Chapter 3

Atoms and Molecules

Ancient Indian and Greek philosophers have always wondered about the unknown and unseen form of matter. The idea of divisibility of matter was considered long back in India, around 500 BC. An Indian philosopher Maharishi Kanad, postulated that if we go on dividing matter (*padarth*), we shall get smaller and smaller particles. Ultimately, a stage will come when we shall come across the smallest particles beyond which further division will not be possible. He named these particles *Parmanu*. Another Indian philosopher, Pakudha Katyayama, elaborated this doctrine and said that these particles normally exist in a combined form which gives us various forms of matter.

Around the same era, ancient Greek philosophers – Democritus and Leucippus suggested that if we go on dividing matter, a stage will come when particles obtained cannot be divided further. Democritus called these indivisible particles atoms (meaning indivisible). All this was based on philosophical considerations and not much experimental work to validate these ideas could be done till the eighteenth century.

By the end of the eighteenth century, scientists recognised the difference between elements and compounds and naturally became interested in finding out how and why elements combine and what happens when they combine.

Antoine L. Lavoisier laid the foundation of chemical sciences by establishing two important laws of chemical combination.

3.1 Laws of Chemical Combination

The following two laws of chemical combination were established after much experimentations by Lavoisier and Joseph L. Proust.

3.1.1 Law of conservation of mass

Is there a change in mass when a chemical change (chemical reaction) takes place?

Activity 3.1

- Take one of the following sets, X and Y of chemicals–

	X	Y
(i)	copper sulphate 1.25 g	sodium carbonate 1.43 g
(ii)	barium chloride 1.22 g	sodium sulphate 1.53 g
(iii)	lead nitrate 2.07 g	sodium chloride 1.17 g

- Prepare separately a 5% solution of any one pair of substances listed under X and Y each in 10 mL in water.
- Take a little amount of solution of Y in a conical flask and some solution of X in an ignition tube.
- Hang the ignition tube in the flask carefully; see that the solutions do not get mixed. Put a cork on the flask (see Fig. 3.1).

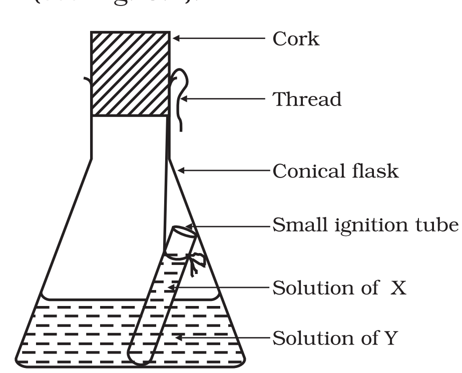

Fig. 3.1: *Ignition tube containing solution of X, dipped in a conical flask containing solution of Y.*

- Weigh the flask with its contents carefully.
- Now tilt and swirl the flask, so that the solutions X and Y get mixed.
- Weigh again.
- What happens in the reaction flask?
- Do you think that a chemical reaction has taken place?
- Why should we put a cork on the mouth of the flask?
- Does the mass of the flask and its contents change?

Law of conservation of mass states that mass can neither be created nor destroyed in a chemical reaction.

3.1.2 Law of constant proportions

Lavoisier, along with other scientists, noted that many compounds were composed of two or more elements and each such compound had the same elements in the same proportions, irrespective of where the compound came from or who prepared it.

In a compound such as water, the ratio of the mass of hydrogen to the mass of oxygen is always 1:8, whatever the source of water. Thus, if 9 g of water is decomposed, 1 g of hydrogen and 8 g of oxygen are always obtained. Similarly in ammonia, nitrogen and hydrogen are always present in the ratio 14:3 by mass, whatever the method or the source from which it is obtained.

This led to the law of constant proportions which is also known as the law of definite proportions. This law was stated by Proust as "*In a chemical substance the elements are always present in definite proportions by mass*".

The next problem faced by scientists was to give appropriate explanations of these laws. British chemist John Dalton provided the basic theory about the nature of matter. Dalton picked up the idea of divisibility of matter, which was till then just a philosophy. He took the name 'atoms' as given by the Greeks and said that the smallest particles of matter are atoms. His theory was based on the laws of chemical combination. Dalton's atomic theory provided an explanation for the law of conservation of mass and the law of definite proportions.

John Dalton

John Dalton was born in a poor weaver's family in 1766 in England. He began his career as a teacher at the age of twelve. Seven years later he became a school principal. In 1793, Dalton left for Manchester to teach mathematics, physics and chemistry in a college. He spent most of his life there teaching and researching. In 1808, he presented his atomic theory which was a turning point in the study of matter.

According to Dalton's atomic theory, all matter, whether an element, a compound or a mixture is composed of small particles called atoms. The postulates of this theory may be stated as follows:

(i) All matter is made of very tiny particles called atoms, which participate in chemical reactions.

(ii) Atoms are indivisible particles, which cannot be created or destroyed in a chemical reaction.

(iii) Atoms of a given element are identical in mass and chemical properties.

(iv) Atoms of different elements have different masses and chemical properties.

(v) Atoms combine in the ratio of small whole numbers to form compounds.

(vi) The relative number and kinds of atoms are constant in a given compound.

You will study in the next chapter that all atoms are made up of still smaller particles.

Questions

1. *In a reaction, 5.3 g of sodium carbonate reacted with 6 g of acetic acid. The products were 2.2 g of carbon dioxide, 0.9 g water and 8.2 g of sodium acetate. Show that these*

observations are in agreement with the law of conservation of mass.

sodium carbonate + acetic acid → sodium acetate + carbon dioxide + water

2. *Hydrogen and oxygen combine in the ratio of 1:8 by mass to form water. What mass of oxygen gas would be required to react completely with 3 g of hydrogen gas?*
3. *Which postulate of Dalton's atomic theory is the result of the law of conservation of mass?*
4. *Which postulate of Dalton's atomic theory can explain the law of definite proportions?*

3.2 What is an Atom?

Have you ever observed a mason building walls, from these walls a room and then a collection of rooms to form a building? What is the building block of the huge building? What about the building block of an ant-hill? It is a small grain of sand. Similarly, the building blocks of all matter are atoms.

How big are atoms?

Atoms are very small, they are smaller than anything that we can imagine or compare with. More than millions of atoms when stacked would make a layer barely as thick as this sheet of paper.

Atomic radius is measured in nanometres.

$1/10^9$ m = 1 nm

1 m = 10^9 nm

Relative Sizes	
Radii (in m)	**Example**
10^{-10}	Atom of hydrogen
10^{-9}	Molecule of water
10^{-8}	Molecule of haemoglobin
10^{-4}	Grain of sand
10^{-3}	Ant
10^{-1}	Apple

We might think that if atoms are so insignificant in size, why should we care about them? This is because our entire world is made up of atoms. We may not be able to see them, but they are there, and constantly affecting whatever we do. Through modern techniques, we can now produce magnified images of surfaces of elements showing atoms.

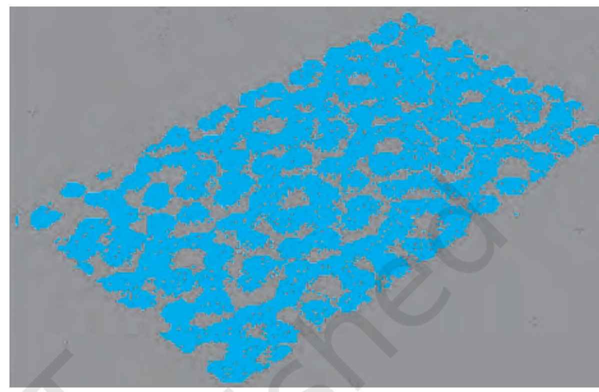

Fig. 3.2: *An image of the surface of silicon*

3.2.1 WHAT ARE THE MODERN DAY SYMBOLS OF ATOMS OF DIFFERENT ELEMENTS?

Dalton was the first scientist to use the symbols for elements in a very specific sense. When he used a symbol for an element he also meant a definite quantity of that element, that is, one atom of that element. Berzilius suggested that the symbols of elements be made from one or two letters of the name of the element.

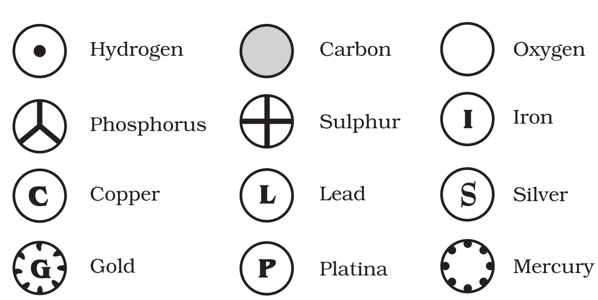

Fig. 3.3: *Symbols for some elements as proposed by Dalton*