

## 5. Acids, Bases and Salts



➤ Arrhenius theory of acids and bases ➤ Concentration of an acid or a base  
➤ pH of a solution ➤ pH of an acid and a base ➤ Salts



**Can you recall?**

How are the following substances classified into three groups with the help of litmus? Lemon, tamarind, baking soda, buttermilk, vinegar, orange, milk, lime, tomato, milk of magnesia, water, alum.

We have earlier seen that some foodstuffs are sour to taste while some others are bitter and slippery or soapy to touch. When these substances are studied scientifically, it is found that they contain acidic and basic substances respectively. We have also learnt an easy and safe method of using an indicator like litmus to identify acids and bases.

How are acids and alkalies identified with the help of litmus paper?

We shall now learn more about acids and bases. But let us first review what the molecules of compounds are made up of?

**Fill in the columns in the part a of the following table.**

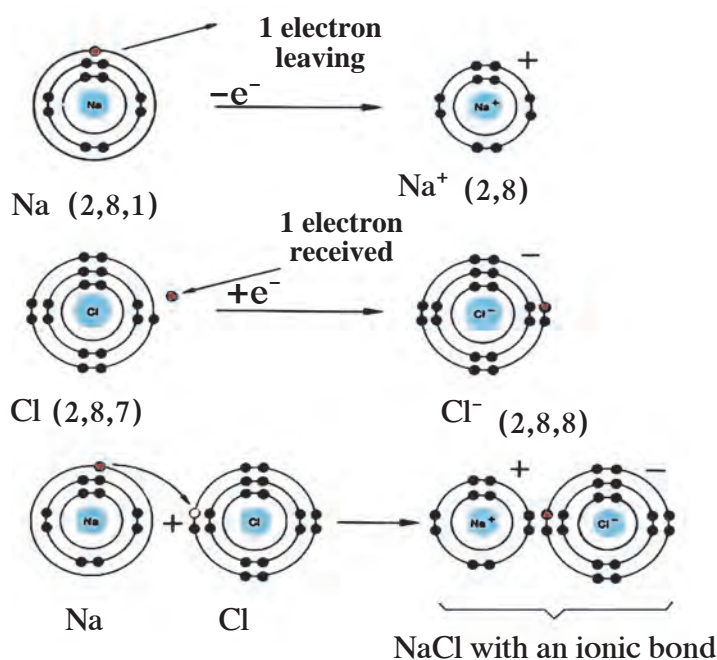
A				B
Name of the compound	Molecular formula	Basic radical	Acidic radical	Type of the compound
Hydrochloric acid	HCl	H <sup>+</sup>	Cl <sup>-</sup>	Acid
	HNO <sub>3</sub>			
	HBr			
	H <sub>2</sub> SO <sub>4</sub>			
	H <sub>3</sub> BO <sub>3</sub>			
	NaOH			
	KOH			
	Ca(OH) <sub>2</sub>			
	NH <sub>4</sub> OH			
	NaCl			
	Ca(NO <sub>3</sub> ) <sub>2</sub>			
	K <sub>2</sub> SO <sub>4</sub>			
	CaCl <sub>2</sub>			
	(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>			

Some compounds are seen to have H<sup>+</sup> as the basic radical in their molecules. These are all acids. Some compounds are seen to have OH<sup>-</sup> as the acidic radical in their molecule. All these compounds are bases. Those ionic compounds which have a basic radical other than H<sup>+</sup> and an acidic radical other than OH<sup>-</sup> are called salts.

Now complete part B of the above table. It will be clear that there are three types of ionic compounds and these are acids, bases and salts.

### Ionic compounds : recapitulation

The molecule of an ionic compound has two constituents, namely, cation (positive ion/basic radical) and anion (negative ion/acidic radical). There is a force of attraction between these ions as they are oppositely charged, and that is called the ionic bond. The force of attraction between one positive charge on a cation and one negative charge on an anion makes one ionic bond.



5.1 Formation of the compound NaCl  
Electron configuration

While studying static electricity we have learnt that there is a natural tendency of any body to change from an electrically charged state into an electrically neutral state. Why, then, is an electrically charged ion formed from an electrically balanced, that is, neutral atom? The explanation lies in the electronic configuration of atoms. Let us see once again how the sodium and chlorine atoms form the  $\text{Na}^+$  and  $\text{Cl}^-$  and as a result, how the NaCl salt is formed.

Figure 5.1 shows how this takes place.

The outermost shell of the sodium and the chlorine atoms is not a complete octet. However outermost shell in both the  $\text{Na}^+$  and  $\text{Cl}^-$  ions is a complete octet.

An electronic configuration with a complete octet indicates a stable state. Further, an ionic bond is formed between the oppositely charged  $\text{Na}^+$  and  $\text{Cl}^-$  ions and therefore an ionic compound NaCl having very high stability is formed.

### Dissociation of ionic compounds

On mixing the substances as shown here, what are the resulting mixtures formed by mixing the following substances called?

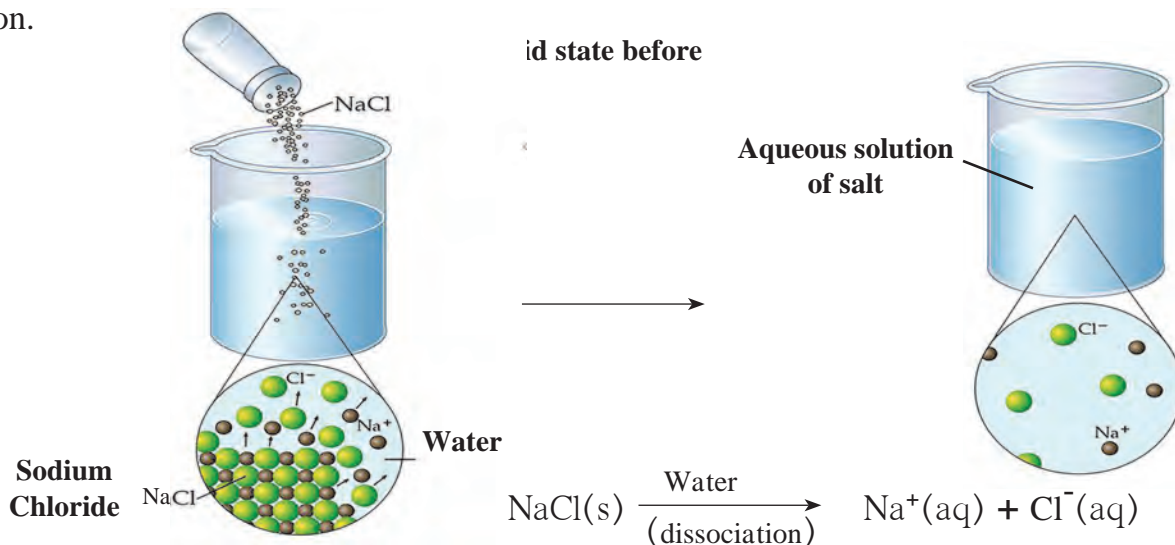


Can you recall?

1. Water and salt
2. Water and sugar
3. Water and sand
4. Water and sawdust

On dissolving in water, an ionic compound forms an aqueous solution. In the solid state, the oppositely charged ions in the ionic compound are sitting side by side. When an ionic compound begins to dissolve in water, the water molecules push themselves in between the ions of the compound and separate them from each other. That is to say, an ionic compound dissociates while forming an aqueous solution. (See figure 5.2)

Each of the dissociated ions in the aqueous solution is surrounded by water molecules. This state is indicated by writing (aq), meaning aqueous, on the right of the symbol of the ion.

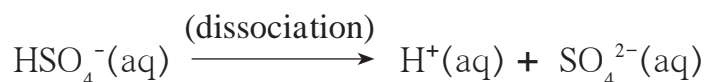
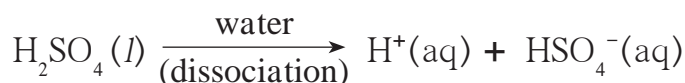
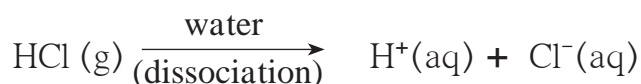


## 5.2 Dissociation of salt in aqueous solution

### Arrhenius theory of acids and bases

The Swedish scientist Arrhenius put forth a theory of Acids and Bases in the year 1887. This theory gives definitions of acids and bases as follows :

**Acid :** An acid is a substance which on dissolving in water gives rise to  $\text{H}^+$  ion as the only cation. For example,  $\text{HCl}$ ,  $\text{H}_2\text{SO}_4$ ,  $\text{H}_2\text{CO}_3$ .

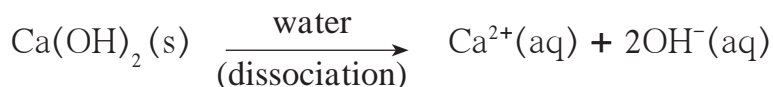
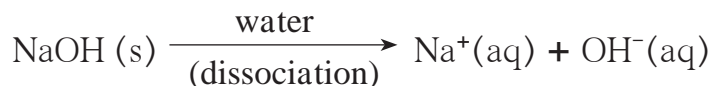


**Use your brain power !**

- What are the names of the following compounds?  
 $\text{NH}_3$ ,  $\text{Na}_2\text{O}$ ,  $\text{CaO}$ .
- When the above compounds are mixed with water they combine with water. Complete the following table by writing the ions formed by their combination with water.
- Into which type will you classify the above compounds- acid, base or salt ?

$\text{NH}_3 (\text{g}) + \text{H}_2\text{O}(\text{l})$	$\longrightarrow$	$\text{NH}_4^+ (\text{aq}) + \text{OH}^-(\text{aq})$
$\text{Na}_2\text{O}(\text{s}) + \dots\dots\dots$	$\longrightarrow$	$2 \text{Na}^+(\text{aq}) + \dots\dots\dots$
$\text{CaO}(\text{s}) + \text{H}_2\text{O}(\text{l})$	$\longrightarrow$	$\dots\dots\dots + \dots\dots\dots$

Base : A base is a substance which on dissolving in water gives rise to the  $\text{OH}^-$  ion as the only anion. For example,  $\text{NaOH}$ ,  $\text{Ca(OH)}_2$



## Classification of acids and bases

### 1. Strong and weak acids, bases and alkali

1. Acids and bases are classified into strong and weak types on the basis of the extent to which they dissociate in their aqueous solutions.

**Strong acid :** On dissolving in water, a strong acid dissociates almost completely and the resulting aqueous solution contains mainly  $\text{H}^+$  ions and the concerned acidic radical. For example,  $\text{HCl}$ ,  $\text{HBr}$ ,  $\text{HNO}_3$ ,  $\text{H}_2\text{SO}_4$ .

**Weak acid :** On dissolving in water a weak acid does not dissociate completely, and the resulting aqueous solution contains  $\text{H}^+$  ion and the concerned acidic radical in small proportion along with large proportion of the undissociated molecules of the acid. For example,  $\text{H}_2\text{CO}_3$ ,  $\text{CH}_3\text{COOH}$  (Acetic Acid).

**Strong base :** On dissolving in water, a strong base dissociates almost completely and the resulting aqueous solution contains mainly  $\text{OH}^-$  ions and the concerned basic radicals. For example,  $\text{NaOH}$ ,  $\text{KOH}$ ,  $\text{Ca(OH)}_2$ ,  $\text{Na}_2\text{O}$ .

**Weak base :** On dissolving in water a weak base does not dissociate completely, and the resulting aqueous solution contains a small proportion of  $\text{OH}^-$  ions and the concerned basic radical along with a large proportion of undissociated molecules of the base. For example,  $\text{NH}_4\text{OH}$ .

**Alkali :** The bases which are highly soluble in water are called alkali. For example,  $\text{NaOH}$ ,  $\text{KOH}$ ,  $\text{NH}_3$ . Here,  $\text{NaOH}$  and  $\text{KOH}$  are strong alkalies while  $\text{NH}_3$  is a weak alkali.

### 2. Basicity and acidity

Complete the following table.

Acid : Number of $\text{H}^+$ obtained from one molecule.						
$\text{HCl}$	$\text{HNO}_3$	$\text{H}_2\text{SO}_4$	$\text{H}_2\text{CO}_3$	$\text{H}_3\text{BO}_3$	$\text{H}_3\text{PO}_4$	$\text{CH}_3\text{COOH}$
Base : Number of $\text{OH}^-$ ions obtained from one molecule						
$\text{NaOH}$	$\text{KOH}$	$\text{Ca(OH)}_2$	$\text{Ba(OH)}_2$	$\text{Al (OH)}_3$	$\text{Fe(OH)}_3$	$\text{NH}_4\text{OH}$

Acids and bases are also classified according to their basicity and acidity respectively.

**Basicity of acids :** The number of  $\text{H}^+$  ions obtainable by the dissociation of one molecule of an acid is called its basicity.

**Acidity of bases :** The numbers of  $\text{OH}^-$  ions obtainable by the dissociation of one molecule of a base is called its acidity.



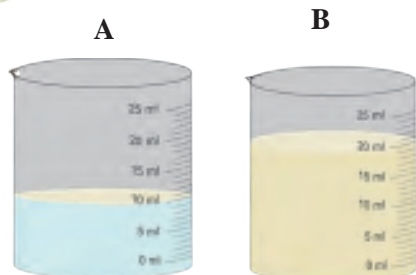
**Use your brain power !**

1. On the basis of the above table give examples of monobasic, dibasic and tribasic acids.
2. On the basis of the above table give the three types of bases their examples.

### Concentration of acid and base



**Try this**



**5.3 Solution of lemon juice**

Cut a lemon into two equal parts. Take the juice of each part into two separate beakers. Pour 10ml of drinking water in one beaker and 20ml in the second. Stir the solutions in both the beakers and taste them. Is there any difference in the tastes of the solutions in the two beakers? What is that difference?

In the above activity, the sour taste of the solutions is because of the solute, lemon juice, in them. The quantity of the lemon juice is the same in both the solutions. Yet their taste is different. The solution in the first beaker is more sour than the one in the second. Why is it so?

Although the quantity of the solute is the same in both the solutions, the quantity of the solvent is different. Ratio of the quantity of the solute to the quantity of the resulting solution is different. This ratio is larger for the solution in the first beaker and, therefore, that solution tastes more sour. On the other hand, the proportion of the lemon juice in the total solution in the second beaker is smaller and the taste is less sour.

The taste of foodstuff depends upon the nature of the taste-giving ingredient and its proportion in the foodstuff. Similarly, all the properties of a solution depend on the nature of the solute and solvent and also on the proportion of the solute in the solution. The Proportion of a solute in a solution is called the concentration of the solute in the solution. When the concentration of a solute in its solution is high, it is a concentrated solution, while the solution is called a dilute solution when the concentration of the solute is low.

Several units are used to express the concentration of a solution. Two of these units are used more frequently. The first unit is the mass of solute in grams dissolved in one litre of the solution. (grams per litre, g/L). The second unit is the number of moles of the solute dissolved in one litre of the solution. This is also called the molarity (M) of the solution. The molarity of a solute is indicated by writing its molecular formula inside a square bracket. For example  $[\text{NaCl}] = 1$  means the molarity of this solution of common salt is 1M (1 Molar).

**Complete the following table of the concentration of various aqueous solutions.**

Solute			Quantity of solute		Volume of solution	Concentration of the solution	
A	B	C	D	$E = \frac{D}{C}$	F	$G = \frac{D}{F}$	$H = \frac{E}{F}$
Name	Molecular formula	Molecular mass (u)	Gram (g)	Mole (mol)	Litre (L)	Gram/litre (g/L)	Molarity (M) mole/litre (mol/L)
Sodium Chloride	NaCl	58.5 u	117 g	2 mol	2 L	58.5 g/L	1 M
.....	HCl	.....	3.65 g	.....	1 L	.....	.....
.....	NaOH	.....	.....	1.5 mol	2 L	.....	.....

### The pH of solution

We have seen that acids and bases dissociate to a smaller or larger extent on dissolving in water forming  $H^+$  and  $OH^-$  ions respectively.  $H^+$  and  $OH^-$  ions are found in different proportions in all natural aqueous solutions, and that determines the properties of those solutions.

For example, the proportion of  $H^+$  and  $OH^-$  ions divides soil into the acidic, neutral and basic types of soil. It is necessary for blood, cell sap, etc. to have  $H^+$  and  $OH^-$  ions in certain definite proportions for their proper functioning. Fermentation carried out with the help of micro-organisms, other biochemical processes and also many chemical processes require the proportion of  $H^+$  and  $OH^-$  ions to be maintained within certain limits. Pure water, also, undergoes dissociation to a very small extent and gives rise to  $H^+$  and  $OH^-$  ions in equal proportion.



Due to this property of water to undergo dissociation, there exist both  $H^+$  and  $OH^-$  ions in any aqueous solution. However, their concentration may be different.

### pH of some common aqueous solutions

	Solution	pH
Strong acids ↑	1M HCl	0.0
	Gastric juice	1.0
	Lemon juice	2.5
	Vinegar	3.0
	Tomato juice	4.1
	Black coffee	5.0
	Acid rain	5.6
Weak acids	Urine	6.0
Neutral	Rain, milk	6.5
Weak bases ↓	Pure water, sugar solution	7.0
	Blood	7.4
	Solution of baking soda	8.5
	Toothpaste	9.5
	Milk of magnesia	10.5
	Limewater	11.0
	Strong bases	14.0



The concentration of  $H^+$  ions formed by dissociation of water at  $25^{\circ}C$  is  $1 \times 10^{-7} \text{ mol/L}$ . At the same temperature, the concentration of  $H^+$  ions in 1M solution of HCl is  $1 \times 10^0 \text{ mol/L}$ . While in a 1M NaOH solution, the concentration of  $H^+$  ions is  $1 \times 10^{-14} \text{ mol/L}$ . Thus, we see that in common aqueous solutions, the range of  $H^+$  ion concentration is very wide from  $10^0$  to  $10^{-14} \text{ mol/L}$ . In 1909, the Danish scientist Sorensen introduced a convenient new scale of expressing  $H^+$  ion concentration which is found to be very useful in chemical and biochemical processes. It is the pH scale (pH : power of hydrogen) The pH scale extends from 0 to 14. According to this scale pure water has a pH of 7 meaning pure water has  $[H^+] = 1 \times 10^{-7} \text{ mol/L}$ . pH 7 indicates a neutral solution. This pH is the midpoint of the scale. The pH of an acidic solution is less than 7 and that of a basic solution is greater than 7. The table (See page no. 63) gives the pH values of some common solutions.

By which other method could we find out the pH of a solution?

### Universal indicators

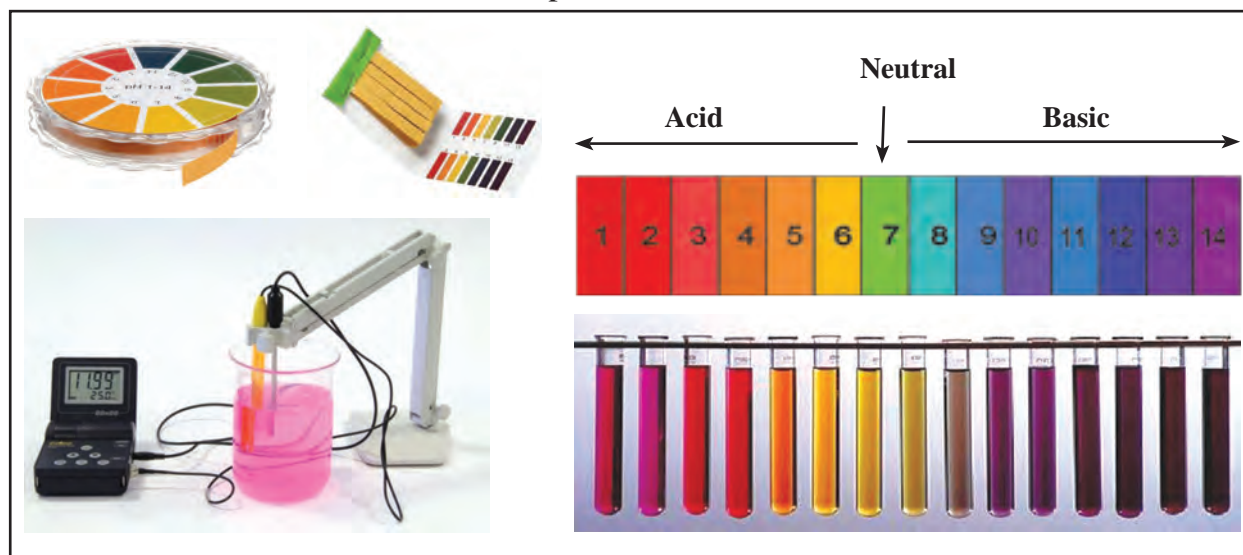


**Can you recall?**

What are the colours of the following natural and synthetic indicators in acidic and basic solutions?

Litmus, turmeric, *jamun*, methyl orange, phenolphthalein?

We know that some natural and synthetic dyes show two different colours in acidic and basic solutions, and such dyes are used as acid-base indicators. In the pH scale, the pH of solutions varies from 0 to 14 in accordance with the strength of the acid or base. To show these variations in pH, a universal indicator is used. A universal indicator shows different colours at different values of pH.

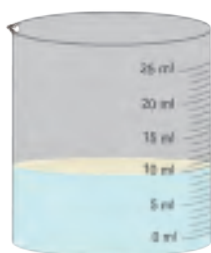


#### 5.4 Measurement of pH : universal indicator and pH meter

A universal indicator is made by mixing several synthetic indicators in specific proportions. The pH of a solution can be determined by means of a universal indicator solution or the pH paper made from it. However, the most accurate method of measuring the pH of a solution is to use an electrical instrument called pH meter. In this method, pH is measured by dipping electrodes into the solution.



### Try this



Dilute HCl

Glass rod

Indicator strip

## 5.5 Neutralization

## Reactivity of acids and bases

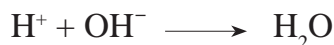
### 1. Neutralization

**Do this :** Take 10ml dilute HCl in a beaker. Use a glass rod to put a drop of this solution on a pH paper and record the pH of the solution. Add to it a few drops of dilute NaOH solution by means of a dropper and stir the solution with the glass rod. Measure the pH of the resulting solution by putting a drop of this solution on another pH paper. In this manner, go on adding dilute NaOH drop by drop and recording the pH. What do you find? Stop adding NaOH when a green colour appears on the pH paper, that is when the pH of the solution becomes 7.

**The neutralization reaction :** Why does the pH increase as NaOH solution is added drop by drop to the HCl solution? The answer lies in the process of dissociation. Both HCl and NaOH dissociate in their aqueous solutions. Addition of NaOH solution to HCl solution is like adding a large concentration of  $\text{OH}^-$  ions to a large concentration of  $\text{H}^+$  ions. However water dissociates into  $\text{H}^+$  and  $\text{OH}^-$  ions to a very small extent. Therefore, on mixing, the excess  $\text{OH}^-$  ions combine with the excess  $\text{H}^+$  ions to form  $\text{H}_2\text{O}$  molecules which mix with the solvent water. This change can be represented by the ionic equation shown as follows.



It can be seen from the above equation that the  $\text{Na}^+$  and  $\text{Cl}^-$  ions are on both the sides. Therefore the net ionic reaction is



As the NaOH solution is added drop by drop to the HCl solution, the concentration of  $\text{H}^+$  goes on decreasing due to combination with added  $\text{OH}^-$  ions, and that is how the pH goes on increasing.

When enough NaOH is added to HCl, the resulting aqueous solution contains only  $\text{Na}^+$  and  $\text{Cl}^-$  ions, that is, NaCl, a salt, and the solvent water. The only source of  $\text{H}^+$  and  $\text{OH}^-$  ions in this solution is dissociation of water. Therefore, this reaction is called the neutralization reaction. The neutralization reaction is also represented by the following simple equation.



**Complete the following table of neutralization reactions and also write down the names of the acids, bases and salts in it.**

Acid	+	base	→	Salt	+	Water
$\text{HNO}_3$	+	.....	→	$\text{KNO}_3$	+	$\text{H}_2\text{O}$
.....	+	$2 \text{NH}_4\text{OH}$	→	$(\text{NH}_4)_2 \text{SO}_4$	+	.....
.....	+	KOH	→	KBr	+	





### Always remember

In the neutralization reaction, an acid reacts with a base to form a salt and water.



### Use your brain power !

What would be the definition of an acid and a base with reference to the neutralization reaction?

## 2. Reaction of acids with metals

The reaction of acids with metals is determined by the strength and the concentration of the acid and also by the reactivity of the metal and the temperature. It is easy to bring about the reaction of a dilute solution of strong acids with moderately reactive metals at normal temperature.



### Try this

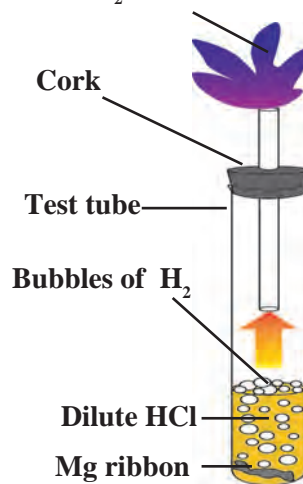
**Activity :** Take a big test tube. Choose a rubber stopper in which a gas tube can be fitted. Take a few pieces of magnesium ribbon in the test tube and add some dilute HCl to it. Take a lighted candle near the end of the gas tube and observe. What did you observe?

Magnesium metal reacts with dilute hydrochloric acid and an inflammable gas, hydrogen, is formed. During this reaction, the reactive metal displaces hydrogen from the acid to release hydrogen gas. At the same time, the metal is converted into basic radical which combines with the acidic radical from the acid to form the salt.

**Complete the following reactions.**



### Burning of $\text{H}_2$ with an explosion



### 5.6 Reaction of a dilute solution of a strong acid with a metal



### Try this



Take some water in a test tube and add a little red oxide (the primer used before painting iron articles) to it. Now add a small quantity of dilute HCl to it, shake the test tube and observe.

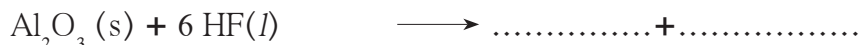
1. Does the red oxide dissolve in water?
2. What change takes place in the particles of red oxide on adding dilute HCl ?

The chemical formula of red oxide is  $\text{Fe}_2\text{O}_3$ . The water-insoluble red oxide reacts with  $\text{HCl}$  to produce a water soluble salt  $\text{FeCl}_3$ . This gives a yellowish colour to the water. The following chemical equation can be written for this chemical change.



**Complete the following.**

**Metal oxide + dilute acid  $\longrightarrow$  Salt + Water**



1. What type of compound is a metal oxide, with reference to neutralization reaction?
2. Explain the statement 'Metal oxides are basic in nature.'

#### 4. Reaction of bases with oxides of non-metals



**Try this**

Bases react with oxides of non-metals to form a salt and water. Hence, oxides of non-metals are said to be acidic in nature. Sometimes the oxides of non-metals themselves are said to be examples of acids.

**Complete the following reactions.**

**Oxide of non-metal + base  $\longrightarrow$  salt + water**



Zinc oxide reacts with sodium hydroxide to form sodium zincate ( $\text{Na}_2\text{ZnO}_2$ ) and water. Similarly, aluminium oxide reacts with sodium hydroxide to form sodium aluminate ( $\text{NaAlO}_2$ ) and water.



**Use your brain power !**

1. Write down chemical equations for both these reactions.
2. Can we call  $\text{Al}_2\text{O}_3$  and  $\text{ZnO}$  acidic oxides on the basis of these reactions?
3. Define 'amphoteric oxides' and give two examples.

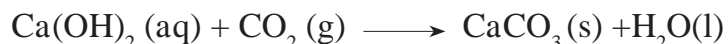
#### 5. Reaction of acids with carbonates and bicarbonates of metals



**Try this**

**Activity :** Fit a bent tube in a rubber cork. Take some lime water in a test tube and keep it handy. Take some baking soda in another test tube and add some lemon juice to it. Immediately fit the bent tube over it. Insert its other end into the lime water. Note down your observations of both the test tubes. Repeat the procedure using washing soda, vinegar and dilute  $\text{HCl}$  properly. What do you see ?

In this activity, when limewater comes in contact with the gas released in the form of an effervescence, it turns milky. This is a chemical test for carbon dioxide gas. When lime water turns milky, we infer that the effervescence is of carbon dioxide gas. This gas is produced on reaction of acids with carbonate and bicarbonate salts of metals. A precipitate of  $\text{CaCO}_3$  is produced on its reaction with the limewater  $\text{Ca(OH)}_2$ . This reaction can be represented by the following chemical equation.



## Salts

### Types of salts : acidic, basic and neutral salts



#### Try this

**Activity :** Prepare 10 ml aqueous solutions from 1gm each of sodium chloride, ammonium chloride and sodium bicarbonate. Measure pH of each solution by means of pH paper. Are the values the same for all three? Classify the salts based on the pH values.

We have seen that salts are formed by the reaction between acids and bases. Though this reaction is called a neutralization reaction, the resulting salts are not always neutral. A neutral salt is formed by neutralization of a strong acid by a strong base. The aqueous solution of a neutral salt has pH equal to 7.

An acidic salt is formed by the neutralization reaction between a strong acid and a weak base. The pH of the aqueous solution of an acidic salt is less than 7. On the contrary, a basic salt is formed by a neutralization reaction between a weak acid and a strong base. The pH of an aqueous solution of such a basic salt is greater than 7.

Classify the following salts into the types acidic, basic and neutral. Sodium sulphate, potassium chloride, ammonium nitrate, sodium carbonate, sodium acetate, sodium chloride.

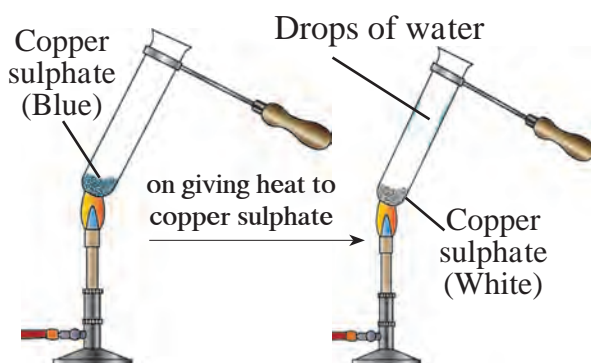
### Complete the reactions in the following table.

Carbonate salt of metal + dilute acid $\longrightarrow$ Another salt of metal + Carbon dioxide		
$\text{Na}_2\text{CO}_3 (\text{s}) + 2 \text{HCl} (\text{aq})$	$\longrightarrow$	$2 \text{NaCl} (\text{aq}) + \text{CO}_2 (\text{g})$
$\text{Na}_2\text{CO}_3 (\text{s}) + \dots\dots\dots$	$\longrightarrow$	$\text{Na}_2\text{SO}_4 (\text{aq}) + \text{CO}_2 (\text{g})$
$\text{CaCO}_3 (\text{s}) + 2 \text{HNO}_3 (\text{aq})$	$\longrightarrow$	$\dots\dots\dots + \dots\dots\dots$
$\text{K}_2\text{CO}_3 (\text{s}) + \text{H}_2\text{SO}_4 (\text{aq})$	$\longrightarrow$	$\dots\dots\dots + \dots\dots\dots$
Bicarbonate salt of metal + dilute acid $\longrightarrow$ Another salt of metal + carbon dioxide + water		
1. $\text{NaHCO}_3 (\text{s}) + \text{HCl} (\text{aq})$	$\longrightarrow$	$\text{NaCl} (\text{aq}) + \text{CO}_2 (\text{g}) + \text{H}_2\text{O} (\text{l})$
2. $\text{KHCO}_3 (\text{s}) + \text{HNO}_3 (\text{aq})$	$\longrightarrow$	$\dots\dots\dots + \dots\dots\dots + \dots\dots\dots$
3. $\text{NaHCO}_3 (\text{s}) + \dots\dots\dots$	$\longrightarrow$	$\text{CH}_3\text{COONa} (\text{aq}) + \dots\dots\dots + \dots\dots\dots$

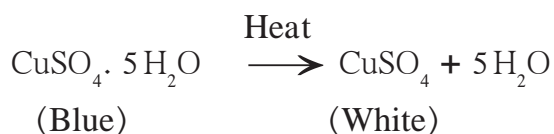
## Water of crystallisation



### Try this



### 5.7 Properties of water of crystallisation



It is called water of crystallization. On adding water to the white powder a solution was formed which had the same colour as the solution in the first test tube. From this we come to know that no chemical change has occurred in the crystals of blue vitriol due to heating. Losing water on heating blue vitriol, breaking down of the crystal structure, losing blue colour and regaining blue colour on adding water are all physical changes.

Repeat the above activity for Ferrous sulphate, sodium carbonate and write chemical equations.



### Try this

**Apparatus :** Evaporating dish, Bunsen burner, tripod stand, wire gauze, etc.  
**Chemicals :** Alum.

**Procedure :** Take a small stone of alum in the evaporating dish. Keep the dish on the tripod stand and heat it with the help of burner.

What did you see in the dish? What is meant by puffed alum?

Ionic compounds are crystalline in nature. These crystals are formed as a result of definite arrangement of ions. In the crystals of some compounds water molecules are also included in this arrangement. That is the water of crystallization. The water of crystallization is present in a definite proportion of the chemical formula of the compound. It is indicated in the chemical formula as shown below.

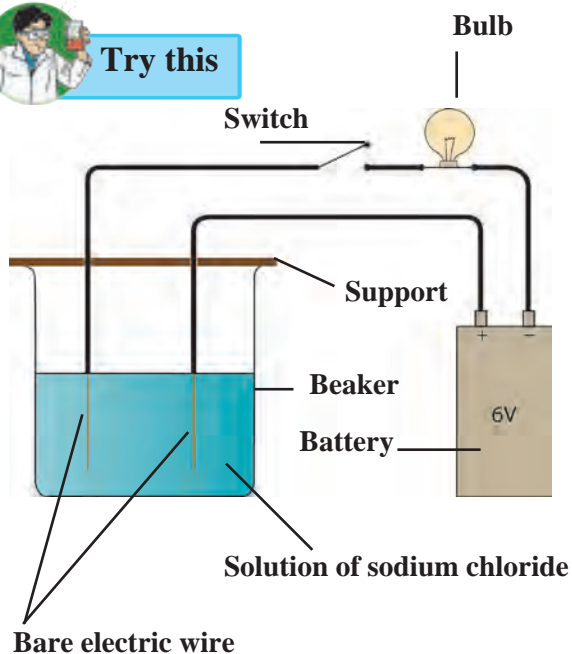
1. Crystalline blue vitriol-  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$
2. Crystalline ferrous sulphate  
(Green vitriol) -  $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$
3. Crystalline washing soda -  $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$
4. Crystalline alum -  $\text{K}_2\text{SO}_4 \cdot \text{Al}_2(\text{SO}_4)_3 \cdot 24\text{H}_2\text{O}$

1. Crystalline substances contain water of crystallization.
2. The molecules of water of crystallization are part of the internal arrangement of the crystal.
3. On heating or just by keeping, the water of crystallization is lost and the crystalline shape of that part is lost.

## Ionic compounds and electrical conductivity



### Try this



5.8 Testing the electrical conductivity of a solution



### Use your brain power !

1. With which solutions did the bulb glow?
2. Which solutions are electrical conductors?

The bulb glows only when electric current passes through it. And this can happen only when the electric circuit is complete. In the above activity, the circuit is found to be complete when the aqueous solutions of  $\text{NaCl}$ ,  $\text{CuSO}_4$ ,  $\text{H}_2\text{SO}_4$  and  $\text{NaOH}$  are used. It means that these solutions are conductors of electricity.

Electrons conduct electricity through electrical wires; and ions conduct electricity through a liquid or a solution. Electrons leave the battery at the negative terminal, complete the electric circuit and enter the battery at the positive terminal. When there is a liquid or a solution in the circuit, two rods, wires or plates are immersed in it. These are called electrodes. Electrodes are usually made of a conducting solid. The electrode connected to the negative terminal of a battery by means of a conducting wire is called a **cathode** and the electrode connected to the positive terminal of a battery is called an **anode**.

Why does the electric circuit get completed on immersing the electrodes in certain liquids or solutions? In order to understand this phenomenon, let us look more closely at the solutions in the above activity, which were found to be electrical conductors.

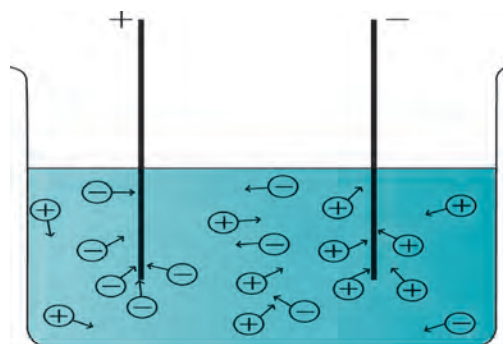
### Dissociation of ions and electrical conductivity

In the above activity it was found that the aqueous solutions of the compounds  $\text{NaCl}$ ,  $\text{CuSO}_4$ ,  $\text{H}_2\text{SO}_4$  and  $\text{NaOH}$  are electricity conductors. Out of these  $\text{NaCl}$  and  $\text{CuSO}_4$  are salts,  $\text{H}_2\text{SO}_4$  is a strong acid and  $\text{NaOH}$  is a strong base. We have seen that salts, strong acids and strong bases dissociate almost completely in their aqueous solutions. Therefore, the aqueous solutions of all these three contain large numbers of cations and anions.

**Activity :** Prepare a solution of 1g sodium chloride in 50ml water. Take two electrical wires. Connect one wire to the positive terminal of a 6V battery. While connecting the other wire to the negative terminal of the battery, include one switch and one holder with an electric bulb. Remove the insulating cladding from 3cm portion of the other free ends of the two wires. Take the salt solution in a 100ml capacity beaker and immerse the uncovered ends of the two wires in it keeping the wire erect with the help of a support. Switch on the current. Note whether the bulb glows. Repeat the same procedure using solutions of 1g copper sulphate, 1g glucose, 1g urea, 5ml dilute  $\text{H}_2\text{SO}_4$  and 5ml dilute  $\text{NaOH}$  each in 50ml water. Record your observations in a table. **(Do not forget to clean the beaker and uncovered part of the wires with water, every time you change the solution.)**



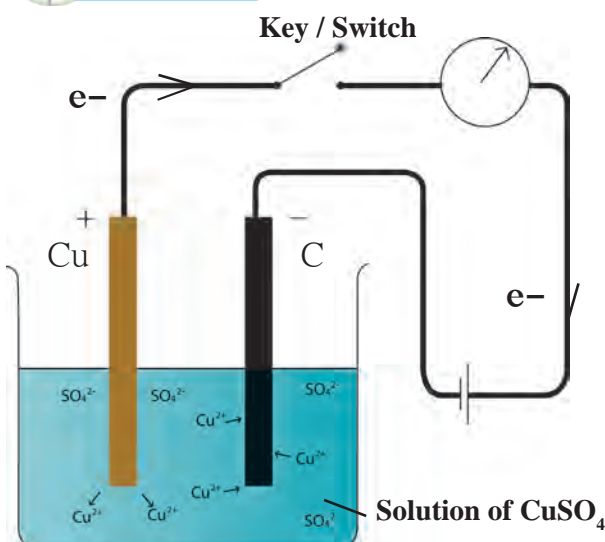
A characteristic of the liquid state is the mobility of its particles. Due to this mobility, the positively charged cations in the solution are attracted towards the negative electrode or cathode and move towards the cathode; on the other hand, the negatively charged anions move in the direction of the anode. The movement of ions in the solution towards the respective electrodes amounts to the conduction of electricity through the solution. From this, you will understand that those liquids or solutions which contain a large number of dissociated ions conduct electricity.



5.9 Dissociation of ions



### Try this



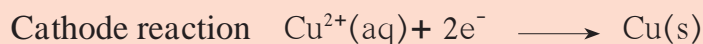
5.10 Electrolysis

### Electrolysis

**Procedure :** Take a solution of 1g copper sulphate in 50ml water in a 100ml capacity beaker. Use a thick plate of copper as anode and a carbon rod as cathode. Arrange the apparatus as shown in the figure and pass an electric current through the circuit for some time. Do you see any changes?

In the above activity copper appears to have deposited on the portion of the cathode immersed in the solution. How did this happen? When an electric current started flowing through the circuit, the cations, that is,  $\text{Cu}^{2+}$  ions in the solution got attracted towards the cathode. Cu atoms are formed when electrons coming out from the cathode combine with the  $\text{Cu}^{2+}$  ions. A deposit of the copper appeared on the cathode. Even though

the  $\text{Cu}^{2+}$  ions in the solution were used up in this manner, the colour of the solution remained the same. Because, while electric current was on, electrons were removed from the Cu atoms of the anode and sent to the battery through the electric wire. The  $\text{Cu}^{2+}$  ions formed in this manner, entered the solution. In this way decomposition of the solute in the solution took place due to the electric current. This is called electrolysis. There are two parts in the electrolysis process. These are the cathode reaction and the anode reaction. The two parts of the electrolysis process that take place in the above activity are shown below.







### Always remember

1. It is necessary for the liquid/solution to have a large number of dissociated ions for electrolysis to take place. Therefore, substances which undergo dissociation to great extent in the liquid state or a solution are called electrolytes. Salts, strong acids and strong bases are electrolytes. Their solutions have high electrical conductivity. In other words electrolytes are good conductors of electricity in their liquid or solution state.
2. An assembly that consists of a container electrolyte and the electrodes dipped in it, is called an electrolytic cell.



### Use your brain power !

1. In the above activity, if electric current passed through the electrolytic cell for a long time, what change would be seen at the anode?
2. Would water be a good conductor of electricity?

### Website for more information

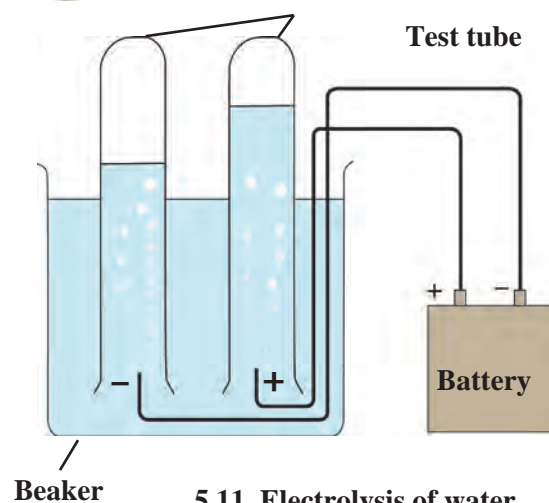
[www.chemicalformula.org](http://www.chemicalformula.org)

If pure water is used in an electrolytic cell, current does not flow even on putting on the switch. From this we learn that pure water is a bad conductor of electricity. And we have already seen the reason behind this. The concentration of  $\text{H}^+$  and  $\text{OH}^-$  ions formed by dissociation of water is very low, only  $1 \times 10^{-7}$  mol/L for each ion. However, the electrical conductivity of water increases on mixing a small amount of salt or a strong acid/base in it due to their dissociation and electrolysis of water takes place.

### Electrolysis of water



### Try this

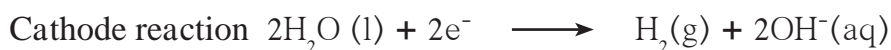


5.11 Electrolysis of water

**Activity :** Dissolve 2g salt in 500ml pure water. Take 250 ml of this solution in a 500ml capacity beaker. Connect two electrical wires to the positive and negative terminals of a power supply. Remove the insulating cladding from about 2cm portions at the other ends of the wires. These are the two electrodes. Fill two test tubes upto the brim with the prepared dilute salt solution. Invert them on the electrodes without allowing any air to enter. Start the electric current under 6V potential difference from the power supply. Observe what happens in the test tubes after some time.

1. Did you see the gas bubbles forming near the electrodes in the test tubes?
2. Are these gases heavier or lighter than water?
3. Are the volumes of the gases collected over the solution in the two test tubes the same or different?

It is found in the above activity that the volume of the gas formed near the cathode is double that of the gas formed near the anode. Scientists have shown that hydrogen gas is formed near the cathode and oxygen gas near the anode. From this, it is clear that electrolysis of water has taken place and its constituent elements have been released. The concerned electrode reactions are as follows.



1. Test the solutions in the two test tubes with litmus paper, what do you see ?
2. Repeat the activity by using dilute  $\text{H}_2\text{SO}_4$  as well as dilute  $\text{NaOH}$  as the electrolyte.



### Research

There are many applications of electrolysis of electrolytes. Collect information about them.

## Exercises



### 1. Identify the odd one out and justify.

- (a) Chloride, nitrate, hydride, ammonium
- (b) Hydrogen chloride, sodium hydroxide, calcium oxide, ammonia
- (c) Acetic acid, carbonic acid, hydrochloric acid, nitric acid
- (d) Ammonium chloride, sodium chloride, potassium nitrate, sodium sulphate
- (e) Sodium nitrate, sodium carbonate, sodium sulphate, sodium chloride
- (f) Calcium oxide, magnesium oxide, zinc oxide, sodium oxide.
- (g) Crystalline blue vitriol, crystalline common salt, crystalline ferrous sulphate, crystalline sodium carbonate.
- (h) Sodium chloride, potassium hydroxide, acetic acid, sodium acetate.

### 2. Write down the changes that will be seen in each instance and explain the reason behind it.

- (a) 50ml water is added to 50ml solution of copper sulphate.
- (b) Two drops of the indicator phenolphthalein were added to 10ml

solution of sodium hydroxide.

- (c) Two or three filings of copper were added to 10ml dilute nitric acid and stirred.
- (d) A litmus paper was dropped into 2ml dilute  $\text{HCl}$ . Then 2ml concentrated  $\text{NaOH}$  was added to it and stirred.
- (e) Magnesium oxide was added to dilute  $\text{HCl}$  and magnesium oxide was added to dilute  $\text{NaOH}$ .
- (f) Zinc oxide was added to dilute  $\text{HCl}$  and zinc oxide was added to dilute  $\text{NaOH}$ .
- (g) Dilute  $\text{HCl}$  was added to limestone.
- (h) Pieces of blue vitriol were heated in a test tube. On cooling, water was added to it.
- (i) Dilute  $\text{H}_2\text{SO}_4$  was taken in an electrolytic cell and electric current was passed through it.

### 3. Classify the following oxides into three types and name the types.

$\text{CaO}$ ,  $\text{MgO}$ ,  $\text{CO}_2$ ,  $\text{SO}_3$ ,  $\text{Na}_2\text{O}$ ,  $\text{ZnO}$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{Fe}_2\text{O}_3$

### 4. Explain by drawing a figure of the electronic configuration.

- a. Formation of sodium chloride from

sodium and chlorine.

- b. Formation of a magnesium chloride from magnesium and chlorine.

**5. Show the dissociation of the following compounds on dissolving in water, with the help of chemical equation and write whether the proportion of dissociation is small or large.**

Hydrochloric acid, Sodium chloride, Potassium hydroxide, Ammonia, Acetic acid, Magnesium chloride, Copper sulphate.

**6. Write down the concentration of each of the following solutions in g/L and mol/L.**

- a. 7.3g HCl in 100ml solution
- b. 2g NaOH in 50ml solution
- c. 3g  $\text{CH}_3\text{COOH}$  in 100ml solution
- d. 4.9g  $\text{H}_2\text{SO}_4$  in 200ml solution

**7. Obtain a sample of rainwater. Add to it a few drops of universal indicator. Measure its pH. Describe the nature of the sample of rainwater and explain the effect if it has on the living world.**

**8. Answer the following questions.**

- a. Classify the acids according to their basicity and give one example of each type.
- b. What is meant by neutralization? Give two examples from everyday life of the neutralization reaction.
- c. Explain what is meant by electrolysis of water. Write the electrode reactions and explain them.

**9. Give reason for the following.**

- a. Hydronium ions are always in the form  $\text{H}_3\text{O}^+$
- b. Buttermilk spoils if kept in a copper or brass container.

**10. Write the chemical equations for the following activities.**

- (a) NaOH solution was added to HCl solution.
- (b) Zinc dust was added to dilute  $\text{H}_2\text{SO}_4$ .
- (c) Dilute nitric acid was added to calcium oxide.
- (e) Carbon dioxide gas was passed through KOH solution.
- (f) Dilute HCl was poured on baking soda.

**11. State the differences.**

- a. Acids and bases
- b. Cation and anion
- c. Negative electrode and positive electrode.

**12. Classify aqueous solutions of the following substances according to their pH into three groups : 7, more than 7, less than 7.**

Common salt, sodium acetate, hydrochloric acid, carbon dioxide, potassium bromide, calcium hydroxide, ammonium chloride, vinegar, sodium carbonate, ammonia, sulphur dioxide.

**Project :**

Collect information about electroplating. Make a list of articles in day-to-day life, where this technique is used.

