime water turns milky.
- On passing the excess of $CO_2$ gas, lime water becomes clear again.

From the above activity it can be concluded that if sodium carbonate or sodium hydrogen carbonate react with dilute hydrochloric acid, carbon dioxide gas is evolved. The respective reactions are:

| $Na_2CO_3(s)$ | + | $2HCl(aq)$ | $\longrightarrow$ | $2NaCl(aq)$ | + | $H_2O(l)$ | + | $CO_2(g)\uparrow$ |
|---|---|---|---|---|---|---|---|---|
| sodium carbonate | | dil. hydrochloric acid | | sodium chloride | | water | | carbon dioxide |

| $NaHCO_3(s)$ | + | $HCl(aq)$ | $\longrightarrow$ | $NaCl(aq)$ | + | $H_2O(l)$ | + | $CO_2\ (g)\uparrow$ |
|---|---|---|---|---|---|---|---|---|
| sodium hydrogen carbonate | | dil. hydrochloric acid | | sodium chloride | | water | | carbon dioxide |

On passing the evolved carbon dioxide gas through lime water, $Ca(OH)_2$, the later turns milky due to the formation of white precipitate of calcium carbonate

| $Ca(OH)_2(aq)$ | + | $CO_2(g)$ | $\longrightarrow$ | $CaCO_3(s)$ | + | $H_2O(l)$ |
|---|---|---|---|---|---|---|
| lime water | | carbon dioxide | | calcium carbonate (white ppt.) | | water |

If excess of carbon dioxide gas is passed through lime water, the white precipitate of calcium carbonate disappears due to the formation of water soluble calcium hydrogen carbonate.

| $CaCO_3(s)$ | + | $H_2O(l)$ | + | $CO_2(g)$ | $\longrightarrow$ | $Ca(HCO_3)_2(aq)$ |
|---|---|---|---|---|---|---|
| calcium carbonate (white ppt.) | | water | | Carbon dioxide | | calcium hydrogen carbonate (soluble in water) |

Thus, we can summarize that,

Metal carbonate + Acid $\longrightarrow$ Salt + Water + Carbon dioxide

and Metal hydrogen carbonate + Acid $\longrightarrow$ Salt + Water + Carbon dioxide

### 6. Reaction of Acids with metal oxides

We can study the reaction of acids with metal oxides with the help of activity 8.4.

## ACTIVITY 8.4

This activity may be carried out in the chemistry laboratory of your study centre.

**Aim :** To study the reaction of acids with metal oxides.

### What is required?

A beaker, glass rod, copper oxide and dilute hydrochloric acid.

### What to do?

- Take a small amount of black copper oxide in a beaker.
- Add about 10 mL of dilute hydrochloric acid and stir the solution gently with the help of a glass rod. [Fig. 8.3(a)].
- Observe the beaker as the reaction occurs. [Fig. 8.3(b)].

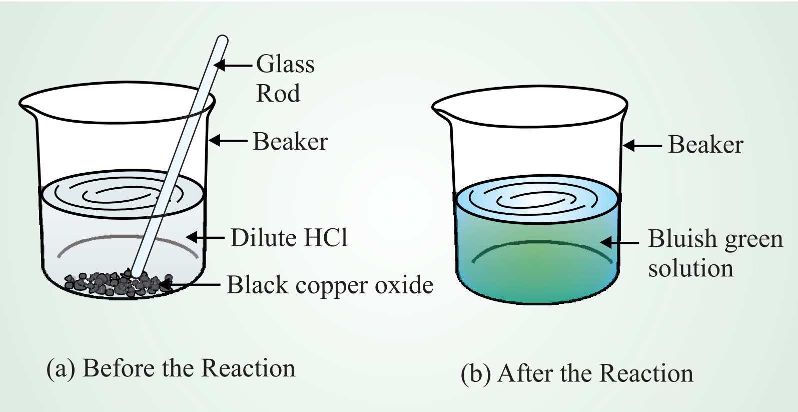



**Fig. 8.3** *Reaction between dilute hydrochloric acid and copper oxide (a) before reaction black particles of copper oxide in transparent dilute hydrochloric acid and (b) after reaction bluish green solution.*

### What to Observe?

- When a mixture of dilute HCl and copper oxide is mixed, the black particles of copper oxide can be seen suspended in colourless dilute hydrochloric acid.
- As the reaction proceeds, the black particles slowly dissolve and the colour of the solution becomes bluish green due to the formation of copper (II) chloride (cupric chloride) – a salt.

From this activity, we can conclude that the reaction between copper oxide and dilute hydrochloric acid results in the formation of copper (II) chloride (cupric chloride) which is a salt of copper. This salt forms bluish green solution. The reaction is:

$$\underset{\text{copper oxide}}{CuO(s)} + \underset{\text{dil. hydrochloric acid}}{2HCl(aq)} \longrightarrow \underset{\text{copper (II) chloride}}{CuCl_2(aq)} + \underset{\text{water}}{H_2O(l)}$$

Many other metal oxides like magnesium oxide (MgO) and calcium oxide (CaO) or quick lime also react with acid in a similar way. For example,

$$\underset{\substack{\text{calcium oxide}\\\text{(quick lime)}}}{CaO(s)} + \underset{\substack{\text{dil. hydrochloric}\\\text{acid}}}{2HCl(aq)} \longrightarrow \underset{\text{calcium chloride}}{CaCl_2(aq)} + \underset{\text{water}}{H_2O(l)}$$

So, we can summarize with a general reaction between metal oxides and acids as:

$$\text{Metal oxide} + \text{Acid} \longrightarrow \text{Salt} + \text{Water}$$

### 7. Reaction of acids with bases

Let us study the reaction of acids with bases with the help of the following activity.

### ACTIVITY 8.5

This activity may be carried out in the chemistry laboratory of your study centre.

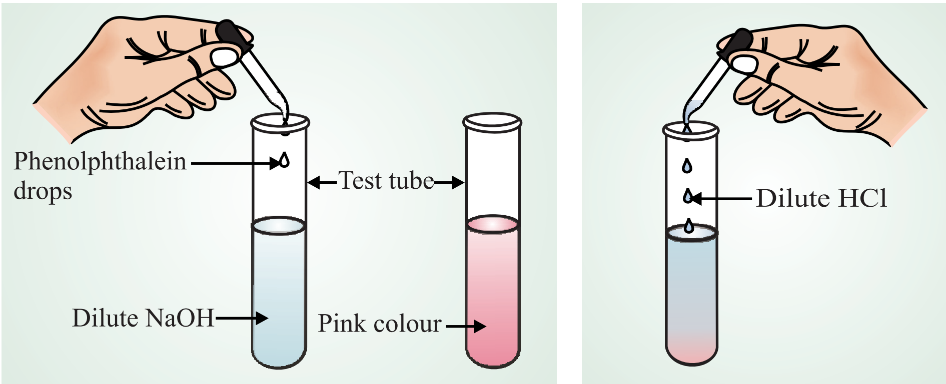
**Aim :** To study the reaction between acids and bases.

#### What is required?

A test tube, dropper, phenolphthalein indicator, solution of sodium hydroxide and dil. hydrochloric acid.

#### What to do?

- Take about 2 mL solution of sodium hydroxide in a test tube.
- Add a drop of phenolphthalein indicator to it and observe the colour.
- With the help of a dropper add dil. HCl dropwise and stir the solution constantly till the colour disappears.
- Now add a few drops of NaOH solution. The colour of the solution is restored.




(a) (b)

**Fig. 8.4:** *Reaction between NaOH and HCl (a) Pink colour solution containing NaOH solution and a drop of phenolphthalein (b) The solution becomes colourless on addition of dil HCl*

## What to Observe?

- When a drop of phenolphthalein is added to a solution of NaOH the solution becomes pink in colour.
- On adding HCl, the colour of the solution fades due to the reaction between HCl and NaOH.
- When whole of NaOH has reacted with HCl, the solution becomes colourless.
- On adding NaOH, the solution becomes pink again.

From this activity, we can see that when dilute HCl is added to NaOH solution, the two react with each other. When sufficient HCl is added, the basic properties of NaOH and acidic properties of HCl disappear. The process is therefore called **neutralization**. It results in the formation of salt and water. The reaction between hydrochloric acid and sodium hydroxide forms sodium chloride and water.

| | | | | | | |
|---|---|---|---|---|---|---|
| $HCl(aq)$ | + | $NaOH(aq)$ | $\longrightarrow$ | $NaCl(aq)$ | + | $H_2O(l)$ |
| hydrochloric acid | | sodium hydroxide | | sodium chloride | | water |

Similar reactions occur with other acids and bases. For example ,sulphuric acid and potassium hydroxide react to form potassium sulphate and water.

| | | | | | | |
|---|---|---|---|---|---|---|
| $H_2SO_4(aq)$ | + | $2KOH(aq)$ | $\longrightarrow$ | $K_2SO_4(aq)$ | + | $2H_2O(l)$ |
| sulphuric acid | | potassium hydroxide | | potassium sulphate | | water |

In general, the reaction between and acid and a base can be written as:

$$\text{Acid} + \text{Base} \longrightarrow \text{Salt} + \text{Water}$$

### 8. Corrosive Nature

The ability of acids to attack various substances like metals, metal oxides and hydroxides is referred to as their corrosive nature. (It may be noted here that the term 'corrosion' is used with reference to metals and refers to various deterioration processes (oxidation) they undergo due to their exposure to environment). Acids are corrosive in nature as they can attack variety of substances.

**'Strong' is different from 'corrosive'**

Corrosive action of acids is not related to their strength. It is related to the negatively charged part of the acid. For example, hydrofluoric acid, (HF )is a weak acid. Yet, it is so corrosive that it attacks and dissolves even glass. The fluoride ion attacks the silicon atom in silica glass while the hydrogen ion attacks the oxygen of silica ($SiO_2$) in the glass.

$$\underset{\text{silica (in glass)}}{SiO_2} + \underset{\text{hydrofluoric acid}}{4HF} \longrightarrow \underset{\text{silicon tetra fluoride}}{SiF_4} + \underset{\text{water}}{2H_2O}$$

### 8.2.2 Properties of Bases

The following are the characteristic properties of bases:

### 1. Taste and touch

Bases have a bitter taste and their solutions are soapy to touch.

**Warning**

Although we talk of 'taste' of acids and bases, it is not advisable to taste any acid or base. Most of them are harmful. Similarly touching the solutions of strong acids and bases should be avoided. They may harm the skin.

### 2.Action on Indicators

As seen earlier (section 8.1.3) each indicator shows characteristic colour in presence of bases. The colours shown by three commonly used indicators in presence of bases are listed below for easy recall.

**Table 8.3 Colours of some common indicators in basic solution**

| Indicator | Colour in basic medium |
|---|---|
| 1. Litmus | Blue |
| 2. Phenolphthalein | Pink |
| 3. Methyl orange | Yellow |

### 3. Conduction of electricity and dissociation of bases

Aqueous solutions (solution in water) of bases conduct electricity which is due to the formation of ions. Like acids, bases also dissociate on dissolving in water. Bases produce hydroxyl ions ($OH^-$) which are responsible for their characteristic properties.

The bases which are soluble in water and give $OH^-$ ions in their aqueous solution are called **alkalies**. *All alkalies are bases but all bases are not alkalies*. On the basis of the extent of dissociation occurring in their solution, bases are classified as strong and weak bases.

### A. Strong and Weak Bases

Bases are classified as strong and weak bases and their characteristics are as follow :

| Strong Bases | Weak Bases |
|---|---|
| These bases are completely dissociated in water to form the cation and hydroxide ion ($OH^-$). For example, potassium hydroxide dissociates as<br>$KOH(aq) \longrightarrow K^+(aq) + OH^-(aq)$<br>There are only eight strong bases. These are the hydroxides of the elements of the Groups 1 and 2 of the periodic table<br>1. LiOH Lithium hydroxide<br>2. NaOH Sodium hydroxide<br>3. KOH Potassium hydroxide<br>4. RbOH Rubidium hydroxide<br>5. CsOH Caesium hydroxide<br>6. $Ca(OH)_2$ Calcium hydroxide<br>7. $Sr(OH)_2$ Strontium hydroxide<br>8. $Ba(OH)_2$ Barium hydroxide | Weak bases do not furnish $OH^-$ ions by dissociation. They react with water to furnish $OH^-$ ions.<br>$NH_3(g) + H_2O(l) \longrightarrow NH_4OH$<br>$NH_4OH(aq) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$<br>or<br>$NH_3(g) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$<br>The reaction resulting in the formation of $OH^-$ ions does not go to completion and the solution contains relatively low concentration of $OH^-$ ions. The two half arrows are used in the equation to indicate that equilibrium is reached before the reaction is completed. Examples of weak bases (i) $NH_4OH$, (ii) $Cu(OH)_2$ (iv) $Cr(OH)_3$ (v) $Zn(OH)_2$ etc. |

### 4. Reaction of bases with metals

Like acids, bases also react with active metals liberating hydrogen gas. Such reactions can also be studied with the help of activity 8.2 given earlier. For example, sodium hydroxide reacts with zinc as shown below:

$$\underset{\text{zinc metal}}{Zn(s)} + \underset{\text{sodium hydroxide}}{2NaOH(aq)} \longrightarrow \underset{\text{sodium zincate}}{Na_2ZnO_2(aq)} + \underset{\text{hydrogen}}{H_2(g)\uparrow}$$

### 5. Reaction of Bases with non-metal oxides

Bases react with oxides of non-metals like $CO_2$, $SO_2$, $SO_3$, $P_2O_5$ etc. to form salt and water.

For example,

$$\underset{\substack{\text{calcium hydroxide}\\ \text{(lime water)}}}{Ca(OH)_2(aq)} + \underset{\substack{\text{carbon}\\ \text{dioxide}}}{CO_2(g)} \longrightarrow \underset{\substack{\text{calcium}\\ \text{carbonate}}}{CaCO_3(s)} + \underset{\text{water}}{H_2O(l)}$$

The reaction can be written in a general form as:

$$\text{Base + Non-metal oxide} \longrightarrow \text{Salt + Water}$$

### 6. Reaction of bases with acids

We have learnt the mutual reaction between acids and bases in previous section. Such reactions are called *neutralization* reactions and result in the formation of salt and water. The following are some more examples of neutralization reactions:

$$HCl(aq) + KOH(aq) \longrightarrow KCl(aq) + H_2O(l)$$

$$H_2SO_4(aq) + 2NaOH(aq) \longrightarrow Na_2SO_4(aq) + 2H_2O(l)$$

**Caustic nature**

Strong bases like sodium hydroxide and potassium hydroxide are corrosive towards organic matter and break down the proteins of the skin and flesh to a pasty mass. This action is called caustic action and it is due to this property that sodium hydroxide is called 'caustic soda' and potassium hydroxide is called 'caustic potash'. The term 'caustic' is not used for corrosive action of acids.

## INTEXT QUESTIONS 8.2

1. Name the substances in which the following acids are present:
   (a) Ethanoic acid (b) Tartaric acid
2. Which of these acids would be partially dissociated in their aqueous solution?
   (a) HBr (b) HCN
   (c) $HNO_3$ (d) $C_2H_5COOH$
3. An acid reacts with a substance X with liberation of a gas which burns with a 'pop' sound when a burning match stick is brought near it. What is the nature of X?
4. An acid reacts with a substance Z with the liberation of $CO_2$ gas. What can be the nature of Z?
5. Which of the following oxides will react with a base?
   (a) CaO (b) $SO_2$

## 8.3 WATER AND DISSOCIATION OF ACIDS AND BASES

In the previous sections, we have learnt that a substance is an acid if it furnishes $H^+$ ions in its aqueous solution and a base if it furnishes $OH^-$ ions. Water plays very important role in these processes, we shall learnt about it in this section.

### 8.3.1 Role of water in dissociation of acids and bases

If a dry strip of blue litmus paper is brought near the mouth of the test tube containing dry HCl gas , its colour does not changes. When it is moistened with a drop of water and again brought near the mouth of the test tube , its colour turns red. It shows that there are no $H^+$ ion in dry HCl gas. Only when it dissolves in water, $H^+$ ions are formed and it shows its acidic nature by turning the colour of the blue litmus paper to red.

A similar behavior is exhibited by bases. If we take a pallet of dry NaOH in dry atmosphere and quickly bring a dry strip of red litmus paper in its contact, no colour change is observed. NaOH is a **hygroscopic** compound and soon absorbs moisture from air and becomes wet. When this happens, the colour of the red litmus paper immediately changes to blue. Thus in dry solid NaOH although $OH^-$ ions are present but they are not free and do not show basic nature on coming in contact with water, $OH^-$ ions becomes free and show the basic nature by changing red litmus blue. From the above discussion, it is clear that acidic and basic characters of different substances can be observed only when they are dissolved in water.

**Warning**

Dissolution of $H_2SO_4$ in water is highly exothermic process. Therefore, to prepare an aqueous solution, conc. sulphuric acid is added slowly to water with constants stirring. Water is **never** added to con. sulphuric acid as huge amount of heat is liberated. Due to that spattering occurs and the acid can cause serious burns on skins or damage the items on which it falls.

(i) When an acid like sulphuric acid or a base like sodium hydroxide is dissolved in water, the solution that is formed is hotter. It shows that the dissolution process is **exothermic**. A part of the thermal energy which is released during the dissolution process is used up in overcoming the forces holding the hydrogen atom or hydroxyl group in the molecule of the acid or the base in breaking the chemical bond holding them and results in the formation of free $H^+(aq)$ and $OH^-(aq)$ ions.

(ii) Many bases are ionic compounds and consist of ions even in the solid state. For example sodium hydroxide consists of $Na^+$ and $OH^-$ ion. These ions are held very tightly due to the strong electrostatic forces between the oppositely charged ions. Presence of water as a medium (solvent) weakens these forces greatly and the ions become free to dissolve in water.

### 8.3.2 Self dissociation of water

Water plays an important role in acid base chemistry. We have seen that it helps in the dissociation of acids and bases resulting in the formation of $H^+$(aq) and $OH^-$(aq) ions respectively. Water itself undergoes dissociation process which is called 'self-dissociation of water'.Let us learn about it.

#### Self-dissociation of water

Water dissociates into $H^+$(aq) and $OH^-$(aq) ions as:

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

The dissociation of water is extremely small and only about two out of every billion ($10^9$) water molecules are dissociated at 25°C. As a result, the concentrations of $H^+$(aq) and $OH^-$(aq) ions formed is also extremely low. At 25°C (298K),

$$[H^+] = [OH^-] = 1.0 \times 10^{-7} \text{ mol L}^{-1}$$

Here, square brackets denote the molar concentration of the species enclosed within. Thus, $[H^+]$ denotes the concentration of $H^+$(aq) ions in moles per litre and $[OH^-]$ the concentration of $OH^-$(aq) ions in moles per litre.

It must be noted here that in pure water and in all aqueous **neutral solutions**,

$$[H^+] = [OH^-]$$

Also, in pure water as well as in all aqueous solutions at a given temperature, product of concentrations of $H^+$(aq) and $OH^-$(aq) always remains constant. This product is called 'ionic product of water' and is given the symbol *Kw*. It is also called **ionic product constant of water**. Thus,

$$Kw = [H^+] [OH^-]$$

At 25°C (298 K), in pure water, *Kw* can be calculated as:

$$\begin{aligned} Kw &= (1.0 \times 10^{-7}) \times (1.0 \times 10^{-7}) \\ &= 1.0 \times 10^{-14} \end{aligned}$$

### 8.3.3 Neutral, acidic and basic solutions

We have seen that in pure water $H^+$(aq) and $OH^-$(aq) ions are produced in equal numbers as a result of dissociation of water and therefore, their concentrations are also equal i.e.

$$[H^+] = [OH^-]$$

#### (i) Neutral solutions

In all neutral aqueous solutions, the concentrations of $H^+$(aq) and $OH^-$(aq) ions remains equal i.e.

$$[H^+] = [OH^-]$$

In other words the neutral solution is the one in which the concentrations of $H^+$ and $OH^-$ ions are equal.

#### (ii) Acidic solutions

Acids furnish $H^+$(aq) ions in their solutions resulting in increase in their concentration. Thus, in acidic solutions

$$[H^+] > [OH^-]$$

and $$[H^+] > 1.0 \times 10^{-7} \text{ mol L}^{-1}$$

In other words the acidic solution is the one in which the concentration of $H^+(aq)$ is greater than that of $OH^-(aq)$ ions.

We have seen earlier that the ionic product of water *Kw* is constant at a given temperature. It can remain so only if the concentration of $OH^-(aq)$ ions decreases.

$$[OH^-] < 10^{-7} \text{ mol L}^{-1}$$

### (iii) Basic solutions

Bases furnish $OH^-(aq)$ ions in their solutions. This results in an increase in their concentration. Therefore, in basic solution

$$[OH^-] > [H^+]$$

and $$[OH^-] > 1.0 \times 10^{-7} \text{ mol L}^{-1}$$

In other words, the basic solution is the one in which the concentration of $H^+(aq)$ ions is smaller than that of $OH^{-1}(aq)$ ions.

Here also, because of constancy of ionic product of water Kw, the concentration of $H^+(aq)$ decreases. Thus

and $$[H^+] < 1.0 \times 10^{-7} \text{ mol L}^{-1}$$

We may summarize the nature of aqueous solution in terms of concentration of hydrogen ions $H^+(aq)$ as shown in table 8.3.

**Table 8.3 Concentration of $H^+(aq)$ ions in different types of aqueous solutions**

| Nature of solution | Concentration of $H^+$ ions at 25°C (298 K) |
|---|---|
| Neutral | $[H^+] = 1.0 \times 10^{-7}$ mol $L^{-1}$ |
| Acidic | $[H^+] > 1.0 \times 10^{-7}$ mol $L^{-1}$ |
| Basic | $[H^+] < 1.0 \times 10^{-7}$ mol $L^{-1}$ |

## INTEXT QUESTIONS 8.3

1. Why does the colour of dry blue litmus paper remains unchanged even when it is brought in contact with HCl gas?
2. How does water help in dissociation of acids and bases?
3. Identify the nature of the following aqueous solutions (whether acidic, basic or neutral)
   (a) Solution A: $[H^+] < [OH^-]$
   (b) Solution B: $[H^+] > [OH^-]$
   (c) Solution C: $[H^+] = [OH^-]$

## 8.4 pH AND ITS IMPORTANCE

When dealing with range of concentrations (such as these of $H^+(aq)$ ions) that spans many powers of ten, it is convenient to represent them on a more compressed logarithmic scale. By convention, we use the **pH scale** for denoting the concentration of hydrogen ions. **pH** notation was devised by the Danish biochemist Soren Sorensen in 1909. The term pH means "power of hydrogen".

The pH is the logarithm (see box) of the reciprocal of the hydrogen ion concentration. It is written as:

$$pH = \log \frac{1}{\left[H^+\right]}$$

Alternately, the pH is the negative logarithm of the hydrogen ion concentration i.e

$$pH = -\log [H^+].$$

Because of the negative sign in the expression, if $[H^+]$ increases, pH would decrease and if it decreases, pH would increase.

In pure water at 25° (298 K)

$$[H^+] = 1.0 \times 10^{-7} \text{ mol L}^{-1}$$

$$\log[H^+] = \log(10^{-7}) = -7$$

and $\quad pH = -\log[H^+] = -(-7)$

$$pH = 7$$

Since in pure water at 25°C (298 K)

$$[OH^-] = 1.0 \times 10^{-7} \text{ mol L}^{-1}$$

Also, $\quad pOH = 7$

Since, $\quad Kw = 1.0 \times 10^{-14}$

$$pKw = 14$$

**Logarithm**

Logarithm is a mathematical function

If $\quad x = 10^y$

then $\quad y = \log_{10}x$

Here $\log_{10}x$ mean log of x to the base 10. Usually, the base 10 is omitted in the notation thus, $y = \log x$.

e.g. $\quad \log 10^3 = 3 \times \log 10 = 3 \times 1 = 3$

$\log 10^{-5} = -5 \times \log 10 = -5 \times 1 = -5$

**Note :** $\log 10 = 1$

The relationship between pKw, pH and pOH is

$$pKw = pH + pOH$$

at 25°C (298 K)

$$14 = pH + pOH$$

### 8.4.1 Calculations based on pH concept

In the last section, we learned the concept of pH and its relationship with hydrogen ion or hydroxyl ion concentration. In this section, we shall use these relations to perform some calculations.

The method of calculation of pH used in this unit are valid for (i) solutions of *strong* acids and bases only and (ii) the solutions of acids or bases should not be extremely dilute and the concentrations of acids and bases *should not be less than* $10^{-6}$ *mol* $L^{-1}$.

**Example 8.1:** Calculate the pH of 0.001 molar solution of HCl.

**Solution:** HCl is a strong acid and is completely dissociated in its solutions according to the process:

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

From this process it is clear that one mole of HCl would give one mole of $H^+$ ions. Therefore, the concentration of $H^+$ ions would be equal to that of HCl i.e. 0.001 molar or $1.0 \times 10^{-3}$ mol $L^{-1}$.

Thus, $[H^+] = 1 \times 10^{-3}$ mol $L^{-1}$

$$pH = -\log[H^+] = -(\log 10^{-3})$$

$$= -(-3 \times \log 10) = -(3 \times 1) = 3$$

Thus, $pH = 3$

**Example 8.2:** What would be the pH of an aqueous solution of sulphuric acid which is $5 \times 10^{-5}$ mol $L^{-1}$ in concentration.

**Solution:** Sulphuric acid dissociates in water as:

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

Each mole of sulphuric acid gives two mole of $H^+$ ions in the solution. One litre of $5 \times 10^{-5}$ mol $L^{-1}$ solution contains $5 \times 10^{-5}$ moles of $H_2SO_4$ which would give $2 \times 5 \times 10^{-5} = 10 \times 10^{-5}$ or $1.0 \times 10^{-4}$ moles of $H^+$ ion in one litre solution. Therefore,

$$[H^+] = 1.0 \times 10^{-4} \text{ mol } L^{-1}$$

$$pH = -\log[H^+] = -\log 10^{-4} = -(-4 \times \log 10)$$

$$= -(-4 \times 1) = 4$$

**Example 8.3:** Calculate the pH of $1 \times 10^{-4}$ molar solution of NaOH.

**Solution:** NaOH is a strong base and dissociate in its solution as:

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

One mole of NaOH would give one mole of $OH^-$ ions. Therefore,

$$[OH^-] = 1 \times 10^{-4} \text{ mol L}^{-1}$$

$$pOH = -\log[OH^-] = -\log \times 10^{-4} = -(-4)$$

$$= 4$$

Since $$pH + pOH = 14$$

$$pH = 14 - pOH = 14 - 4$$

$$= 10$$

**Example 8.4:** Calculate the pH of a solution in which the concentration of hydrogen ions is $1.0 \times 10^{-8}$ mol $L^{-1}$.

**Solution:** Here, although the solution is extremely dilute, the concentration given is *not of acid or base* but that of $H^+$ ions. Hence, the pH can be calculated from the relation:

$$pH = -\log[H^+]$$

$$\text{given } [H^+] = 1.0 \times 10^{-8} \text{ mol L}^{-1}$$

$$\therefore \quad pH = -\log 10^{-8} = -(-8 \times \log 10)$$

$$= -(-8 \times 1) = 8$$

### 8.4.2 pH Scale

The pH scale ranges from 0 to 14 on this scale. pH 7 is considered neutral, below 7 acidic and above 7 basic. Farther from 7, more acidic or basic the solution is. The scale is shown below in Fig. 8.5.

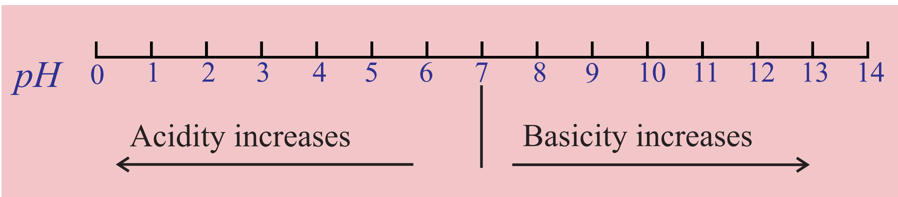



**Fig. 8.5:** *The pH scale*

We have learnt earlier that the sum of pH and pOH of any aqueous solution remains constant. Therefore, when one increases the other decreases. This relationship is shown in Fig. 8.6

$$pH + pOH = 14$$

**Fig. 8.6:** *Relationship between pH and pOH at 25°C.*

pH of some common substances is shown in table 8.5.

**Table 8.5: pH of some common acids and bases**

| Common Acids | pH | Common Bases | pH |
|---|---|---|---|
| HCl (4%) | 0 | Blood plasma | 7.4 |
| Stomach acid | 1 | Egg white | 8 |
| Lemon juice | 2 | Sea water | 8 |
| Vinegar | 3 | Baking soda | 9 |
| Oranges | 3.5 | Antacids | 10 |
| Soda, grapes | 4 | Ammonia water | 11 |
| Sour milk | 4.5 | Lime water | 12 |
| Fresh milk | 5 | Drain cleaner | 13 |
| Human saliva | 6-8 | Caustic soda 4% (NaOH) | 14 |
| Pure water | 7 | | |

### 8.4.3 Determination of pH

pH of a solution can be determined by using proper indicator or with the help of a pH meter. The latter is a device which gives accurate value of pH. You will study more about it in higher classes. We shall discuss here the use of indicators for finding out the pH of a solution.

#### Universal Indicator/pH paper.

It is a mixture of a number of indicators. It shows a specific colour at a given pH. A colour guides is provided with the bottle of the indicator or the strips of paper impregnated with it which are called pH paper strips. The test solution is tested with a drop of the universal indicator, or a drop of the test solution is put on pH paper. The colour of the solution on the pH paper is compared with the colour chart/guard and pH is read from it. The pH values thus obtained are only approximate values.

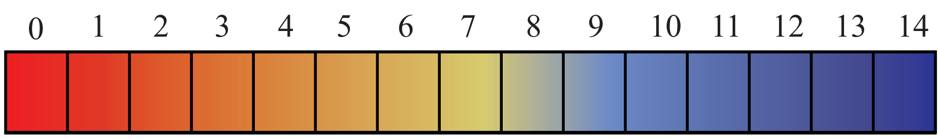



**Fig. 8.7:** *Colour chart/guide of universal indicator/pH paper.*

### 8.4.2 Importance of pH in everyday life

pH plays a very important role in our everyday life. Some such examples are described here.

#### (a) pH in humans and animals

Most of the biochemical reactions taking place in our body are in a narrow pH range of 7.0 to 7.8. Even a small change in pH disturbs these processes.

### (b) Acid Rain

When the pH of rain water falls below 5.6, it is called **acid rain**. When acid rain flows into rivers, the pH of the river water also falls and it become acidic. As a result, the survival of aquatic life become difficult.

### (c) pH in plants

Plants have a healthy growth only when the soil has a specific pH range which should be neither highly alkaline nor highly acidic.

### (d) In digestive system

Our stomach produce hydrochloric acid which helps in digestion of food. When we eat spicy food, stomach produces too much of acid which causes 'acidity' i.e. irritation and sometimes pain too. To get rid of this we use 'antacids' which are bases like 'milk of magnesia' (suspension of magnesium hydroxide in water).

### (e) Self defence of animals and plants

Bee sting causes severe pain and burning sensation. It is due to the presence of methanoic acid in it. Use of a mild base like baking soda can provides relief from pain.

Some plants like 'nettle plant' have fine stinging hair which inject methanoic acid into the body of any animal or human being that comes in its contact. This causes severe pain and buring sensation. The leaves of dock plant that grows near the nettle plant when rubbed on the affected area provides relief.

**Fig. 8.8** *Nettle plant*

### (f) Tooth decay

Tooth enamel is made of calcium phosphate which is the hardest substance in our body and can withstand the effect of various food articles that we eat. If mouth is not washed properly after every meal, the food particles and sugar remaining in the mouth undergoes degradation due to the bacterial present in the mouth. This process produces acids and the pH goes below 5.5. The acidic condition thus created corrode the tooth enamel and in the long run can result in tooth decay.

## INTEXT QUESTIONS 8.4

1. pOH of a solution is 5.2. What is its pH. Comment on the nature (acidic, basic or neutral) of this solution.
2. pH of a solution is 9. What is the concentration of $H^+$ ions in it.

3. What is the nature (whether acidic, basic or neutral) of the following solutions?
   (a) Solution A: pH = pOH
   (b) Solution B: pH > pOH
   (c) Solution C: pH < pOH

## 8.5 SALTS

Salts are ionic compounds made of a cation other than $H^+$ ion and an anion other than $OH^-$ ion.

### 8.5.1 Formation of salts

Salts are formed in many reactions involving acids and bases.

**1. By Neutralization of acids and bases**

Salts are the product (besides water) of a neutralization reaction.

For example,

| | Base | | Acid | | Salt | | Water |
|---|---|---|---|---|---|---|---|
| | $NaOH$ | + | $HCl$ | $\longrightarrow$ | $NaCl$ | + | $H_2O$ |
| | $KOH$ | + | $HNO_3$ | $\longrightarrow$ | $KNO_3$ | + | $H_2O$ |
| In general, | $MOH$ | + | $HX$ | $\longrightarrow$ | $MX$ | + | $H_2O$ |

In all the above cases we can see that the positively charged cation of the salt comes from the base. Therefore, it is called the 'basic radical'. The negatively charged anion of the salt comes from the acid. It is therefore, called the 'acid radical' of the salt. For example, in the salt NaCl, the cation $Na^+$ comes from the base NaOH and is its basic radical and the anion $Cl^-$ comes from the acid HCl and is its 'acid radical'.

**2. By action of acids on metals**

In a reaction between an acid and a metal, salt is produced along with hydrogen,

| Metal | | Acid | | Salt | | Hydrogen |
|---|---|---|---|---|---|---|
| $Zn$ | + | $H_2SO_4$ | $\longrightarrow$ | $ZnSO_4$ | + | $H_2$ |

**3. By action of acids on metal carbonates and hydrogen carbonates**

Salts are produced in reactions between acids and metal carbonates and hydrogen carbonates (bicarbonates) along with water and carbon dioxide.

| Metal carbonate or hydrogen carbonate | | Acid | | Salt | | Water | | Carbon dioxide |
|---|---|---|---|---|---|---|---|---|
| $CaCO_3$ | + | $2HCl$ | $\longrightarrow$ | $CaCl_2$ | + | $H_2O$ | + | $CO_2$ |
| $NaHCO_3$ | + | $HCl$ | $\longrightarrow$ | $NaCl$ | + | $H_2O$ | + | $CO_2$ |

Type of salt and the nature of its aqueous solution:

| | Salt of | | Nature of Salt Solution | pH (at 25°C) |
|---|---|---|---|---|
| | Acid | Base | | |
| 1. | Strong | Strong | Neutral | pH = 7 |
| 2. | Weak | Strong | Basic | pH > 7 |
| 3. | Strong | Weak | Acidic | pH < 7 |
| 4. | Weak | Weak | More information required | – |

## 8.6 SOME COMMONLY USED SALTS

A large number of salts are used in our homes and industry for various purposes. In this section we would learn about some such salts.

### 8.6.1 Baking soda

You must have seen your mother using baking soda while cooking some 'dals'. If you ask her why does she use it, she would tell that it helps in cooking some items fasters which otherwise would take must longer time. Chemically baking soda is sodium hydrogen carbonate, $NaHCO_3$.

#### (a) Manufacture

Baking soda is manufactured by Solvey's process. It is mainly used for manufacturing washing soda but baking soda is obtained as an intermediate.

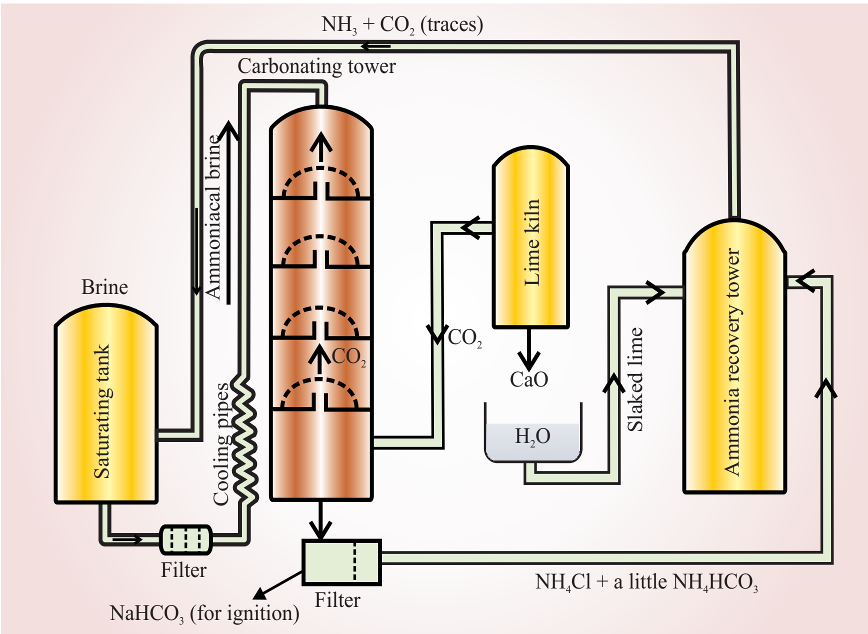



**Fig. 8.9** Solvey's process for manufacturing of Baking soda

## Raw materials required

The raw materials required to manufacture washing soda are:

- Lime stone which is calcium carbonate, $CaCO_3$
- Sodium chloride (NaCl) in the form of brine( Conc. NaCl Solution)
- Ammonia ($NH_3$)

## Process

In Solvey's process, carbon dioxide is obtained by heating limestone strongly,

$$\underset{\text{lime stone}}{CaCO_3(s)} \longrightarrow \underset{\text{quick lime}}{CaO(s)} + \underset{\text{carbon dioxide}}{CO_2(g)\uparrow}$$

It is then passed through cold brine (a concentrated solution of NaCl in water) which has previously been saturated with ammonia,

$$\underset{\substack{\text{sodium chloride}\\\text{in brine}}}{NaCl(aq)} + CO_2(g) + \underset{\text{ammonia}}{NH_3(g)} + H_2O(l) \longrightarrow \underset{\substack{\text{sodium hydrogen}\\\text{carbonate}}}{NaHCO_3(s)\downarrow} + \underset{\substack{\text{ammonium}\\\text{chloride}}}{NH_4Cl(aq)}$$

$NaHCO_3$ is sparingly soluble in water and crystallises out as white crystals. Its solution in water is basic in nature. It is a mild and non-corrosive base.

**Action of heat:** On heating, sodium hydrogen carbonate is converted into sodium carbonate and carbon dioxide is given off,

$$\underset{\text{sodium carbonate}}{2NaHCO_3} \xrightarrow{\text{heat}} Na_2CO_3 + H_2O + CO_2\uparrow$$

### (b) Use

1. Used for cooking of certain foods.
2. For making **baking power** (a mixture of sodium hydrogen carbonate and tartaric acid). On heating during baking, baking soda gives off carbon dioxide. It is this carbon dioxide which raises the dough. The sodium carbonate produced on heating the baking soda gives a bitter taste. Therefore, instead of using the baking soda alone, baking powder is used. The tartaric acid present in it neutralises the sodium carbonate to avoid its bitter taste. Cakes and pastries are made flufly and soft by using baking powder.
3. In medicines

   Being a mild and non-corrosive base, baking soda is used in medicines to neutralise the excessive acid in the stomach and provide relief. Mixed with solid edible acids such as citric or tartaric acid, it is used in effervescent drinks to cure indigestion.
4. In soda acid fire extinguishers

### 8.6.2 Washing soda

Washing soda is used for washing of clothes. It is mainly because of this chemical that the clothes washed by a washerman appear so white. Chemically, washing soda is sodium carbonate decahydrate, $Na_2CO_3.10H_2O$.

#### (a) Manufacture

Washing soda is manufacturing by Solvey's process. We have already learnt about the raw materials required and part of the process in the manufacture of baking soda. Sodium carbonate is obtained by calcination (strong heating in a furnace) of sodium hydrogen carbonate and then recrystallising from water:

$$2NaHCO_3 \xrightarrow{\text{heat}} Na_2CO_3 + H_2O + CO_2$$

$$\underset{\text{sodium carbonate}}{Na_2CO_3} + 10H_2O \longrightarrow \underset{\text{washing soda}}{Na_2CO_3.10H_2O}$$

#### (b) Uses

1. It is used in the manufacture of caustic soda, glass, soap powders, borex and in paper industry.
2. For removing permanent hardness of water.
3. As a cleansing agent for domestic purpose.

### 8.6.3 Plaster of Paris

You must have seen some beautiful designs made on the ceiling and walls of rooms in many houses. These are made of plaster of paris, also called POP. Chemically, it is $2CaSO_4.H_2O$ or $CaSO_4.\frac{1}{2}H_2O$ (calcium sulphate hemi hydrate)

#### (a) Manufacture

**Raw material**

Gypsum, $(CaSO_4.2H_2O)$ is used as the raw material.

**Process**

The only difference between gypsum $(CaSO_4.2H_2O)$ and plaster of paris $(CaSO_4.1/2H_2O)$ is in the less amount of water of crystallization.

When gypsum is heated at about 100° (373 K) temperature, it loses a part of its water of crystallization to form:

$$\underset{\text{gypsum}}{CaSO_4.2H_2O} \xrightarrow[100°C(373\text{ K})]{\text{heat}} \underset{\text{plaster of paris}}{CaSO_4.1/2H_2O} + 3/2H_2O$$

The temperature is not allowed to rise beyond 100°C otherwise whole of water of crystallization is lost and anhydrous calcium sulphate is produced which is called 'dead burnt' as it does not have the property to set after mixing with water.

### (b) Uses

1. In making casts for manufacture of toys and statues.
2. In medicine for making plaster casts to hold fractured bones in place while they set. It is also used for making casts in dentistry.
3. For making the surface of walls and ceiling smooth.
4. For making decorative designs on ceilings, walls and pillars.
5. For making' chalk' for writing on blackboard.
6. For making fire proof materials.

## 8.6.4 Bleaching Powder

Have you ever wondered at the whiteness of a new white cloth? How is it made so white? It is done by bleaching of the cloth at the time of its manufacture. **Bleaching** is a process of removing colour from a cloth to make it whiter. Bleaching powder has been used for this purpose since long. Chemically, it is calcium oxychloride, $CaOCl_2$.

### (a) Manufacture

1. **Raw material required**: The raw material required for the manufacture of bleaching powder are:
   - Slaked lime, $Ca(OH)_2$
   - Chlorine gas, $Cl_2$

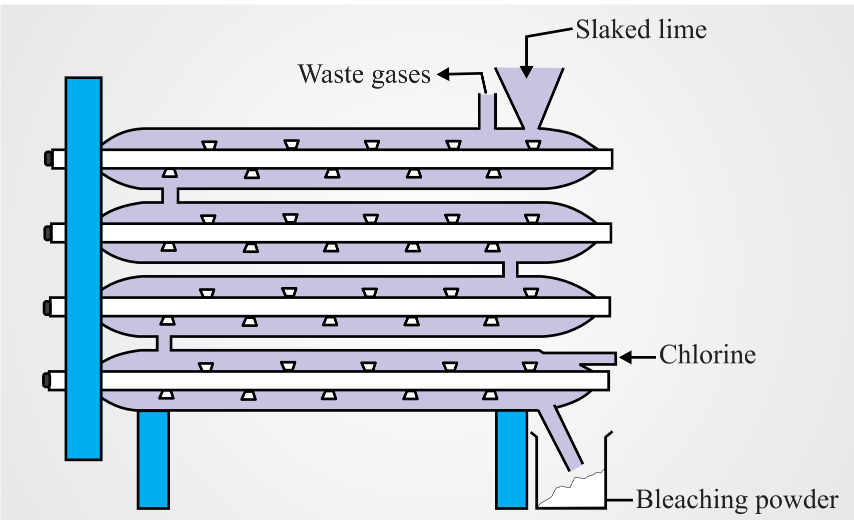



**Fig. 8.10** Hasen-Clever plant for manufacturing of bleaching powder

2. **Process**: It is manufactured by Hasen-Clever Method. The plant consists of four cylinders made of cast iron with inlet for chlorine near the base. The dry slaked lime, calcium hydroxide is fed into the chlorinating cylinders from the top. It moves down slowly and meets the upcoming current of chlorine. As a result of the reaction between them, it is converted into bleaching power which collects at the bottom.

$$\underset{\text{slaked lime}}{Ca(OH)_2} + \underset{\text{chlorine}}{Cl_2} \longrightarrow \underset{\text{bleaching powder}}{CaOCl_2} + H_2O$$

### (b) Uses

1. In textile industry for bleaching of cotton and linen.
2. In paper industry for bleaching of wood pulp.
3. In making wool unshrinkable.
4. Used as disinfactant and germicide for sterilization of water.
5. For the manufacture of chloroform.
6. Used as an oxidizing agent in chemical industry.

## INTEX QUESTIONS 8.5

1. Identify acid radical and basic radical in $CaSO_4$.
2. $CuSO_4$ was prepared by reacting an acid and a base. Identify the acid and the base that must have been used in this reaction.
3. Which one of the following is the correct formula of plaster of paris?

   $CaSO_4.H_2O$ or $2CaSO_4.H_2O$

## WHAT YOU HAVE LEARNT

- Acids are the substances which taste sour, change blue litmus red, are corrosive to metals and furnish $H^+$ ions in their aqueous solutions.
- Bases are the substances which taste bitter, change red litmus blue, feel slippery and furnish $OH^-$ ions in their aqueous solutions.
- Indicators are the substances that show one colour in an acidic medium and another colour in a basic medium. Litmus, phenolphthalein and methyl orange are commonly used indicators.

- Acids are presents in many unripe fruits, vinegar, lemon, sour milk etc., while bases are present in lime water, window pane cleaners, many drain cleaners etc.
- Aqueous solutions of acids and bases both conduct electricity as they dissociate on dissolving in water and liberate cations and anions which help in conducting electricity.
- Strong acids and bases dissociate completely in water. HCl, HBr, HI, $H_2SO_4$, $HNO_3$, $HClO_4$ and $HClO_3$ are strong acids and LiOH, NaOH, KOH, RbOH, CsOH, $Ca(OH)_2$, $Sr(OH)_2$ and $Ba(OH)_2$ are strong bases.
- Weak acids and bases dissociate partially in water. For example, HF, HCN, $CH_3COOH$ etc. are some weak acid and $NH_4OH$, $Cu(OH)_2$, $Al(OH)_3$ etc. are some weak bases.
- Acids and bases react with metals to produce salt and hydrogen gas.
- Acids react with metal carbonates and metal hydrogen carbonates to produce salt, water and $CO_2$.
- Acids react with metal oxides to produce salt and water.
- Bases react with non-metal oxides to produce salt and water.
- Acids and bases react with each other to produce salt and water. Such reactions are called neutralization reactions.
- Acids and bases dissociate only on dissolving in water.
- Water itself undergoes dissociation and furnishes $H^+$ and $OH^-$ ions in equal numbers. This is called self dissociation of water. The extent of dissociation is very small.
- Concentrations of $H^+$ and $OH^-$ ion formed by the self dissociation of water are $1.0 \times 10^{-7}$ molar each at 25°C.
- Product of concentrations of hydrogen and hydroxyl ions is called the 'ionic product' or ionic product constant' of water, Kw. It remains unchanged even when some substance (acid, base or salt etc.) is dissolved in it.
- pH is defined as $\log \frac{1}{\left[H^+\right]}$ or $-\log[H^+]$, likewise pOH = $-\log[OH^-]$ and pKw = $-\log$ Kw
- In pure water or in any aqueous solution pH + pOH = pKw = 14 at 25°C.
- In pure water $[H^+] = [OH^-]$. It is also true in any neutral aqueous solution. In terms of pH, pH = pOH = 7 in water and any neutral solution.
- In acidic solution $[H^+] > [OH^-]$ and pH < pOH. Also pH < 7 at 25°C.
- In basic solutions $[H^+] < [OH^-]$ and pH > pOH. Also pH > 7 at 25°C.
- Universal indicator is prepared by mixing a number of indicators. It shows a different but characteristic colour at each pH.

- Maintenance of correct pH is very important for biochemical process occuring in humans and animals.
- If pH of rain water falls below 5.6, it is called acid rain and is quite harmful.
- pH plays an important role in proper growth of plants and also for proper digestion in our bodies.
- Salts are ionic compounds made of a cation other than $H^+$ ion and an anion other than $OH^-$ ion. They are formed in neutralization reaction.
- Salts are also formed in reaction of acids and bases with metals, of acid with metal carbonates, hydrogen carbonates and oxides and in reaction of bases with non-metal oxides.

## TERMINAL EXERCISE

### *A. Objective Type Questions*

### I. Mark the correct choice

1. Lemon juice contains
   (a) tartaric acid (b) ascorbic acid
   (c) acetic acid (d) lactic acid
2. Aqueous solutions of acids conduct electricity. This shows that
   (a) They contain $H^+$ ions
   (b) They contain $OH^-$ ion
   (c) They contain cations and anions
   (d) They contain both $H^+$ and $OH^-$ ions
3. Which of the following is not a strong acid?
   (a) HCl (b) HBr
   (c) HI (d) HF
4. Self dissociation of water produces
   (a) a large number of $H^+$ ions
   (b) a large number of $OH^-$ ions
   (c) $H^+$ and $OH^-$ ions in equal numbers
   (d) $H^+$ and $OH^-$ ions in unequal numbers
5. In any aqueous basic solution
   (a) $[H^+] > [OH^-]$ (b) $[H^+] < [OH^-]$
   (c) $[H^+] = [OH^-]$ (d) $[H^+] = 0$

6. In an aqueous solution of HCl which of the following species is not present?
   (a) $H^+$ (b) $OH^-$
   (c) HCl (d) $Cl^-$
7. Which of the following is not a raw material for manufacturing washing soda?
   (a) Lime stone (b) Ammonia
   (c) Slaked lime (d) Sodium chloride

## II. Mark the following statements as true (T) or false (F):

1. Acids furnish $H^+$ ions only in the presence of water.
2. Lime water turns blue litmus red.
3. HF is a strong acid.
4. $H_2$ gas is produced when acids react with metal oxides.
5. Corrosive action of acids is due to $H^+$ ions present in them.
6. When the pH of the rain water become more than 5.6 it is called acid rain.
7. Aqueous solutions of all the salts are neutral in nature i.e. neither acidic nor basic in nature.

## III. Fill in the blanks

1. Acids taste ..................... while bases taste .....................
2. Milk of magnesia turns ..................... litmus .....................
3. One mole of sulphuric acid would furnish ..................... mole/s of $H^+$ ions and ..................... moles of $SO_4^{2-}$ ions.
4. ..................... gas is produced when acids react with metal hydrogen carbonates.
5. Lime water turns milky on passing $CO_2$ gas due to the formation of .....................
6. The reaction between an acid and a base is known as .....................
7. Bee sting injects ..................... acid which causes severe pain and burning sensation.
8. In $NH_4NO_3$ the acid radical is ..................... and the basic radical is .....................
9. Chemically baking soda is .....................

## *B. Descriptive Questions*

1. What is an acid?
2. Give two examples of acids found in food articles.
3. What is a base?
4. Give two examples of bases.

5. What are indicators?
6. What is the colour of methyl orange indicator in (i) acidic medium and (ii) basic medium.
7. Why do solutions of acids and bases conduct electricity?
8. Differentiate between strong and weak acids and give one example of each.
9. Write down the reaction between zinc and sulphuric acid.
10. Which gas is evolved when an acid reacts with metal carbonates? Which other category of compounds would produce the same gas on reacting with acids?
11. What type of oxides react with acids? Give one examples of this type of oxide and write down the balanced equation for the reaction.
12. What is the name given to the reaction between an acid and a base? What are the products formed in such reactions?
13. "Corrosive action of acids is not related to their strength". Justify this statement.
14. Give one example each of the following (i) a strong base (ii) a weak base
15. List three categories of substances that can react with a base. Give one example of each and write the chemical reaction involved in each case.
16. What happens when a dry strip of each of red litmus paper and blue litmus paper is brought in contact with HCl gas? In which case a change would be observed if the strips are moistened and then brought in contact with HCl gas and what would be the change?
17. A small palette of NaOH is kept on dry red litmus paper. Initially, no change is observed but after some time its colour starts changing to blue around the place where the palette of NaOH is kept. Explain these observations.
18. How does water help in dissociation of acids and bases? Explain.
19. What is 'self dissociation of water'? Name the resulting species and give their concentrations at 25°C.
20. What is ionic product constant of water? Give its value at 25°C. Will the value change if an acid, base or a salt is dissolved in water?
21. Give the relationships between the concentrations of hydrogen ions and hydroxyl ions in (i) pure water (ii) a neutral solution (iii) an acidic solution and (iv) a basic solution.
22. What is pH? What happens to the pH if the hydroxyl ion concentration in the solution increases?
23. Predict whether a given aqueous solution is acidic, basic or neutral if its pH is (a) 7.0, (b) 11.9 and (c) 3.2.
24. Calculate the pH of $1.0 \times 10^{-4}$ molar solution of $HNO_3$.

25. What is the pH of $1.0 \times 10^{-5}$ molar solution of KOH?
26. What is the pH of $1.0 \times 10^{-2}$ mol $L^{-1}$ solution of NaCl?
27. What do you understand by the term 'universal indicator'?
28. What is acid rain?
29. What is the importance of pH for humans and animals, and our digestive system?
30. Which chemical causes pain and burning sensation when somebody accidentally touches 'nettle plant'?
31. What is a salt? Give two examples.
32. How are salts obtained from an acid? Mention four types of substances that can be used for it.
33. Give chemical formula of (i) baking soda and (ii) washing soda.
34. List the raw materials required for the manufacture of baking soda and describe the process with the help of suitable chemical equations.
35. Distinguish between baking powder and baking soda. Why is baking powder preferred for making cakes?
36. Give any two uses of baking soda.
37. What is washing soda? Give its chemical formula. How is it manufactured by Solvey's method?
38. Give two uses of washing soda.
39. What is the chemical formula of 'plaster of paris'? How is it manufactured? What precaution is taken during its manufacture?
40. List any four uses of 'plaster of paris'.
41. What is bleaching? Chemically, what is bleaching powder? Give its any four uses.
42. List the raw materials required and the method of manufacture of bleaching powder. Write the equation for the reaction involved.

## ANSWERSTO INTEXT QUESTIONS

### 8.1

1. Acidic : (b), (c) and (e)

   Basic : (a), (d) and (f)

2. Phenolphthalein: Colourless on unripe apple and pink in solutions of caustic soda and soap.

   Litmus: Red on unripe apple and curd, and blue in solutions of caustic soda and soap solution.

### 8.2

1. (a) Vinegar (b) tamarind
2. (b) and (d)
3. It must be a metal.
4. It may be either a metal carbonate or hydrogen carbonate.
5. $SO_2$

### 8.3

1. It is because HCl gas does not contain $H^+(aq)$ ions and is non acidic
2. (i) The heat released in dissolution process help in the dissociation process by overcoming the forces that hold the hydrogen atom or the hydroxyl group in the molecules of the acid or the base, or in breaking the chemical bond holding them.
   (ii) Presence of water weaken the electrostatic forces between anion and cations.
3. (a) Solution A – basic
   (b) Solution B – acidic
   (c) Solution C – neutral

### 8.4

1. Since $\text{pH} + \text{pOH} = 14$
   $\text{pH} = 14 - \text{pOH} = 14 - 5.2$
   $= 8.8$
   Since $\text{pH} > 7.0$, it is basic in nature
2. $\text{pH} = -\log[H^+] = 9$
   $\therefore$ $\log[H^+] = -9$
   or $[H^+] = 10^{-9}\ \text{mol L}^{-1}$
3. (a) Solution A — neutral
   (b) Solution B — basic (since $[H^+] < [OH^-]$ in it)
   (c) Solution C — acidic (since $[H^+] > [OH^-]$ in it)

### 8.5

1. Acid radical $SO_4^{2-}$
   Basic radical $Ca^{2+}$
2. Acid: $H_2SO_4$ (corresponding to the acid radical $SO_4^{2-}$)
   Base: $Cu(OH)_2$ (corresponding to the basic radical $Cu^{2+}$)
3. (a) Carbonates (b) potassium salts
4. $2CaSO_4.H_2O$

# MODULE - 3

# MOVING THINGS

9. Motion and its Description
10. Force and motion
11. Gravitation