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 seen earlier 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 about an easy and safe method of using an indicator like litmus to detect acids and bases.

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

We shall now learn more about acids and bases. But let us first recapitulate on the constituents of molecules of compounds.

Fill in the columns in the part 'A' of the following table.

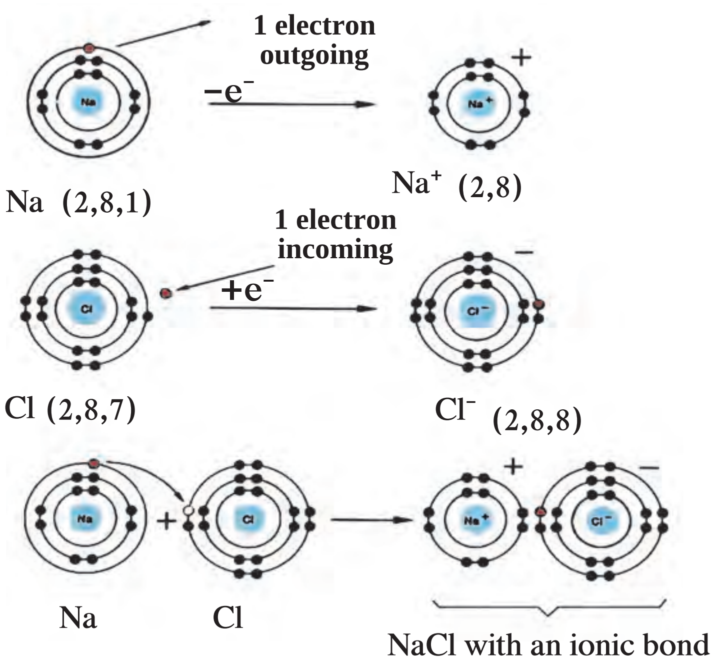
A				B
Name of the compound	**Molecular formula**	**Basic radical**	**Acidic radical**	**Type of the compound**
Hydrochloric acid	HCl	H^+	Cl^-	Acid
	HNO_3			
	HBr			
	H_2SO_4			
	H_3BO_3			
	NaOH			
	KOH			
	$Ca(OH)_2$			
	NH_4OH			
	NaCl			
	$Ca(NO_3)_2$			
	K_2SO_4			
	$CaCl_2$			
	$(NH_4)_2SO_4$			

Some compounds are seen to have H^+ as the basic radical in their molecules. These are all acids. Some compounds are seen to have OH^- as the acidic radical in their molecules. All these compounds are bases. These ionic compounds having basic radicals other than H^+ and acidic radicals other than OH^- are called salts.

Now complete part 'B' of the table on page 58. It will be clear that there are three types of ionic compounds and these are acids, bases and salts.

Ionic compounds : A recapitulation

The molecule of an ionic compound has two constituents, namely, cation (postive 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 Electronic 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. Figure 5.1 shows how the sodium and chlorine atoms form the Na^+ and Cl^- and as a result, how the NaCl salt is formed.

The outermost shell of a sodium and a chlorine atoms is not a complete octet. However outermost shells in both the Na^+ and Cl^- ions are complete octet.

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

Dissociation of ionic compounds

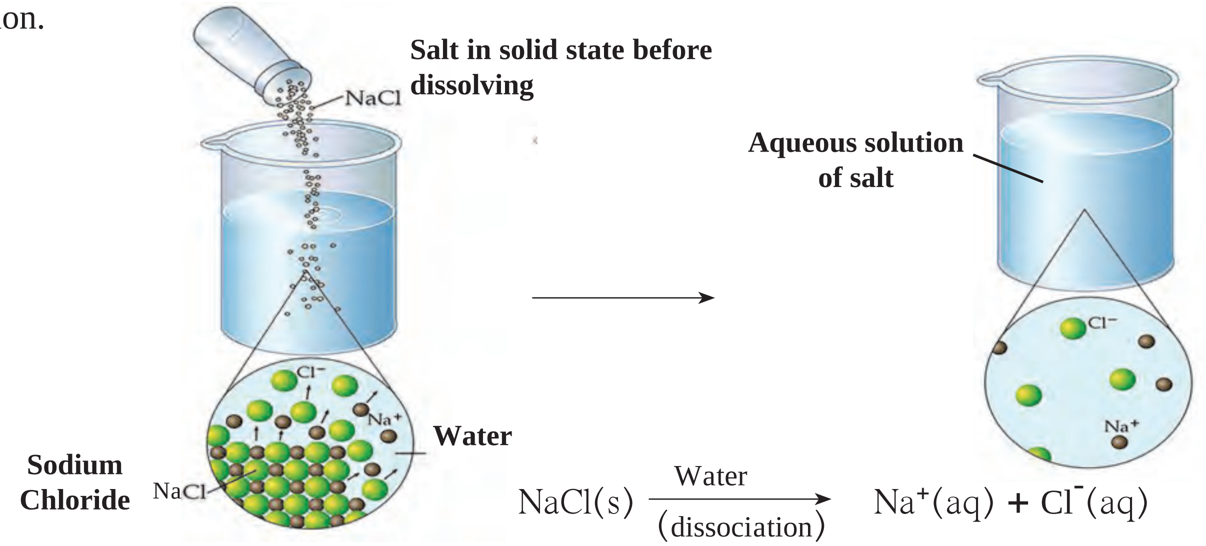
Can you recall?

What are the resulting mixtures formed by mixing the following substances?

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

An ionic compound forms an aqueous solution on dissolving in water. 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 penetrate in between the ions of the compound and separate them from each other. That is to say, an ionic compound dissociates during formation of 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.



$$NaCl(s) \xrightarrow[\text{(dissociation)}]{\text{Water}} Na^{+}(aq) + Cl^{-}(aq)$$

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 H^+ ion as the only cation. For example, HCl, H_2SO_4, H_2CO_3.

$$HCl\,(g) \xrightarrow[\text{(dissociation)}]{\text{water}} H^{+}(aq) + Cl^{-}(aq)$$

$$H_2SO_4\,(l) \xrightarrow[\text{(dissociation)}]{\text{water}} H^{+}(aq) + HSO_4^{-}(aq)$$

$$HSO_4^{-}(aq) \xrightarrow{\text{(dissociation)}} H^{+}(aq) + SO_4^{2-}(aq)$$

Use your brain power !

1. What are the names of the following compounds?
   NH_3, Na_2O, CaO.
2. When the above compounds are mixed with water they combine with water. Complete the following table by showing the ions formed by their combination with water.
3. Into which type will you classify the above compounds-acid, base or salt ?

$NH_3\,(g) + H_2O(l)$	$\longrightarrow$	$NH_4^{+}\,(aq) + OH^{-}(aq)$
$Na_2O(s)$ + ...	$\longrightarrow$	$2\,Na^{+}(aq)$ +.............
$CaO(s) + H_2O(l)$	$\longrightarrow$	.... + ...

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

$$NaOH\ (s) \xrightarrow[\text{(dissociation)}]{\text{water}} Na^+(aq) + OH^-(aq)$$

$$Ca(OH)_2\ (s) \xrightarrow[\text{(dissociation)}]{\text{water}} Ca^{2+}(aq) + 2OH^-(aq)$$

Classification of acids and bases

1. Strong and weak acids, bases and alkali

1. Acids and bases are classified as strong and weak 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 H^+ ions and the concerned acidic radical. For example, HCl, HBr, HNO_3, H_2SO_4.

Weak acid : On dissolving in water a weak acid does not dissociate completely. The resulting aqueous solution contains H^+ ion and the concerned acidic radical in small proportion along with large proportion of the undissociated molecules of the acid. For example, CH_3COOH (Acetic Acid), CO_2.

Strong base : On dissolving in water, a strong base dissociates almost completely and the resulting aqueous solution contains mainly OH^- ions and the concerned basic radicals. For example, NaOH, KOH, $Ca(OH)_2$, Na_2O.

Weak base : On dissolving in water a weak base does not dissociate completely. The resulting aqueous solution contains a small proportion of OH^- ions and the concerned basic radical along with a large proportion of undissociated molecules of the base. For example, NH_3.

Alkali : The bases which are highly soluble in water are called alkali. For example, NaOH, KOH, NH_3. Here, NaOH and KOH are strong bases while NH_3 is a weak base.

2. Basicity and acidity

Complete the following table.

Acid : Number of H^+ obtained from one molecule.						
HCl	HNO_3	H_2SO_4	H_2CO_3	H_3BO_3	H_3PO_4	CH_3COOH
Base : Number of OH^- ions obtained from one molecule						
NaOH	KOH	$Ca(OH)_2$	$Ba(OH)_2$	$Al\ (OH)_3$	$Fe(OH)_3$	NH_4OH

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

Basicity of acids : The number of H^+ ions obtainable by the dissociation of one molecule of an acid is called its basicity.

Acidity of bases : The number of OH^- ions obtainable by the dissociation of one molecule of a base is called its acidity.

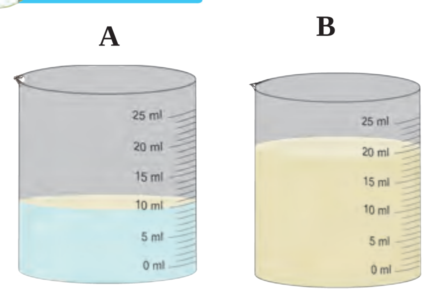
Use your brain power !

1. Refer to the table on page no. 61 and give examples of monobasic, dibasic and tribasic acids.
2. Refer to the table on page no. 61 and give the three types of bases and their examples.

Concentration of acid and base

Try this

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 it?



5.3 Solution of lemon juice

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 to 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 '[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	......	....

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. It is necessary for blood, cell sap, etc. to have H^+ and OH^- ions in certain definite proportions for their proper functioning. Fermentation and other biochemical processes carried out with the help of micro-organisms, 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.

$$H_2O \xrightarrow{\text{dissociation}} H^+ + OH^-$$

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 ↓	1 M NaOH	14.0

The concentration of H^+ ions formed by dissociation of water is 1 x 10^{-7} mol/L at 25^0C. At the same temperature, the concentration of H^+ ions in 1M solution of HCl is 1 x 10^0 mol/L, on the other hand in a 1M NaOH solution, the concentration of H^+ ions is 1 x 10^{-14} 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} 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 which means that pure water has '$[H^+]$ = 1 x 10^{-7} 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.

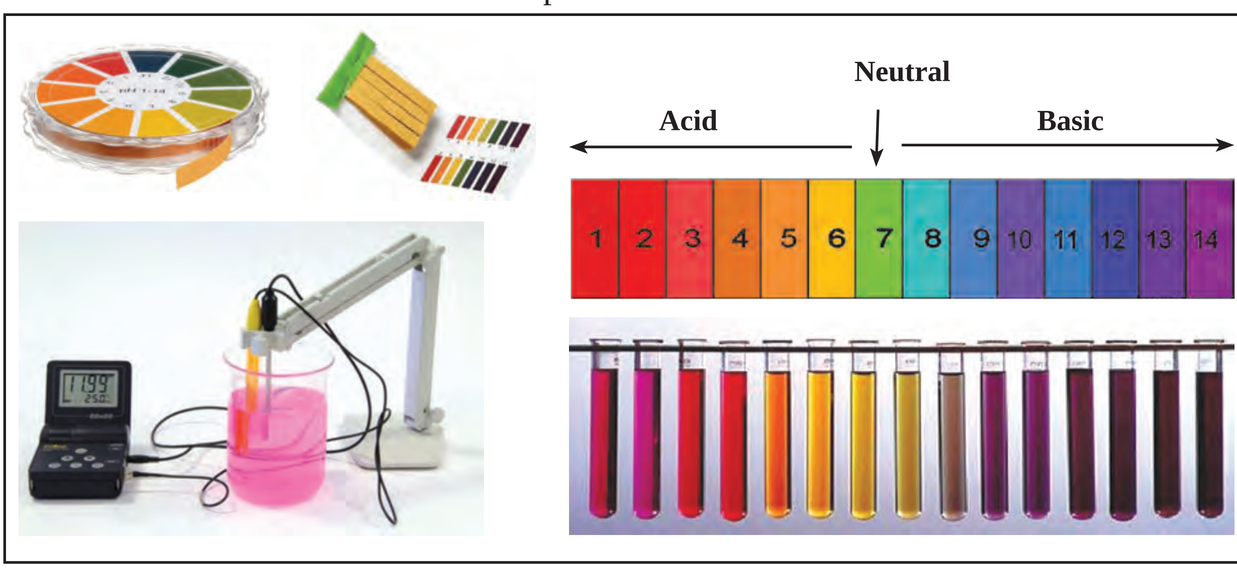
By which other method could we find out the pH of a solution?

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?

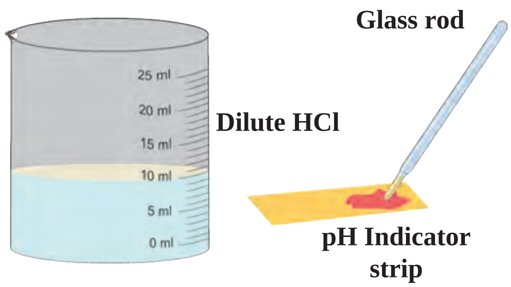
We know that some natural and synthetic dyes show two different colours in acidic and basic solutions, and such dyes are used as acid-base indicators. In the pH scale, the pH of solutions varies from 0 to 14 in accordance with the strength of the acid or base. To show these variations in pH, a universal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



5.5 Neutralization

Reactions 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 pH indicator strip 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 OH^- ions to a large concentration of H^+ ions. However water dissociates into H^+ and OH^- ions to a very small extent. Therefore, on mixing, the excess OH^- ions combine with the excess H^+ ions to form H_2O molecules which mix with the solvent water. This change can be represented by the ionic equation shown as follows.

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

It can be seen from the above equation that the Na^+ and Cl^- ions are on both the sides. Therefore the net ionic reaction is $H^+ + OH^- \longrightarrow H_2O$

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

When enough NaOH is added to HCl, the resulting aqueous solution contains only Na^+ and Cl^- ions, that is, NaCl, a salt, and the solvent water. The only source of H^+ and 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.

$$\underset{\text{Acid}}{HCl} + \underset{\text{base}}{NaOH} \longrightarrow \underset{\text{Salt}}{NaCl} + \underset{\text{Water}}{H_2O}$$

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
HNO_3 + ...	$\longrightarrow$	$KNO_3 + H_2O$
...............+ 2 NH_4OH	$\longrightarrow$	$(NH_4)_2SO_4$ + ...
..............+ KOH	$\longrightarrow$	KBr +

Always remember

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

Use your brain power !

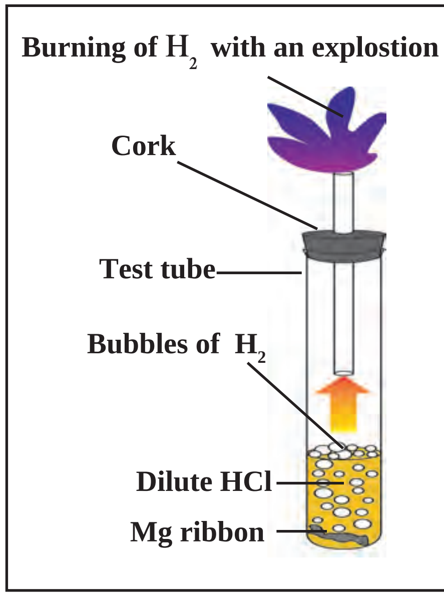
What would be the definition of an acid and a base with reference to the neutralization reaction ?

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 ?



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

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.

Metal + Dilute acid $\longrightarrow$ Salt + Hydrogen

$Mg(s) + 2HCl\,(aq) \longrightarrow MgCl_2\,(aq) + H_2\,(g)$

$Zn\,(s) + ... (aq) \longrightarrow ZnSO_4\,(aq) + ...$

$........(s) + ...\,(aq) \longrightarrow Cu\,(NO_3)_2\,(aq) + H_2\,(g)$

3. Reaction of acids with oxides of metals

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 Fe_2O_3. The water-insoluble red oxide reacts with HCl to produce a water soluble salt $FeCl_3$. This gives a yellowish colour to the water. The following chemical equation can be written for this chemical change.

$$Fe_2O_3\,(s) + 6HCl\,(aq) \longrightarrow 2FeCl_3\,(aq) + 3H_2O\,(l)$$

Complete the following.

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

$CaO\,(s) + 2\,HCl\,(aq) \longrightarrow$ .... + ...

$MgO\,(s) +$ .... $\longrightarrow MgCl_2\,(aq) + H_2O\,(l)$

$ZnO\,(s) + 2\,HCl\,(aq) \longrightarrow$ ....+...............

$Al_2O_3\,(s) + 6\,HF(l) \longrightarrow$ ....+................

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

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.

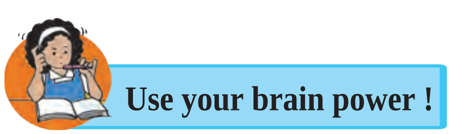
Oxide of non-metal + base $\longrightarrow$ salt + water

$CO_2\,(g) + 2\,NaOH\,(aq) \longrightarrow Na_2CO_3\,(aq) + H_2O\,(l)$

..........$+ 2\,KOH\,(aq) \longrightarrow K_2CO_3\,(aq) + H_2O\,(l)$

$SO_3\,(g) +$ .... $\longrightarrow Na_2SO_4\,(aq) + H_2O\,(l)$

Zinc oxide reacts with sodium hydroxide to form sodium zincate (Na_2ZnO_2) and water. Similarly, aluminium oxide reacts with sodium hydroxide to form sodium aluminate ($NaAlO_2$) and water.



1. Write down chemical equations for both these reactions.
2. Can we call Al_2O_3 and 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

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 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 $CaCO_3$ is produced on its reaction with the limewater $Ca(OH)_2$. This reaction can be represented by the following chemical equation.

$$Ca(OH)_2\,(aq) + CO_2\,(g) \longrightarrow CaCO_3\,(s) + H_2O(l)$$

Complete the reactions in the following table.

Carbonate salt of metal + dilute acid	$\longrightarrow$	Another salt of metal + Carbon dioxide
Na_2CO_3 (s) + 2 HCl (aq)	$\longrightarrow$	2 NaCl (aq) + CO_2 (g) + H_2O (*l*)
Na_2CO_3 (s) + ...	$\longrightarrow$	Na_2SO_4 (aq) + CO_2 (g) + ...
$CaCO_3$ (s) + 2 HNO_3 (aq)	$\longrightarrow$	.... + ... + ...
K_2CO_3 (s) + H_2SO_4 (aq)	$\longrightarrow$	.... + ... + ...

Bicarbonate salt of metal + dilute acid	$\longrightarrow$	Another salt of metal + carbon dioxide + water
1. $NaHCO_3$ (s) + HCl (aq)	$\longrightarrow$	NaCl (aq) + CO_2 (g) + H_2O (*l*)
2. $KHCO_3$ (s) + HNO_3 (aq)	$\longrightarrow$	.... + ... + ...
3. $NaHCO_3$ (s) + ...	$\longrightarrow$	CH_3COONa (aq)+ .... + ...

Salts

Types of salts : acidic, basic and neutral salts

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.

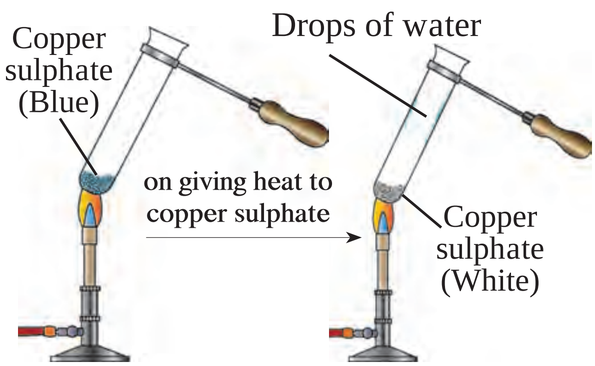
We have seen that salts are formed by the reaction between acids and bases. Though this reaction is called a neutralization reaction, the resulting salts are not always neutral. A neutral salt is formed by neutralization of a strong acid by a strong base. The aqueous solution of a neutral salt has pH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

Water of crystallisaton

Try this



5.7 Properties of water of crystallisation

$$CuSO_4 . 5H_2O \xrightarrow{\text{Heat}} CuSO_4 + 5H_2O$$

(Blue) (White)

Activity : Take some crystals of blue vitriol in two test tubes.
Add some water in one test tube and shake it. What did you see?
What is the colour of the solution formed?
Heat the other test tube on low flame of a burner. What did you see?
What change did occur in the colour of blue vitriol?
What did you see in the upper part of the test tube?

When the second test tube cools down add some water in it and shake. What is the colour of the resulting solution? What inference can be drawn from this observation?

On heating, the crystalline structure of blue vitriol broke down to form a colourless powder and water came out. This water was part of the crystal structure of blue vitriol. It is called water of crystallisation. 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. Take '*x*' as a coefficient for H_2O.

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?

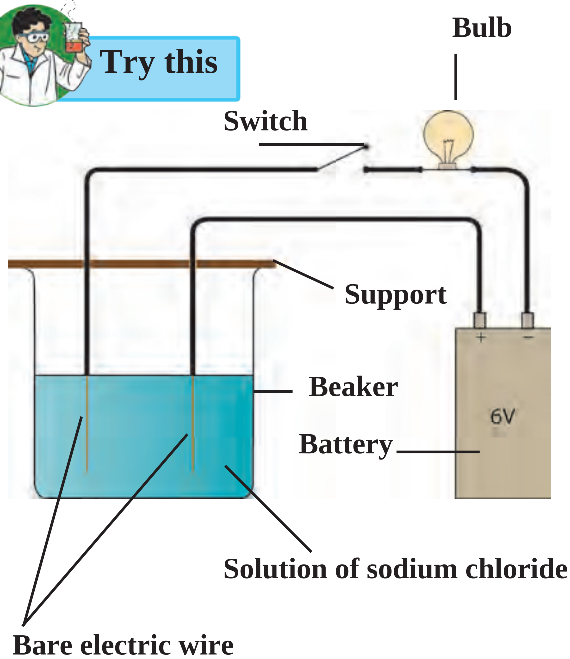
Ionic compounds are crystalline in nature. These crystals are formed as a result of definite arrangement of ions. In the crystals of some compounds water molecules are also included in this arrangement. That is the water of crystallisation. The water of crystallisation is present in a definite proportion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

1. Crystalline blue vitriol – $CuSO_4.5H_2O$
2. Crystalline ferrous sulphate (Green vitriol) – $FeSO_4.7H_2O$
3. Crystalline washing soda – $Na_2CO_3.10H_2O$
4. Crystalline alum - $K_2SO_4.Al_2(SO_4)_3.24\ H_2O$

1. Crystalline substances contain water of crystallisation.
2. The molecules of water of crystallisation are part of the internal arrangement of the crystal.
3. On heating or just by keeping, the water of crystallisation 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

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 H_2SO_4 and 5ml dilute 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.)**

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 NaCl, $CuSO_4$, H_2SO_4 and NaOH are used. It means that these solutions are conductors of electricity.

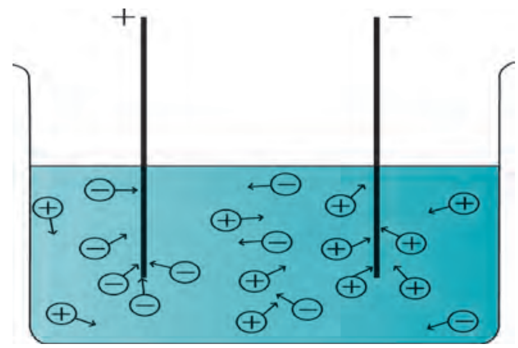
Electrons conduct electricity through electrical wires; and ions conduct electricity through a liquid or a solution. Electrons leave the battery at the negative terminal, complete the electric circuit and enter the battery at the positive terminal. When there is a liquid or a solution in the circuit, 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

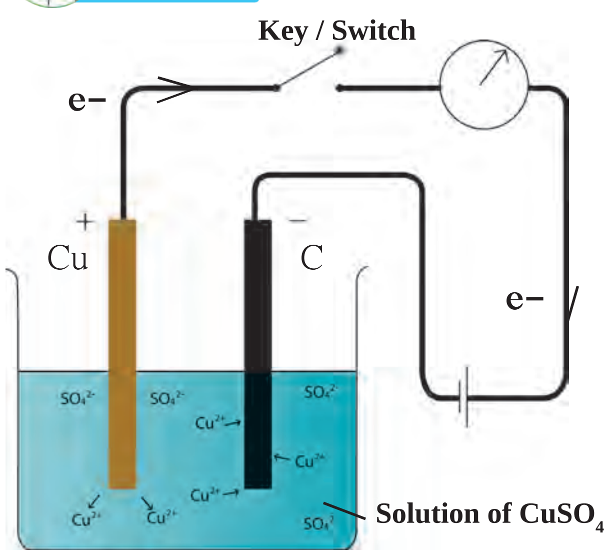
In the above activity it was found that the aqueous solutions of the compounds NaCl, $CuSO_4$, H_2SO_4 and NaOH are electricity conductors. Out of these NaCl and $CuSO_4$ are salts, H_2SO_4 is a strong acid and NaOH is a strong base. We have seen that salts, strong acids and strong bases dissociate almost completely in their aqueous solutions. Therefore, the aqueous solutions of all these three contain large numbers of cations and anions.

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 though 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, Cu^{++} ions in the solution got attracted towards the cathode. Cu atoms are formed when electrons coming out from the cathode combine with the Cu^{++} ions. A deposit of the copper appeared on the cathode. Even though the Cu^{++} 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 Cu^{++} 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.

Cathode reaction	$Cu^{2+}(aq) + 2e^-$	$\longrightarrow$	$Cu(s)$
Anode reaction	$Cu(s)$	$\longrightarrow$	$Cu^{2+}(aq) + 2e^-$

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 strong **electrolytes**. Salts, strong acids and strong bases are strong electrolytes. Their solutions have high electrical conductivity. In other words strong electrolytes are good conductors of electricity in their liquid or solution state. Weak acids and weak bases are weak electrolytes.
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 passesd 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

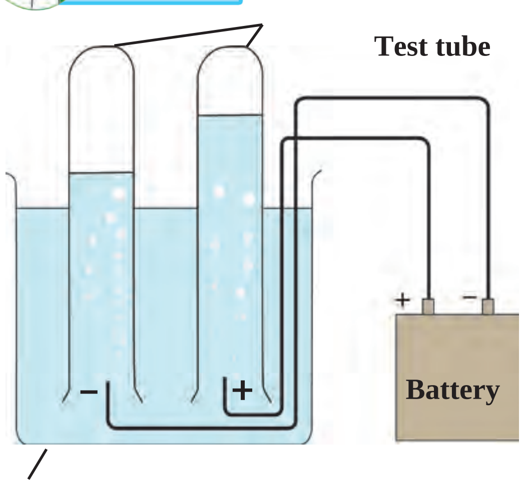
www.chemicalformula.org

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 H^+ and OH^- ions formed by dissociation of water is very low, only 1 x 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

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 form the power supply. Observe what happens in the test tubes after some time.



5.11 Electrolysis of water

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.

$$\text{Cathode reaction} \quad 2H_2O\,(l) + 2e^- \longrightarrow H_2(g) + 2OH^-(aq)$$

$$\text{Anode reaction} \quad 2H_2O\,(l) \longrightarrow O_2\,(g) + 4H^+(aq) + 4e^-$$

1. Test the solutions in the two test tubes with litmus paper, what do you see ?
2. Repeat the activity by using dilute H_2SO_4 as well as dilute 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 HCl. Then 2ml concentrated NaOH was added to it and stirred.

(e) Magnesium oxide was added to dilute HCl and magnesium oxide was added to dilute NaOH.

(f) Zinc oxide was added to dilute HCl and zinc oxide was added to dilute NaOH.

(g) Dilute 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 H_2SO_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.

CaO, MgO, CO_2, SO_3, Na_2O, ZnO, Al_2O_3, Fe_2O_3

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

a. Formation of sodium chloride from

sodium and chlorine.

b. Formation of 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 CH_3COOH in 100ml solution
d. 4.9g H_2SO_4 in 200ml solution

7. 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.

8. Write the chemical equations for the following activities.

(a) NaOH solution was added to HCl solution.
(b) Zinc dust was added to dilute H_2SO_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.

9. State the differences.

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

10. 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 hydoxide, ammonium chloride, vinegar, sodium carbonate, ammonia, sulphur dioxide.

Project :

1. Collect information about electroplating. Make a list of articles in day-to-day life, where this technique is used.
2. Obtain a sample of rainwater. Add to it a few drops of universal indicator. Meausre its pH. Describe the nature of the sample of rainwater and write the effect it has on the living world.

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