Chapter 3

STRUCTURE OF MATTER

We know many methods by which a mixture can be separated into its constituents e.g. picking, filtration, crystallization, sublimation etc. No chemical reaction is involved in these methods. Substances whose constituents can be separated by simple physical processes are called mixtures. All substances are however, not mixtures. There are some substances whose constituents cannot be separated by simple physical methods. They are called pure substances.

3.1 Different structure of substances

Mixture and pure substances can be recognized and identified by another method too. It is by the change in the state on heating. Pure substances change their state at a particular temperature whereas this temperature for mixtures is not fixed. The temperature depends on the ratio of different constituents in the mixture. Pure substances are of two types – elements and compounds.

What is a compound? How is it different from a mixture? Let us understand through an activity.

Activity - 1

Materials required: Beaker, Copper Sulphate, Pins and Water.

Take water in a beaker and make a solution of copper sulphate. Put 4-5 pins in this solution and let it remain undisturbed for an hour. Do you note any change in the colour of the pins? Does the colour of the solution also change? The change in the colour of pins is due to the deposition of copper present in copper sulphate. Copper cannot be separated from copper sulphate by physical methods.

By putting iron in copper sulphate we get a fixed quantity of copper. (164 g of copper sulphate will always have 64 g of copper). This means copper is a constituent of copper sulphate and is present in a fixed amount, whereas constituents of a mixture are not in a fixed ratio.

The compounds used in daily life are water, salt, sugar etc. whereas the types and examples of different types of mixtures are given in table 3.1.

Table - 3.1

S.NO.	Types of mixture	Examples
1	Gas in gas	Air
2	Gas in liquid	(i) Soda water (carbon dioxide in water) (ii) Oxygen and carbon dioxide in normal water
3	Liquid in liquid	Lemon juice and water
4	Solid in liquid	Sea water, sugar solution
5	Solid in solid	Alloys e.g. brass and bronze
6	Solid in gas	Smoke

The other type of pure substances are those which have only one constituent. They are called elements. Copper separated from copper sulphate in activity 1 is an element. No more constituents can be separated from an element by any physical or chemical method. Some other elements are gold, iron, silver, oxygen, nitrogen etc.

Till date more than 114 elements have been found. Out of these 92 elements are present in nature and the rest have been synthesized by scientists in laboratories.

Every element has its specific properties. These properties help in identifying the elements. Elements are found in all states. Complete table 3.2 by filling some more examples of elements present as solids, liquids and gases at normal temperatures.

Table - 3.2

Elements that are Solid	Elements that are Liquid	Elements that are Gases
Silver	Bromine	Hydrogen
Gold	Mercury	Nitrogen
....	....	....
....	....	....

Elements can be classified into metals and non-metals on the basis of certain properties. Metals are good conductors of heat and electricity. They have a special lusture (shine). Normally they are solids like gold, silver, iron but mercury is a metal that is normally found in liquid state at room temperature. Non-metals occur in all the three states at normal temperature - solid (sulphur), liquid (bromine) and gaseous (Hydrogen, Nitrogen etc). They are bad conductors of electricity.

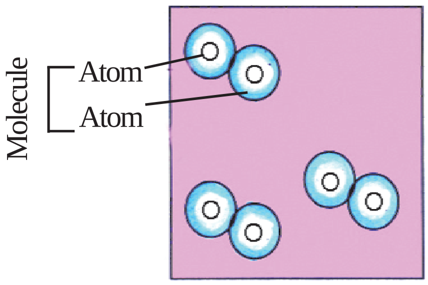
Two or more than two elements can react (chemical reaction) with each other to form compounds. Hydrogen and oxygen react to form water, similarly carbon and oxygen react to form carbon dioxide. If we simply mix oxygen and hydrogen no water is formed. Water is formed only when oxygen reacts chemically with hydrogen.

What is air? An element, compound or a mixture? Till 200 years ago air was considered to be an element. But scientist have now proved that air is not an element but is a mixture of nitrogen, oxygen, carbon dioxide and many other gases.

Elements and compounds can also be classified on the basis of particles also. Let us understand this.

All substances are made up of particles. Different substances have different types of particles. For e.g. the properties of all particles of water will be the same but water particles and iron particles will be very different from each other. These particles are so tiny that they cannot be seen even by a good quality microscope. A crystal of salt is made up of billions of particles. These smallest particles of a substance can be atoms or molecules.

An element has same type of atoms. In some elements these atoms can exist on their own in a free state and in others they can only exist in combination with other atoms. These combinations are known as molecules of the element. e.g. two atoms of oxygen combine to form a molecule. Every atom has a specific mass known as its atomic mass.



3.1 Molecule of oxygen

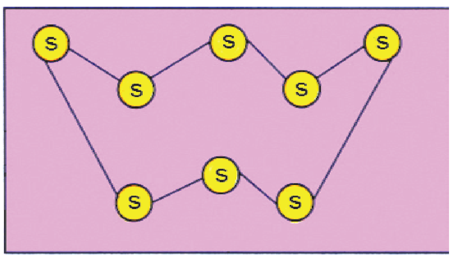


Fig 3.2 Molecule of sulphur

Sulphur is an element in which one molecule is made of eight similar atoms. (Fig. 3.2)

Compounds are formed when two or more than two elements combine together in a fixed ratio. Like hydrochloric acid is a compound in which each molecule is made up of one atom of hydrogen and one atom of chlorine. (fig.3.3)

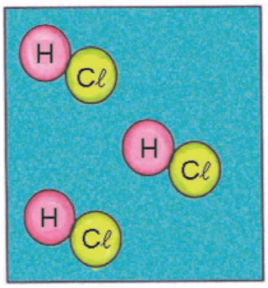


Fig. 3.3 Molecule of hydrochloric acid

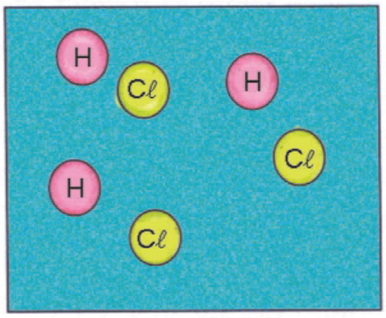


Fig. 3.4 Atoms of hydrogen and chlorine

The smallest particle of a compound is a molecule. On further dividing this molecule of a compound we get constituent atoms of its elements (fig. 3.4).

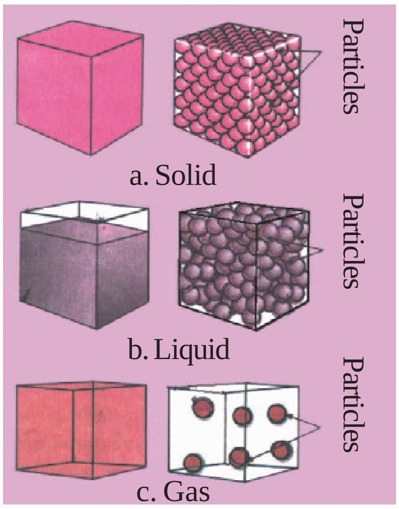


Fig. 3.5 Arrangement of molecules in a. Solid b. Liquid c. Gas

Now we know that substances are made up of atoms and molecules. What is the arrangement of these molecule in the three states of matter? Let us try to find out.

In solids like marbles, iron etc. the molecules are tightly packed, organised and arranged in a definite pattern. Therefore the molecules do not have freedom to move freely. The force of attraction between particles of solids is very strong. The solids therefore have definite shape and volume. (fig. 3.5a).

In liquids the particles are somewhat loosely packed (fig. 3.5b). Therefore, they can be compressed to an extent. These particles can move around each other within the liquid. Liquids take the shape of the container in which they are kept. The force of attraction between particles is weaker.

In gases there is no fixed organisation of the particles and the particles are further apart in comparison to solids and liquids (fig. 3.5c). Thus they can be easily compressed. The particles of a gas are free to move about in any direction. Volume and shape of a gas is not fixed. Gases take the shape and occupy the volume of the container in which they are kept. The force of attraction between the particles of gas is very weak.

Answer these

1. Separate the following substances into elements, compounds and mixtures –

   Copper, air, ice-cream, salt, oxygen, water
2. What is an element?
3. Specify the differences between a mixture and a compound?

Symbols of alchemists

Symbols have been used to represent a substance for a long time. In ancient times alchemists tried to make gold and elixir (amrit) by chemical reactions. They used symbols to keep their knowledge a secret. They used symbols for substances (elements, compounds, mixture) used in daily life and for reactions (fig. 3.6a). Common salt was represented by the symbol ⊖ Sometimes different symbols were used by alchemists to represent the same substance.

After many years John Dalton made formula for compounds using symbols. Symbols used by Dalton are as follows -

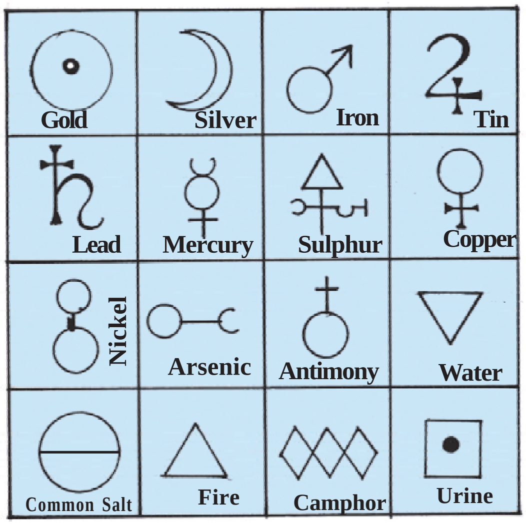


Fig. 3.6 a Symbols used by alchemists

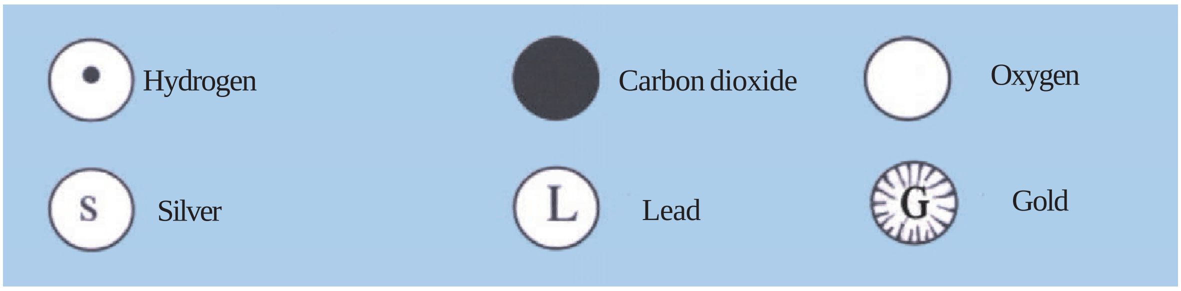


Fig. 3.6 b Symbols used by Dalton

3.2 Symbols

We use symbols and short forms as per our need in our daily life. For example we use NH to represent national highway and a straight arrow to depict a straight path. Till date 118 elements and millions of compounds made by them are known. When referring to a substance it is not convenient to use full name of the substance every time. Therefore scientists use symbols and groups of symbols to represent these elements and compounds. These symbols are accepted internationally.

At present we use simple symbols given by Sweden scientist J.J. Berzelius to represent elements. He had suggested that the symbols of elements should be represented by alphabets in English language. His other suggestions are as follows:-

1. First alphabet of the English name of an element should be used as its symbol e.g. O for oxygen, N for Nitrogen, S for sulphur, and H for hydrogen. This should be written in capital letter.
2. When the name of more than two compounds start with the same alphabet then another alphabet should be added to the first one.

In this situation the first alphabet should be in capital letter and the second one in small letters. For example – elements beginning with the word c are –

C - Carbon
C – Calcium
C – Chlorine
C – Cobalt
C – Chromium

Here carbon is represented by symbol C, for calcium "a" is added with the first alphabet "C". So, the symbol of calcium is "Ca". In this way symbol of chlorine is Cl, cobalt is Co and chromium is Cr.

Symbols of some other elements are as follows:

Table - 3.3

Name of the substance	Symbol
Aluminum	Al
Argon	Ar
Boron	B
Fluorine	F
Helium	He
Iodine	I
Magnesium	Mg
Manganese	Mn
Neon	Ne
Phosphorous	P
Silicon	Si
Sulphur	S
Zinc	Zn

3. Names of some substances are based on their Greek and Latin names. For example the symbol of sodium is 'Na'' instead of 'So' because its latin name is *natrium*. Similarly some more names are being given in table 3.4.

Table - 3.4

Substance	Latin name	Symbol
Potassium	Kalium	K
Silver	Argentum	Ag
Iron	Ferrum	Fe
Copper	Cuprum	Cu
Tin	Stannum	Sn
Gold	Aurum	Au
Lead	Plumbum	Pb
Mercury	Hydrargyrum	Hg
Antimony	Stibium	Sb

3.3 Formula

A symbol represents an atom of an element whereas formula represents a molecule of an element or a compound. It gives information about the number of atoms in the molecule. The formula of a molecule indicates the number of atoms of each constituent element contained in it. The number of atoms is shown at the foot of the symbol of each element. Some elements occur in free state as atoms and some in the form of molecules. To represent an atom only its symbol is used, e.g. the symbol of Helium is He. Its molecule is made up of only one atom, so its formula is He. In case of such substances there is no need to write one at the foot of the symbol.

To write the molecular form of an element, it is necessary to know how many atoms it is made up of. For example a molecule of chlorine is made up of two atoms of chlorine. So atomicity of chlorine is 2.

To show a molecule of chlorine (Fig. 3.7) we use the numeral 2 at the foot of its symbol Cl to make it Cl_2. Similarly nitrogen, iodine and ozone are represented as N_2, I_2 and O_3. This is called the molecular formula.

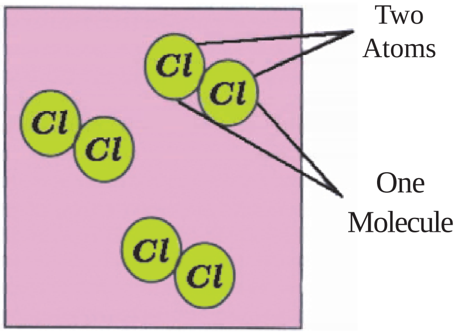


Fig. 3.7 Three molecules of chlorine

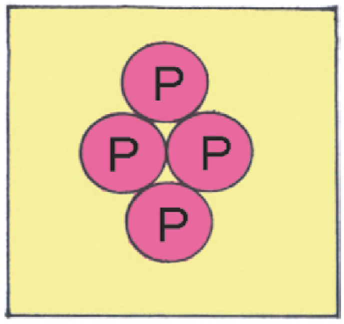


Fig. 3.8 One molecule of phosphorous

Molecules of phosphorous (Fig. 3.8) and sulphur are made up of 4 and 8 atoms respectively. Thus, their molecules are represented by P_4 and S_8. (Most of the solids are found in groups of atoms therefore they are represented by their symbols.)

The number of atoms present in a molecule of an element is known as its atomicity. In this way we can write the formulas of elements by knowing the number of atoms in a molecule. Fill table 3.5 according to the information provided -

Table - 3.5

Element	Symbol	Atomicity	Formula
Bromine	Br	2	…………
Iodine	I	………	I_2
Sulphur	S	8	………
Oxygen	O	…….	O_2
Hydrogen	H	2	……..

All compounds are present as molecules. Therefore they are represented by their molecular formula. We know that compounds are made up of two or more than two elements in a fixed ratio. Therefore, to write the formula of a compound we need to know its constituent elements and how many atoms of each element are present in a molecule. Let us consider this by taking the example of water. One molecule of water (fig. 3.9 a) is made up of two atoms of hydrogen and one atom of oxygen. So its molecular formula is written as H_2O. In a similar way a molecule of carbon dioxide (fig. 3.9 b) is made up of an atom of carbon and two atoms of oxygen. Its molecular formula is CO_2. A molecule of ammonia is made up of an atom of nitrogen and three atoms of hydrogen. Therefore its molecular formula is written as NH_3. Complete table 3.6 –

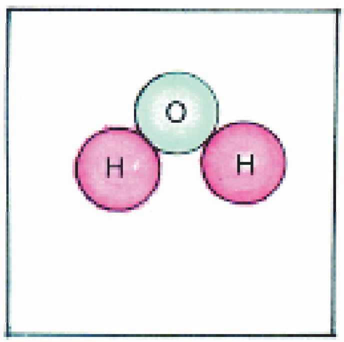


Fig. 3.9 a A molecule of water

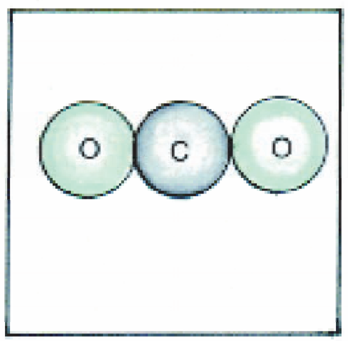


Fig. 3.9 b A molecule of carbon dioxide

Table - 3.6

S.NO.	Compound	Constituent Elements	Number of Atoms	Formula
1.	Sulphur dioxide	S O	1 2	SO_2
2.	Sulphuric acid	H S O	2 1 4	....
3.	Nitric acid	H N O	1 1 3	....
4.	Sodium hydroxide	Na O H	....	NaOH
5.	Hydrochloric acid	H Cl	....	HCl
6.	Ammonium chloride	N H Cl	1 4 1	....
7.	Sodium carbonate	Na C O	2 1 3	....

To represent more than one molecule of an element or a compound or to represent more than one atom of an element, we write the number before the molecular formula or before the symbol. For example if we write 2 NH_4Cl, it means two molecules of ammonium chloride. $2O_2$ represents two molecules of oxygen and 2 Ca represents two atoms of calcium.

3.4 Equations

Activity - 2

Materials required :– iron fillings, sulphur, test tube, source of heat.

Take some iron fillings and sulphur in a big test tube and heat the mixture. Do you find any difference between the substances taken and the substances formed in the reaction?

When a mixture of iron and sulphur is heated, a new substance is formed. This is called iron sulphide. What is the nature of the change in the above reaction physical or chemical? A new substance (Iron sulphide, FeS) is being formed as a result of the reaction between iron and sulphur, hence, it is a chemical change. We can represent this reaction with the help of symbols and formulae as follows:

$$\mathbf{Fe} + \mathbf{S} \longrightarrow \mathbf{FeS}$$

Iron + Sulphur ⟶ Iron sulphide

Coal reacts with oxygen in air to form carbon dioxide.

$$C + O_2 \longrightarrow CO_2$$

Carbon + Oxygen ⟶ Carbon dioxide

Equations used to represent a chemical reaction using symbols and chemical formulae are called chemical equations.

In a chemical equation the substances written on the left side of the arrow (→) take part in the reaction and are called reactants. On the right side of the arrow (→) we write products of the reaction. On either side of the arrow if the reactants or products are more than one then + sign is used. The tip of the arrow is used to show the direction of the reaction. More information about the reaction conditions like need for heat, presence of any other material, sunlight etc. is specified above or below the arrow.

$$\mathbf{Fe} + \mathbf{S} \xrightarrow{\text{on heating}} FeS$$

Reactants **Product**

The number of atoms of each element on both sides of a chemical equation should be equal. Such an equation is known as a balanced equation. In a balanced equation we can use (=) sign in place of ⟶

For example -

$$\mathbf{Fe} + \mathbf{S} \longrightarrow FeS$$

$$\textbf{or Fe} + \mathbf{S} = \mathbf{FeS}$$

A balanced equation signifies that in any reaction, atoms can neither be formed nor destroyed only their rearrangement takes place. Therefore, the number of atoms of an element obtained after a chemical reaction would be the same as number of atoms taking part in the reaction. In the reaction given above the number of atoms of iron and sulphur on both sides of the equation are the same (one each) so the equation is balanced.

What is to be done if the number of atoms of an element is different on the two sides of the equation? Let us understand with an example.

Decomposition of water is represented in the form of following chemical reaction –

$$\mathbf{H_2O} \longrightarrow \mathbf{H_2} + \mathbf{O_2}$$

In this equation the number of molecules of hydrogen is the same on both sides but the number of molecules of oxygen is not the same. On the left there is one atom of oxygen whereas on the right there are two atoms of oxygen. If we take two molecules of water on the left side the number of atoms of oxygen would be balanced. But on doing this the number of atoms of hydrogen on both sides become unequal. On the left side there are four atoms of hydrogen whereas on the right there are only two.

$$\mathbf{2H_2O} \longrightarrow \mathbf{H_2} + \mathbf{O_2}$$

Therefore, to balance the equation we write two in front of hydrogen on the right. In this way the number of atoms of hydrogen on both sides become equal.

$$2H_2O \longrightarrow 2H_2 + O_2$$

In this equation the number of atoms of each element participating is the same on both sides, that is the equation is balanced. This simple and concise method to represent a chemical reaction is called a chemical equation. Here a balanced equation shows that two molecules of water on decomposition give two molecules of hydrogen and one molecule of oxygen. The reaction with the required conditions is represented as follows:

$$2H_2O \xrightarrow[\text{decomposition}]{\text{Electric}} 2H_2 + O_2$$

A chemical equation gives us the following information–

1. What substances take part in the reaction and which substances are formed.
2. How many atoms or molecules of the reactants react and how many atoms or molecules of the products are formed.
3. Under what conditions does the reaction takes place.

Answer these

1. What would be the atomicity of following substances?
   O_3, P_4, S_8, Br_2
2. What is a molecular formula?
3. What information does one get from a chemical equation?

John Dalton

In year 1766 A.D. in England John Dalton was born to a poor weaver's family. He started his work at the age of 12 as a teacher in a village school. He became the headmaster of the school after seven years. In 1793 A.D. he went to Manchester to teach mathematics, physics and chemistry in a school. He resigned from his job soon after as his teaching assignment was hampering his research work.

In 1808 A.C. Dalton gave his atomic theory. He was amongst the first scientist to give the name 'atom' to the smallest particle of an element. Dalton proposed that all atoms of an element behave in the same manner. He postulated atoms as very minute, hard and solid particles. Dalton also proposed that an atom of an element can be represented by a symbol or a sign. Dalton died in the year 1844.

We have learnt

- Substances whose constituents can be separated by physical methods are called mixtures.
- Pure substances that have only one substance are called elements.
- Two or more elements combining in a fixed ratio form a compound. The constituents of a compound can only be separated by chemical methods.
- The smallest freely existing unit of a substance is a molecule. A molecule can sometimes consist of only one atom.
  Two or more atoms can combine to from a molecule.
- In solids, particles of the substance are very close to each other, and are arranged in definite order. The force of attraction between particles of solids is strong.

- In liquids particles are not fixed at one position and a particle can move around anywhere within the liquid. In comparison to solids the force of attraction between particles is weaker.
- In gases, particles are very far from each other. The force of attraction between the particles of a gas is much weaker than for solids and liquids.
- Elements and compounds are represented by symbols and formulae.
- First letter of the English name of an element is written in capital letters to represent its symbol. If necessary another letter written in small case is added to the first capital letter.
- Number of atoms present in a molecule of an element is called its atomicity.
- When one or more than one substance react to form new sustances then the process is called a chemical reaction.
- An equation used to represent a chemical reaction using symbols and chemical formulae is called a chemical equation.
- A balanced equation signifies that no atoms can be produced or destroyed during a chemical reaction.

Questions for practice

1. Match the names of the elements with the corresponding symbols-

i.	Carbon	Cl
ii.	Sulpur	Mn
iii.	Chlorine	Na
iv.	Magnesium	C
v.	Zinc	Mg
vi.	Manganese	S
vii.	Sodium	K
viii.	Gold	Fe
ix.	Iron	Zn
x.	Potassium	Au

2. Match the names of elements with their atomicity –

i.	Iodine	8
ii.	Sulphur	4
iii.	Phosphorous	1
iv.	Sodium	2

3. Fill in the blanks –

1. ……….. metal is found in a liquid state at normal temperature.
2. Elements are formed by the same type of …………
3. Air is a …………..
4. ……………. .... State of matter can be easily compressed.

4. Balance the following chemical equations -

I. $Mg + O_2 \longrightarrow MgO$

II. $N_2 + H_2 \longrightarrow NH_3$

III. $SO_3 \longrightarrow SO_2 + O_2$

5. Write chemical equations for the following reactions -

1. An atom of sulphur reacts with a moleclue of oxygen to from a molecule of sulphur dioxide.
2. An atom of zinc combines with two molecules of hydrochloric acid to form a molecule of zinc chloride and a molecule of hydrogen.

6. Define the following –

a) Element b) Compound

7. Give three examples each of an element and a compound.

8. When a substance A is heated then two substances are formed. Explain with reasons if the substance A is an element or a compound.

9. Explain the difference between:-

1. Mixture and compound
2 Element and compound

Do these also

1. Categorize the substances like soil, stones etc. around you into elements, compounds and mixtures. Write the reasons for the categorization also.

2. Find out the chemical constititutents of the substances specified in the above activity. To do this discuss with the students of higher classes and your teachers. Write their possible formulas also.