Chapter 7

ATOMS, MOLECULES AND CHEMICAL REACTIONS

In the chapter "Is matter around us pure?" we used the terms elements and compounds. You learned about the role of separation techniques in identifying elements. The pure components obtained after separation (or purification) are either elements or compounds.

In this chapter, we can use this knowledge to explain some of the observations made in previous classes like the rusting of iron rod kept outside, etc.

- Does the weight of iron rod increase or decrease, on rusting?

We notice that on burning charcoal, it leaves ash at the end.

- Where does the matter of charcoal go?
- Wet clothes dry after some time - Where does the water go?

These questions and several other similar questions fascinated scientists for many years. Burning and combustion reactions, puzzled them to a greater extent.

Recall the chapter "Metals and non-metals."

- What happens to magnesium on burning it in air ?
- What happens to Sulphur on burning it in air?
- Are the weights of the reactants and products the same or different?

Do you know?

Antoine Lavoisier (1743-1794) was a French nobleman. He made many important contributions to chemistry and some call him as the **Father of Modern Chemistry**.

Lavoisier studied combustion reactions in detail. He was able to find the masses of reactants and products accurately irrespective of their physical states. Based on his observations he proposed the **law of conservation of mass**.

In this chapter, we use the following terms frequently - elements, compounds, reactants and products. Discuss with your friends about meaning of these terms. Think of different examples for each term.

Let us carry on a lab activity to observe what will happen to weights of reactants and products during a chemical reaction.

Lab Activity

Aim: To find out the change in the mass before and after a chemical reaction.

Materials required: Lead nitrate, potassium iodide, distilled water, two conical flasks, spring balance, small test tube, retort stand, rubber cork, thread, etc.

Procedure

1. Prepare a solution of lead nitrate by dissolving approximately 2 grams of lead nitrate in 100 ml of distilled water in a 250 ml conical flask.
2. Prepare a potassium iodide solution by dissolving approximately 2 gm of Potassium iodide in 100 ml water in another conical flask
3. Take 4ml solution of potassium iodide in a small test tube from the above prepared solution.

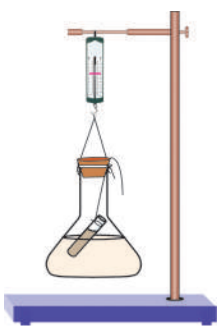

Fig - 1

4. Hang the test tube containing 4ml of potassium iodide solution in the conical flask containing lead nitrate solution carefully, without mixing the solutions. Close the flask with a cork.(see fig.- 1)
5. Weigh the flask with its contents carefully using spring balance.
6. Now tilt and swirl the flask, so that the two solutions mix. (see fig.- 2).

Fig - 2

7. Weigh the flask again using the same spring balance as shown in fig.- 3.

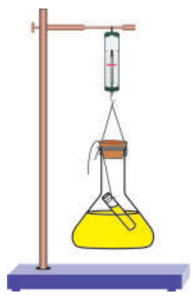

Fig - 3

8. Record your observations:

   Weight of flask and contents before mixing = ...

   Weight of flask and contents after mixing = ...

Now, try to answer these questions:

- Did you observe any precipitate in the reaction?
- Do you think that a chemical reaction has taken place in the flask? Give reasons.

- Do the weights, of the flask and its contents change during the activity?
- What are your conclusions?

Result:

A chemical reaction takes place and the mass remains same before and after the chemical reaction. Therefore, mass is neither created nor destroyed in a chemical reaction.

Think and discuss

- Do you get the same result if the conical flask is not closed?

Law of conservation of mass

Earlier, it was thought that mass of charcoal decreases on burning. But Lavoisier, carried out the burning of charcoal in a closed apparatus and found no change in mass.

Antoine Lavoisier on the basis of his experiment proposed the law of conservation of mass. It states that, **"Matter is neither created nor destroyed during a chemical reaction". More simply, "the mass of products is equal to the mass of the reactants in a chemical reaction".**

Think and discuss

- Recall the burning of the Magnesium ribbon in air. Do you think mass is conserved during this reaction?

Do you know?

Though the law of conservation of mass was proposed by Lavoisier, It was experimentally verfied by Landolt. The experiment carried out by us is a modified form of the experiment performed by Landolt. Ask your teacher about Landolt experiment.

Law of constant proportions

From the experiments on law of conservation of mass, we saw that mass does not change during a chemical reaction.

Now let us look at the results of some experiments carried out by the **Joseph L. Proust** between 1798 and 1808.

Proust took two samples of copper carbonate - a compound of copper, carbon and oxygen. He took a sample from nature and another sample prepared in the lab and decomposed it chemically to find percentage of copper, carbon and oxygen in the two samples.

The results obtained are given in table- 1

Table-1

Element	Weight percentage	
	Natural sample	Synthetic sample
Copper	51.35	51.35
Carbon	38.91	38.91
Oxygen	9.74	9.74

- What do you observe from the table?

- What difference do you observe in the percentage of copper, carbon and oxygen in two samples?

Similarly, Proust took water from different sources, and found that the percentage of oxygen and hydrogen was the same in all samples. There was no relation between the place from where the sample came and its composition.

Based on his experiments, Proust put forward the law of constant (or definite) proportions. It states that, "**a given chemical substance always contains the same elements combined in a fixed proportions by mass**." This means that the relative proportion of elements in a compound is independent of the source or method of preparation.

Think and discuss

- 100 g of mercuric oxide decompose to give 92.6 g of mercury and 7.4 g of oxygen. Let us assume that 10 g of oxygen reacts completely with 125 g of mercury to give mercuric oxide. Do these values agree with the law of constant proportions?
- Discuss with your friends if the carbon dioxide that you breathe out and the carbon dioxide they breathe out are identical. Is the composition of the carbon dioxide of different sources same?

Why are the laws valid?

By early 19th century, the scientists knew some laws governing chemical reactions. Why are these laws valid? Why cannot the elements combine in any arbitrary proportion ?

Many scientists tried to give appropriate explanations. The English school teacher **John Dalton** proposed the basic theory about the nature of matter. Dalton reasoned his proposals as mentioned below.

1. If mass was to be conserved, then all elements must be made up of extremely small particles, called atoms.
2. If law of constant proportion is to be followed, the particles of same substance can not be different.

Based on the above laws, Dalton proposed "a new system of Chemical Philosophy".

Dalton's atomic theory

John Dalton

Postulates of Dalton's Atomic theory :

1. Matter consists of indivisible particles called atoms.
2. Atoms are neither created nor destroyed in a chemical reaction. Reorganisation of atoms occur in chemical reactions.

3. All the atoms of a same element have identical mass and identical chemical properties. Atoms of different elements have different masses and different chemical properties.

4. Compounds are formed when atoms of different elements combine in simple whole number ratios. That is, chemical change is the union or separation of atoms as in whole numbers.

5. When atoms of different elements combine in different whole number of ratios they form different compounds. eg : carbon monoxide (CO); carbondioxide (CO_2). Hence 'C' and 'O' combine in 1:1 and 1: 2 ratios respectively to give two different compounds

Think and discuss

- Which postulate of Dalton's theory is the result of the law of conservation of mass?
- Which postulate of Dalton's theory can explain the law of constant proportions?

Do you know?

About 2600 years ago, an Indian sage (*Rishi*) called *Kanada* also postulated atoms in his *VAISHESIKA SUTRA*. The actual name of *Kanada* was *Kasyapa* - he was renamed after his *KANA SIDHANTHA*. He proposed that all forms of matter are composed of very small particles known as **anu** and each anu may be made up of still smaller particles called **parmanu.**

The word 'atom' is derived from a Greek word 'a-tomio' (means- indivisible)

Atoms and molecules

Very often you may have heard that atoms are the building blocks of all matter. But what does it mean? It means that matter is composed of tiny particles known as atoms.

These atoms are so small that we cannot see them even with a high-powered microscope. The number of atoms present even in a small amount of matter is very large.

Do you know?

The aluminium foil that we use to pack food might seem thin to you. But it has atoms in lakhs, along with its thickness.

- Are elements also made of atoms?

We know that substances are made up of atoms or molecules. Atoms are the most fundamental of all particles that can have an independent existence. Sometimes two or more atoms combine to form a big particle. When atoms combine, they form **molecules**. When the particles of a substance contain only one type of atoms, that substance is called an **element**. In elements the smallest particle may be atom or molecule.

There are many elements whose smallest particle is an atom. Iron, copper, zinc, aluminium, silver, gold, etc are examples of substances in which the smallest particle is an atom.

Oxygen and nitrogen are examples of substances in which the particles are a combination of two identical atoms. The smallest particles of elements that are stable are known as molecules. For example one sodium molecule has one sodium atom but one oxygen molecule has two oxygen atoms.

Atoms of same elements or of different elements can join together to form molecules. If atoms of different elements join together they form a new substance known as **compound**.

So we can have molecules of elements and molecules of compounds. A **molecule** can be defined as the smallest particle of a substance that has independent existence and retains all the properties of that substance.

Why do we name elements?

Do you know what gold is called in your language? But in other languages it would have a different name. There are so many languages in the world that it is not possible to know the different names of each element in different languages. To help scientists communicate without confusion, we must have one name for each element that is accepted by everyone.

Do you know?

John Berzelius suggested that initial letter of an element from its name in english written in capitals should be the symbol of that element, Eg. 'O' for oxygen, 'H' for Hydrogen and so on.

Do you know?

How elements like hydrogen and oxygen got their names?

Sometimes elements are named based on their property. For example, the Latin word for water is '**hydro**'. So the element that combined with oxygen to give water was named hydrogen.

At one time people believed that any substance that reacts with oxygen would be acidic in nature. The Latin word for acid is '**oxy**'. Hence the gas was called oxygen , meaning 'gas that forms acid'. It was later discovered that the acidic property was not related to oxygen. However, by then the name had come into common use so it was not changed.

Place of discovery of element can also play a role in its naming. For example, the gas which was first discovered in the sun (Greek name for Sun is **'helio'**), was named helium.

Can you guess the orgin of names of polonium and californium?

Sometimes elements were named to honour the scientists. For example: Einsteinium, Fermium, Rutherfordium and Mendelevium.

Symbols of elements

You must have realized that chemistry involves a lot of reactions. It will be a waste of time to write the full name of the elements and compounds every time to describe a reaction. To avoid this we use some shortcuts. Using short forms or symbols for naming the elements is one solution.

Over a 118 elements have been discovered so far. How do we decide their symbols?

Table-2: Symbols for some elements

Element Name	Symbol
Hydrogen	H
Oxygen	O
Nitrogen	N
Sulphur	S
Carbon	C
Calcium	Ca
Chlorine	Cl
Chromium	Cr
Boron	B
Barium	Ba
Bromine	Br
Beryllium	Be
Aluminium	Al
Iron	Fe
Gold	Au
Sodium	Na
Potassium	K

Usually, the first letter of the name of the element in English becomes the symbol of that element and is always written as a capital letter (upper case).

How do we write the symbols for Calcium, Chlorine, Chromium?

We have already used the letter 'C' for Carbon. Look at the elements after Carbon and before Aluminium in the table.

Discuss with your teacher and friends how the symbols have been decided for these elements. Notice the following:

- A symbol can have either one or two letters of English.
- The first letter of the symbol is always upper case and the second letter is always lower case.

Activity-1

Some elements and their possible symbols are given in table-3. Correct them and give reasons for your corrections.

Table-3

Element	Possible symbol
Aluminium	al
Carbon	c
Chromium	Chr
Chlorine	CL
Beryllium	Be

Some unusual symbols

This is not the end of the problem. We observe that symbols for some elements come from their names but some don't, which can be seen in Table-4. Certain elements have symbols based on their Latin names (or older names in other languages).

- Would you be able to recognise the elements of the table-2, have symbols of this category?

Activity-2

Write the symbols for given elements

Look up a periodic table and try to find the symbols for the given elements in table 4 and write them against their names.

Table-4

Element	Sodium	Silver	Tungsten	Potassium	Copper	Gold	Iron	Lead	Mercury
Latin name	Natrium	Argentum	Wolfram	Kalium	Cuprum	Aurum	Ferrum	Plumbum	Hydrargyrum
Symbol									

Elements with more than one atom in their molecules

We have learnt that several elements have more than one atom in their smallest constituent particles. It means these elements contains two or more atoms combined together to form a molecule. Oxygen, hydrogen and nitrogen are examples of such elements.

For example, a molecule of oxygen has two atoms. We need a formula to represent such a molecule in a simple way. The formula for oxygen molecule is O_2.

Why don't we write it as 2 O ? Writing a formula in this way indicates two separate atoms of oxygen. Hence first write the symbol for oxygen, and then write 2 as a subscript after the letter O.

Subscript number indicates number of atoms of Oxygen combined to form its molecule.

You might have heard about Ozone gas. This gas is found in large quantities in the upper layers of the earth's atmosphere. It protects us by shielding the earth from harmful ultra violet rays of the sun. Every molecule of ozone has three atoms of oxygen. Can you write the formula of ozone?

Atomicity

Molecules of many elements, such as Argon (Ar), Helium(He), etc are made up of only one atom of that element. But this is not the case with the most of non metals. In non metals the molecules contain more than two atoms of same element.

The number of atoms constituting a molecule is known as its **atomicity**.

For example, a molecule of hydrogen consists of two atoms of hydrogen. Here the atomicity is two; hence it is known as diatomic molecule. Helium (He), Argon(Ar) exist as single atom. Hence they are known as monoatomic.

Observe the following table to know atomicity of molecules of few elements and try to write the symbol of molecule based on its atomicity.

Table-5

Name of the element	Formula	Atomicity
Argon	Ar	Monoatomic
Helium		Monoatomic
Sodium	Na	Monoatomic
Iron		Monoatomic
Aluminium		Monoatomic
Copper		Monoatomic
Hydrogen	H_2	Diatomic
Oxygen		Diatomic
Nitrogen		Diatomic
Chlorine		Diatomic
Ozone	O_3	Triatomic
Phosphorus		Tetratomic
Sulphur	S_8	Octatomic

- Why do some elements be monoatomic?
- Why do some elements form diatomic or triatomic molecules?
- Why do elements have different atomicities ?

To understand the atomicities of molecules of elements and compounds we need to understand the concept of valency.

- What is valency?

Valency

Till now, there are over 118 elements known. These elements react with each other to form compounds. Every element has a definite combining capacity, that determines the atomicity of its molecules. Every element reacts with atoms of other element according to its combining capacity number. This combining capacity number is called valency.

Table-6

Valencies of some elements

Element	Valency
Helium	0
Hydrogen	1
Fluorine	1
Chlorine	1
Oxygen	2
Nitrogen	3
Carbon	4

So atoms of the elements have power to combine with atoms of other elements. This is known as its valency.

What is an ion?

Compounds formed by metals and non metals contain charged particles . The charged particles are known as ions. A negatively charged ion is called anion and the positive charge ion is cation.

For example sodium chloride does not contain discrete molecules as its constituent units. Its constituent particles are positively charged sodium ions (Na^+) and negatively charged chloride ions (Cl^-).

Ions may be a charged independent atoms or a group of atoms (polyatomic) that have a net charge on them. Hence ions are charged particles.

Table-7: Some common, simple and poly atomic ions.

Net Charge	Cation	Symbol	Anion	Symbol
1 unit	Hydrogen	H^+	Hydride	H^-
	Sodium	Na^+	Chloride	Cl^-
	Potassium	K^+	Bromide	Br^-
	Silver	Ag^+	Iodide	I^-
	Copper*	Cu^+	Hydroxide	OH^-
	Ammonium	NH_4^+	Nitrate	NO_3^-
2 units	Magnesium	Mg^{+2}	Oxide	O^{-2}
	Calcium	Ca^{+2}	Sulphide	S^{-2}
	Zinc	Zn^{+2}	Sulphate	SO_4^{-2}
	Copper*	Cu^{+2}	Carbonate	CO_3^{-2}
	Iron*	Fe^{+2}	Dichromate	$Cr_2O_7^{-2}$
3 units	Aluminium	Al^{+3}	Nitride	N^{-3}
	Iron*	Fe^{+3}	Phosphate	PO_4^{-3}

* elements which show variable valency.

Valency of an ion is equal to the magnitude of its charge. For Example valency of chloride ion (Cl^-) is 1. Valency of sulphate ion (SO_4^{-2}) is 2.

Now refer the table-7 and try to write the valencies of some other ions.

Atomic mass

The most remarkable concept that Dalton's atomic theory proposed was "atomic mass". According to him each element had a characteristic atomic mass.

Since, atoms are extremely light and small, scientists find it difficult to measure their individual masses. Hence, the mass of the atom is compared with a standard atomic mass of some other element.

In 1961, it was universally accepted that mass of carbon-12 atom would be used as a standard reference for measuring atomic masses of other elements.

Observe the diagram (fig-4). Let us assume the circle in the diagram represents atomic mass of carbon-12. It is divided into 12 equal parts as shown in the fig.--4, and each part represents 1/12 of atomic mass of carbon-12.

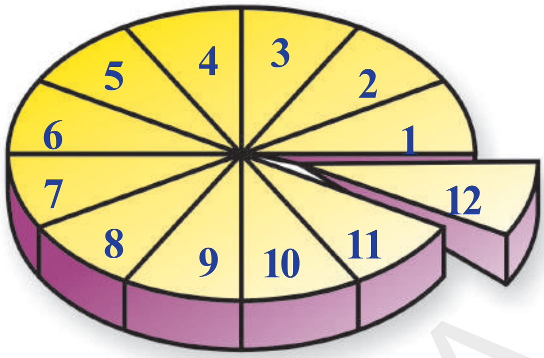

Fig - 4

One atomic mass unit (amu) is defined as the mass exactly one twelth the atomic mass of Carbon-12 isotope.

The number of times one atom of given element is heavier than 1/12th of atomic mass of carbon-12 is called its **atomic mass**.

The atomic mass of an element is defined as the average mass of all the isotopes of the element as compared to $1/12^{th}$ of the mass of one carbon -12 atom.

Atomic mass of an element is a ratio. Hence it has no units, but it is expressed in **amu.** According to latest IUPAC (International Union of Pure and Applied Chemistry) recommendations the **amu** has been replaced by '**u**', which is known as **unified mass**.

Table-8: Atomic masses of a few elements

Element	Atomic Mass (in u)	Element	Atomic Mass (in u)
Hydrogen	1	Aluminium	27
Carbon	12	Phosphorus	31
Nitrogen	14	Sulphur	32
Oxygen	16	Chlorine	35.5
Sodium	23	Potassium	39
Magnesium	24	Calcium	40

Do you know?

1. Atomic weights of elements were determined in the beginning with reference to hydrogen by John Dalton.

   While searching various atomic mass units scientists initially took 1/16th of the mass of an atom of naturally occurring oxygen as a unit. This was considered relevant due to two reasons.

   - Oxygen reacted with a large number of elements and formed compounds.
   - This atomic mass unit gave masses of most of the elements as whole numbers.

2. During nineteenth century there were no facilities to determine the mass of an atom. Hence, chemists determined the mass of one atom relative to another by experiments. Today, atomic mass of an atom can be determined very accurately with the help of an instrument called mass spectrometer.

Molecules of compounds

A molecule may contain one or more atoms. A molecule may be formed by the combination of atoms of same element or different elements. For example, a molecule of water is formed by the combination of two atoms of hydrogen and one atom of oxygen. All the molecules of water are identical.

Is it possible for any number of atoms of hydrogen to combine with any number of atoms of oxygen to form a molecule of water?

For all the molecules of water to be identical, it is essential that the atoms of hydrogen and oxygen that are present in the molecule must be in fixed numbers. If this number is not fixed, how could all the particles of water be identical?

Each molecule of water contains 2 atoms of hydrogen and 1 atom of oxygen.

Chemical formulae of compounds

While writing the formula of a compound we must keep two things in mind. First, we must see the elements present in a molecule of the compound. Second, we must see the number of atoms of each element present in that molecule. 2 atoms of hydrogen and one atom of oxygen are present in a molecule of water, its formula is H_2O.

Another rule is that if the molecule of a substance contains only one atom, subscript need not be written in the formula.

Now look at another example. A molecule of carbon dioxide contains one atom of carbon and two atoms of oxygen. carbon and oxygen also react to form another compound called carbon monoxide. A molecule of carbon monoxide contains one atom of carbon and one atom of oxygen.

- Can you write the formula of carbon dioxide and carbon monoxide? Try to write formula for them as we have done in case of water molecule.

Let us try to write chemical formulae of compound in **criss - cross method** by using valency.

For eg. Sodium carbonate.The following steps should be taken while writing the chemical formula of sodium carbonate.

1. Write the symbols of each atom or group of atoms side by side, usually the cation first and anion next -

   Na CO_3

2. Write the valency of each atom or group of atoms the top of its symbol

   Na^1 $(CO_3)^2$

3. Divide the valency numbers by their highest common factor if any to get the simple ratio. Na^1 $(CO_3)^2$

4. Inter change the valency and write the numbers as the subscript to right side of the constituents as their subscripts. $Na_2\,(CO_3)_1$

5. If any constituent receives the number 1, ignore it while writing the formula.

6. If a constituent has more than one atom enclose it with in brackets, if it carries 2 or more mention as subscripts. [Look at the formula of aluminium sulphate].

Hence the formula for the sodium carbonate is Na_2CO_3.

Examples

1. Formula of hydrogen chloride

   H^1 Cl^1 → H_1 Cl_1 formula: HCl

2. Formula of magnesium chloride

   Mg^2 Cl^1 → Mg_1 Cl_2 formula: $MgCl_2$

3. Formula of calcium oxide

   Ca^2 O^2

   Ca^1 O^1 → Ca_1 O_1 formula: CaO

4. Formula of aluminium sulphate is $Al_2\,(SO_4)_3$

Table-9: Formulae of some compounds

Compound	Formula
Sodium Carbonate	Na_2CO_3
Sodium bicarbonate	$NaHCO_3$
Sodium hydroxide	NaOH
Copper Sulphate	$CuSO_4$
Silver Nitrate	$AgNO_3$
Hydrochloric Acid	HCl
Sulphuric Acid	H_2SO_4
Nitric Acid	HNO_3
Ammonium Chloride	NH_4Cl
Potasium Dichromate	$K_2Cr_2O_7$
Potasium Permanganate	$KMnO_4$

Molecular mass

We have already discussed the concepts of atomic mass. This concept can be extended to calculate molecular masses.

The molecular mass of a substance is the sum of the atomic masses of all the atoms present in a molecule of the substance. As atomic mass is a relative, it is therefore the moleculer mass is also relative. Mass of a molecule expressed in unified Mass (u).

For Example: calculate the molecular mass of H_2SO_4

Solution

2 (atomic mass of hydrogen) + (atomic mass of sulphur) + 4(atomic mass of oxygen) = (2x1)+32+(4x16)=98 u

Formula unit mass

One formula unit of NaCl, means one Na^+ (Sodium ion) and one Cl^- (Cholorine ion), similarly one formula unit of $MgBr_2$ means one Mg^{2+} ion and two Br^- ions, and one formula unit of H_2O means one H_2O molecule. The formula unit mass of a substance is a sum of the atomic masses of all atoms in a formula unit of a compound. Formula unit mass is calculated in the same manner as the molecular mass. The only difference is that formula unit is used for the substances whose constituents particles are ions. Sodium Chloride has a formula unit NaCl. The formula unit mass can be calculated as:

1 x 23 + 1 x 35.5 = 58.5u

Mole concept

We have learnt that atoms and molecules are extremely small in size and their number is really very large. Even in a small amount of any substance we find very large number of atoms or molecules.

How many molecules are there in 18 grams of water?

How many atoms are there in 12 grams of carbon?

You will be surprised to know that the number of molecules in 18 grams of water and no.of atoms in 12 grams of carbon as the same. This number is very large. To handle such large numbers, a unit called mole is introduced. This is a numerical quantity.

One mole of a substance is the amount of the substance which contains as many particles (atoms, molcules, ions ....etc) or entities that are equal to the atoms present in exactly 12 grams of ^{12}C isotope.

The number of particles (atoms or molecules) present in one mole of any substance has a fixed value of $6.022x10^{23}$. This number is called Avogadro constant (N_A) named in honour of the Italian scientist, Amedeo Avogadro.

Do you know?

The word "mole" was introduced by Wilhelm Ostwald, who derived the term from the latin word "moles" meaning a 'heap' or 'pile'. A mole substance may be considered as a heap of atoms or molecules. The unit mole was accepted in 1967 to provide a simple way of reporting a large number-the massive heap of atoms and molecules in a sample.

Molar mass

Having defined mole, it is easier to know the mass of 1 mole of substance. The mass of 1 mole of a substance which is expressed in grams is called its molar mass.

The molar mass and molecular mass are numerically equal but molar mass has units grams and molecular mass has unified mass units.

For example molecular mass of water (H_2O) =18u.

Molar mass of water= 18 g

18 u water has only one molecule of water. But 18 g water has one mole molecules of water that is 6.022×10^{23} molecules.

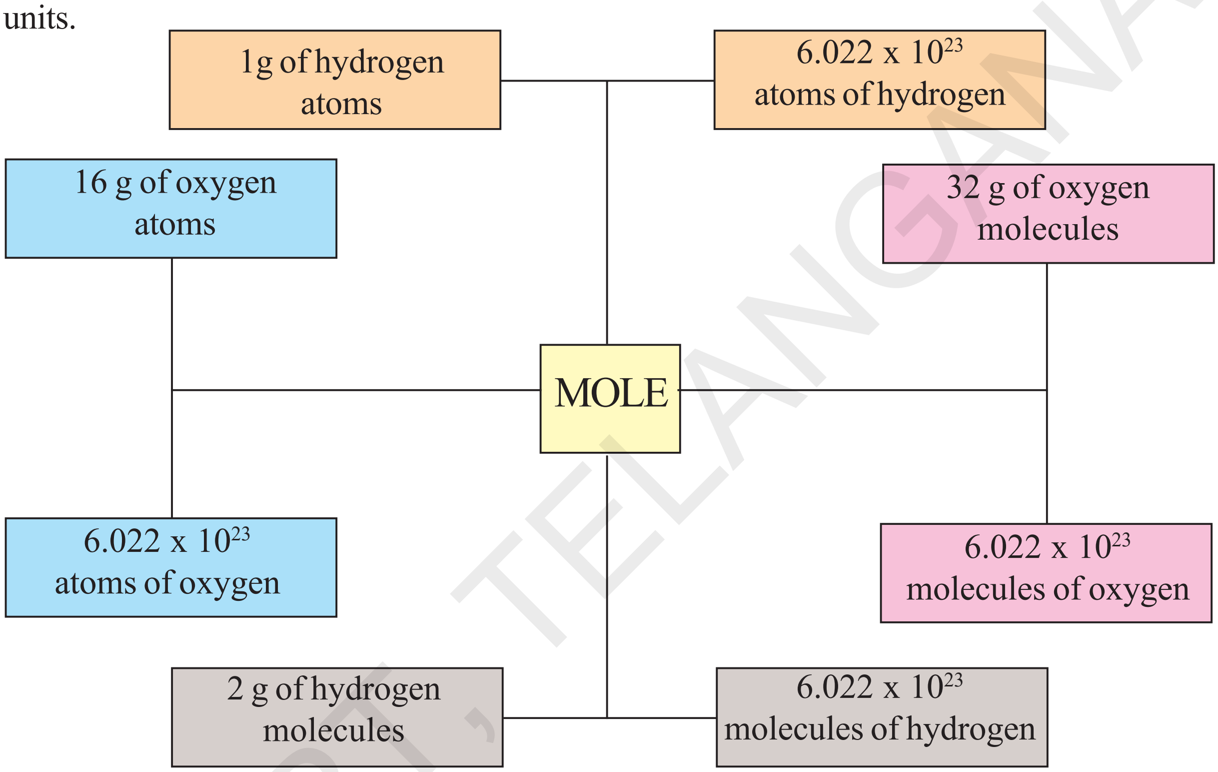

Fig-5: Diagram on concept of mole

Chemical Reactions

We have learnt about elements, molecules and compounds. We also learnt symbols and formulae of some elements and molecules. We know how to write a formula to a compound.

- Have you observed occuring different colours when fire crackers are burnt?
- Have you observed the change when a piece of plastic is burnt?
- Have you observed the change in colour of litmus paper when dipped in acid or base?

These changes are called chemical changes. The chemical substances which are participating in chemical reaction are called reactants and the new substances formed are called products.

Why these changes are occuring?

In chemical reactions atoms are neither created nor destroyed. A chemical reaction is a process that is usually characterized by a *chemical change* in which the starting materials (reactants) are different from the products. Chemical reactions occur with the formation and breaking of *chemical bonds*. (you will learn about chemical bonding in class 10).

These chemical reactions are classified into four types based on the way that chemical reaction takes place.

Types of Chemical Reactions

Chemical Combination

Activity 3

(This activity needs Teacher's assistance)

- Take a small piece (about 3 cm long) of magnesium ribbon.
- Rub the magnesium ribbon with sand paper.
- Hold it with a pair of tongs.
- Burn it with a spirit lamp or burner.

- What do you observe?

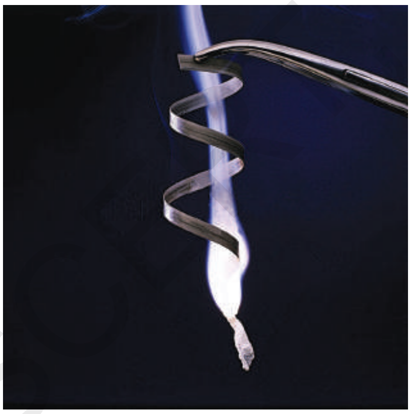

fig-6: Burning of magnesium ribbon

You will notice that, magnesium burns in oxygen by producing dazzling white flame and changes into white powder. The white powder is magnesium oxide.

$$2Mg_{(s)} + O_{2\,(g)} \rightarrow 2MgO_{(s)}$$

Magnesium Oxygen Magnesium oxide

In this reaction magnesium and oxygen combine to form a new substance magnesium oxide. A reaction in which single product is formed from two or more reactants is known as *chemical combination reaction*.

You will also notice release of enormous amount of heat energy when magnesium is burnt in air.

Let us discuss some more examples of combination reactions.

i. Burning of Coal: When coal is burnt in oxygen, carbon dioxide is produced.

$$C_{(s)} + O_{2\,(g)} \rightarrow CO_{2\,(g)} + Q \text{ (heat energy)}$$

ii. Slaked lime is prepared by adding water to quick lime.

$$CaO_{(s)} + H_2O_{(l)} \rightarrow Ca(OH)_{2(aq)} + Q \text{(heat energy)}$$

Large amount of heat energy is released on reaction of water with $CaO_{(s)}$. If you touch the walls of the container you will feel the hotness. Such reactions are called **exothermic** reactions.

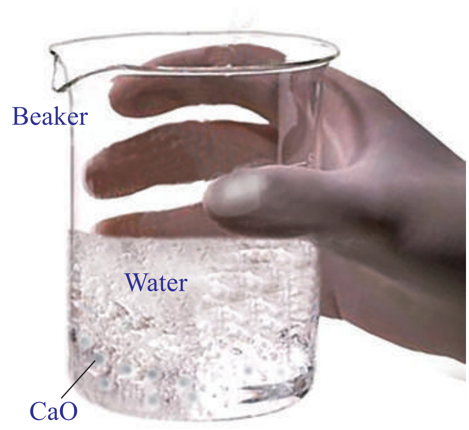

fig-7: Formation of slaked lime by the reaction of CaO with water

A solution of slaked lime produced in the reaction equation (ii) is used to white wash the walls. Calcium hydroxide reacts slowly with the carbon dioxide in air to form a thin layer of calcium carbonate on the walls. It gives a white shiny finish to the walls.

Decompostion Reaction

Activity 4

- Take a pinch of calcium carbonate (lime stone) in a boiling tube.
- Arrange the apparatus as shown in figure 8.
- Heat the boiling tube over the flame of spirit lamp or burner.
- Now bring a burning match stick near the evolved gas as shown in the figure.
- What do you observe?

You will notice that match stick would be put off.

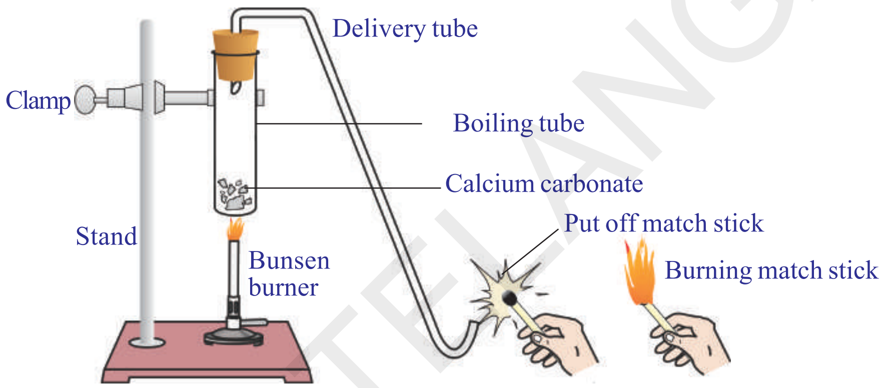

fig-8: Heating of calcium carbonate and testing the gas evolved with burning match stick

In the above activity, on heating calcium carbonate decomposes to calcium oxide and carbon dioxide.

$$\underset{\text{Lime stone}}{CaCO_{3\,(s)}} \xrightarrow{\text{Heat}} \underset{\text{quick lime}}{CaO_{(s)}} + CO_{2\,(g)}$$

It is a thermal decomposition reaction. When a decomposition reaction is carried out by heating, it is called *thermal decomposition reaction*.

Activity 5

Arrange the apparatus as shown in fig.- 9.

- Take about 0.5g of lead nitrate powder in a boiling test tube.
- Hold the boiling tube with a test tube holder.

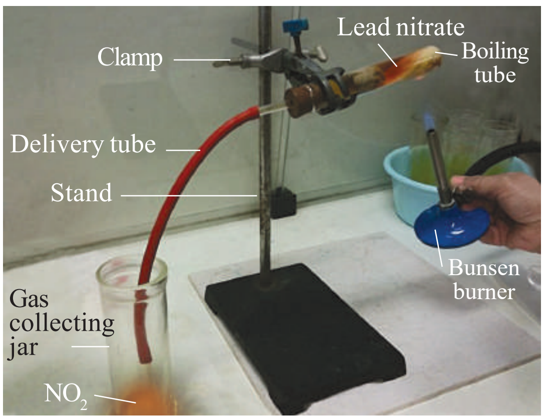

fig-9:Heating of lead nitrate and emission of nitrogen dioxide

- Heat the boiling tube over a flame. (see fig.- 9)
- Note down the change.
- What do you observe?

On heating lead nitrate decomposes to lead oxide, oxygen and nitrogen dioxide. You observe the brown fumes liberating in the boiling tube. These brown fumes are of nitrogen dioxide (NO_2).

$$2Pb(NO_3)_2 \xrightarrow{Heat} 2PbO_{(s)} + 4NO_{2\,(g)} + O_{2(g)}$$

Lead Nitrate — lead oxide — Nitrogen dioxide — Oxygen

This is also a thermal decomposition reaction. Let us perform some more decomposition reactions

Activity 6

- Take a plastic mug. Drill two holes at its base.
- Fit two 'one holed rubber stoppers' in these holes.
- Insert two graphite electrodes in these rubber stoppers.
- Connect the electrodes to 9V battery as shown in fig.
- Fill the mug with water, so that the electrodes are immersed.
- Add few drops of dilute sulphuric acid to water.
- Take two test tubes filled with water and invert them over the two graphite electrodes.
- Switch on the current and leave the apparatus undisturbed for some time.

- What do you observe in the test tubes?

You will notice the liberation of gas bubbles at both the electrodes. These bubbles displace the water in the test tubes. Is the volume of gas collected in both the test tubes same?

Once the test tubes are filled with gases take them out carefully. Test both the gases separately by bringing a burning candle near the mouth of each test tube.

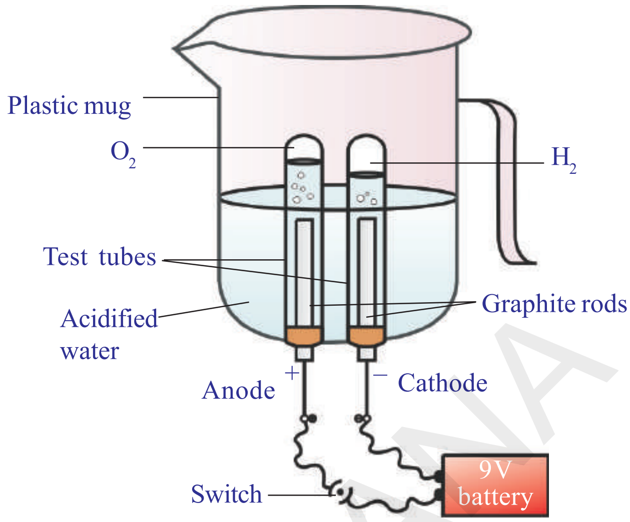

fig-10: Electrolysis of water

- What do you observe in each case?
- Can you predict the gas present in each test tube?

In the above activity on passing the electricity, water dissociates to hydrogen and oxygen. This is called electrolytic composition reaction.

$$2H_2O_{(l)} \xrightarrow{Electrolysis} 2H_{2\,(g)} + O_{2\,(g)}$$

Activity 7

- Take some quantity of silver bromide on a watch glass.
- Observe the colour of silver bromide.
- Place the watch glass in sunlight for some time.
- Now observe the colour of silver bromide.

- What changes do you notice?
- Did the colour of the silver bromide change?

fig-11(a): Silver bromide (light yellow colour)

fig-11(b): when exposed to sunlight (gray colour) silver metal

Silver bromide decomposes to silver and bromine in sunlight. *Light yellow* coloured silver bromide turns to *gray* due to sunlight.

$$2AgBr_{(s)} \xrightarrow{\text{sunlight}} 2\,Ag_{(s)} + Br_{2\,(g)}$$

This decomposition reaction occurs in presence of sunlight and such reactions are called *photochemical reactions*.

All the above decomposition reactions require energy in the form of heat, light or electricity for converting the reactants to products. All these reactions are endothermic.

Carry out the following Activities:

i) Take a pinch of $AgCl$ in a watch glass. Keep it in sunlight for some time and observe the change.

ii) Take some ferrous sulphate crystals in a boiling tube. Heat it over spirit lamp.

iii) Take about 2 gm of barium hydroxide in a test tube. Add about 1 gm of ammonium chloride and mix with glass rod. Touch the test tube with your palm.

What do you observe?

Displacement reaction.

In displacement reaction one element displaces another element from its compound and takes its place there in.

Displacement of hydrogen from acids by metals:

Generally metals which are more active than hydrogen displace it from an acid.

Let us observe the reaction in following activity.

Activity 8

- Take a small quantity of zinc dust in a conical flask.
- Add dilute hydrochloric acid slowly.

fig-12(a)

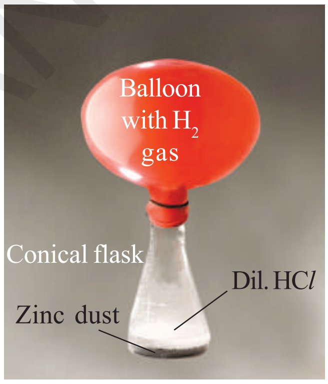

fig-12(b)

- Now take a balloon and tie it to the mouth of the conical flask.
- Closely observe the changes in the conical flask and balloon.
- What do you notice?

You can see the gas bubbles coming out from the solution and the balloon bulges out (fig.-12b). Zinc pieces react with dilute hydrochloric acid and liberate hydrogen gas as shown below.

$$Zn_{(s)} + 2HCl_{(aq)} \rightarrow ZnCl_{2(aq)} + H_{2\,(g)}$$

In the above reaction the element zinc has displaced hydrogen from hydrochloric acid. This is displacement reaction.

Activity 9

- Take two iron nails and clean them by rubbing with sand paper.
- Take two test tubes and mark them as A and B.
- Take about 10ml of copper sulphate solution in each test tube. Dip one iron nail in copper sulphate solution of test tube A and keep it undisturbed for 20 minutes.
- Keep the other iron nail and test tube aside.
- Now take out the iron nail from copper sulphate solution and compare with the other iron nail that has been kept aside. (see fig13-a)

fig-13(a):Iron nail dipped in copper sulphate solution

- Compare the colours of the solutions in the test tubes. (see fig13-b)

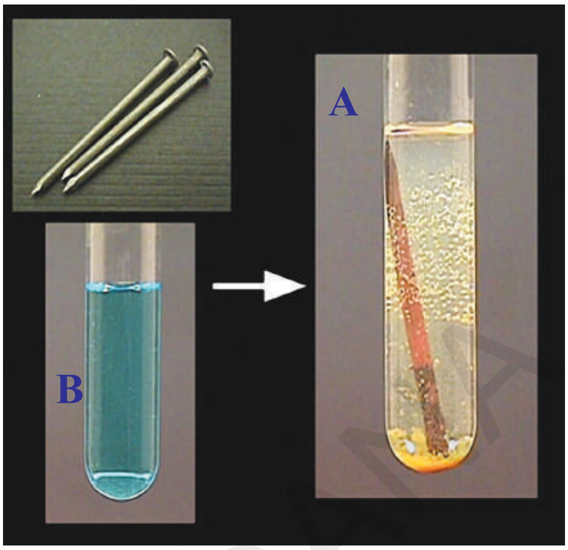

fig-13(b): Iron nail and copper sulphate solutions compared before and after the experiment

- What changes do you observe?

You will find the iron nail dipped in copper sulphate solution becoming brown. The blue colour of copper sulphate solution in test tube 'A' fades.

The chemical reaction in this activity is:

$$Fe_{(s)} + CuSO_{4\,(aq)} \rightarrow FeSO_{4\,(aq)} + Cu_{(s)}$$

Iron is more reactive than copper, so it displaces copper from copper sulphate. This is another example of displacement reaction.

Other examples of displacement reaction are:

i) $Zn_{(s)} + 2AgNO_{3(aq)} \rightarrow Zn(NO_3)_{2(aq)} + 2Ag_{(s)}$

ii) $Pb_{(s)} + CuCl_{2\,(aq)} \rightarrow PbCl_{2\,(aq)} + Cu_{(s)}$

Double displacement reaction

Activity 10

- Take a pinch of lead nitrate and dissolve in 5.0ml of distilled water in a test tube.
- Take a pinch of potassium iodide in a test tube and dissolve in distilled water.
- Mix lead nitrate solution with potassium iodide solution.

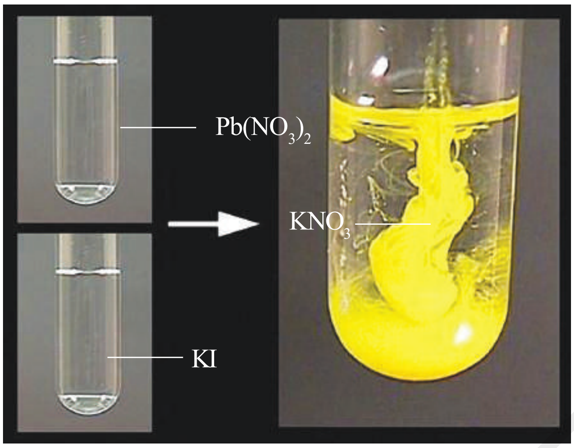

fig-14: formation of lead iodide and potassium nitrate

- What do you observe?

A yellow coloured substance which is insoluble in water, is formed as **precipitate**. The precipitate is lead iodide.

$Pb(NO_3)_{2(aq)} + 2KI_{(aq)} \rightarrow PbI_{2(s)} + 2KNO_{3(aq)}$

lead nitrate   potassium Iodide   lead iodide   potassium nitrate

This reaction is double displacement reaction. If two reactants exchange their constituents chemically and form two products, then the reaction is called as double displacement reaction.

Other examples of double displacement reactions are:

1) Sodium sulphate solution on mixing with barium chloride solution forms a white prepitate of barium sulphate and soluble sodium chloride.

$Na_2SO_{4\,(aq)} + BaCl_{2\,(aq)} \rightarrow BaSO_{4(s)} + 2NaCl_{(aq)}$

2) Sodium hydroxide reacts with hydrochloric acid to form sodium chloride and water.

$NaOH_{(aq)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$

3) Sodium chloride spontaneously combines with silver nitrate in solution giving silver chloride precipitate and Sodium nitrate.

$NaCl_{(aq)} + AgNO_{3(aq)} \rightarrow AgCl_{(s)} + NaNO_{3(aq)}$

Oxidation and Reduction

'Oxidation' is a chemical reaction that involves the addition of oxygen or removal of hydrogen.

'Reduction' is a chemical reaction that involves the addition of hydrogen or removal of oxygen.

Let us try to understand more clearly doing this experiment.

Activity 11

- Take about 1.0g of copper powder in a china dish.
- Keep the china dish on a tripod stand containing wire gauge.
- Heat it with a bunsen burner or with a spirit lamp.
- Do you find any change in colour of copper?

You will notice that the surface layer of copper becomes black.

- Why does the colour of copper change?
- What is the black colour product formed on the surface of copper?

In the activity on heating copper it reacts with oxygen present in the atmosphere to form copper oxide.

The reaction is shown below.

$$Cu_{(s)} + O_{2(g)} \xrightarrow{\text{Heat}} 2\,CuO_{(S)}$$

fig-15(a): Copper Oxide change into black colour

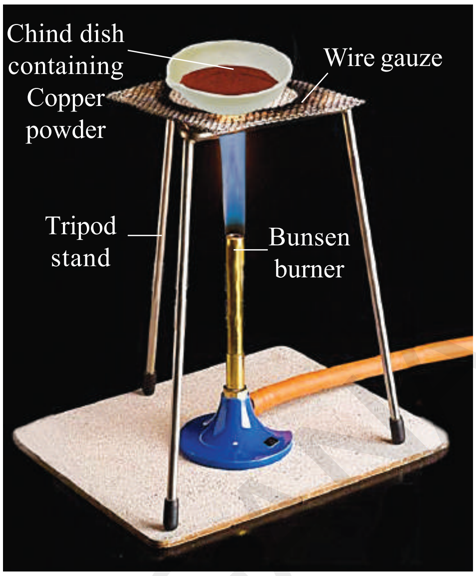

fig-15(b): Oxidation of copper to copper oxide

Here copper combines with oxygen to form copper oxide. Here oxygen is gained and the process is called *oxidation*.

Now pass hydrogen gas over hot copper oxide obtained in above activity and observe the change (see fig. 16).

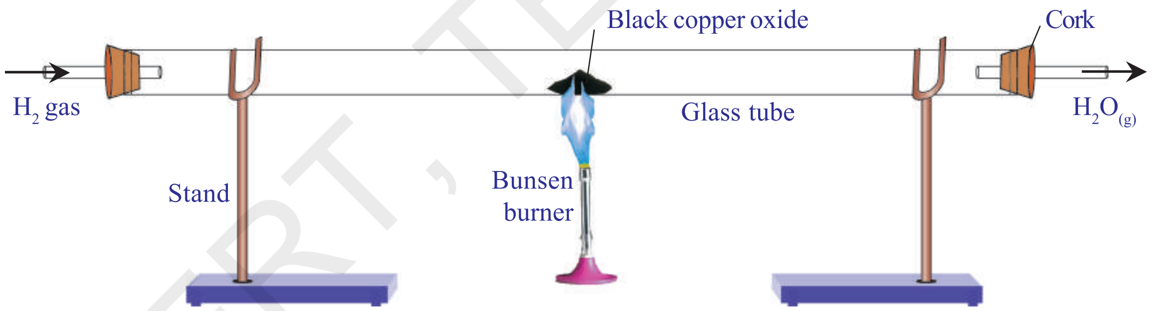

fig-16: Reduction of copper oxide to copper

- What do you notice?
- Is there any change in black colour of copper oxide?

You will notice that the black coating on copper turns brown because copper oxide loses oxygen to form copper. In this process oxygen is lost and the process is called *Reduction*.

$$CuO_{(s)} + H_{2(g)} \xrightarrow{\text{Heat}} Cu_{(s)} + H_2O_{(g)}$$

In the above reaction hydrogen is gained; such reaction is called *reduction reaction*.

Generally oxidation and reduction occur in the same reaction. If one reactant gets oxidized, the other gets reduced. Such reactions are called *oxidation-reduction reactions or redox reactions*.

In the CuO, H_2 reaction CuO is reduced and H_2 is oxidized.

Some other examples of redox reactions are:

i) $2\,Fe_2O_{3(s)} + 3C_{(s)} \rightarrow 4\,Fe_{(s)} + 3CO_{2\,(g)}$

ii) $2\,PbO_{(3)} + C_{(s)} \rightarrow 2Pb_{(s)} + CO_{2\,(g)}$

Have you observe the effects of oxidation reactions in daily life

Corrosion:

You must have observed that a freshly cut apple turns brown after some time. The shining iron articles gradually become reddish brown when left for some time. Burning of crackers produce dazzling light with white fumes.

fig-17: Rusting of iron

- How do these changes occur?

They are all the examples of the process called *oxidation.*

Let us know how?

Oxidation is the reaction of oxygen molecules with different substances starting from metal to living tissue which may come in contact with it.

Apples, pears, bananas, potatoes etc., contain enzyme called polyphenol oxidase or tyrosinase, which reacts with oxygen and changes the colour on the cut surface of the fruit.

The browning of iron, when left for sometime in moist air, is a process commonly known as rusting of iron. This process is basically oxidation reaction which requires both oxygen and water. Rusting does not occur in oxygen free water or dry air.

Burning of crackers is also oxidation process of variety of chemicals, like Magnesium and Sulphur.

- Did you notice the colour coating on copper articles?

When some metals are exposed to moisture, acids etc., they tarnish due to the formation of respective metal oxide on their surface. This process is called ***corrosion***.

Look at the following example:

Green coating on copper (see fig-18)

fig-18: Corrosion of copper

$2Cu + O_2 \rightarrow 2CuO$

Corrosion causes damage to car bodies, bridges, iron railings, ships etc., and to all other objects that are made of metals. Especially corrosion of iron is a serious problem.

Corrosion can be prevented or at least minimized by shielding the metal surface from oxygen and moisture. It can be prevented by painting, oiling, greasing, galvanizing, chrome plating or making alloys. *Galvanizing* is a method of protecting iron from rusting by coating them a thin layer of Zinc.

Alloying is also a very good method of improving properties of metal. Generally pure form of iron is very soft and stretches easily when hot. Iron is mixed with carbon, nickel and chromium to get an alloy called stainless steel. The stainless steel is hard and does not rust.

A metallic substance made by mixing and fusing two or more metals, or a metal and a nonmetal, to obtain desirable qualities such as hardness, lightness, and strength is known as *alloy*.

For example: Brass, bronze, and steel.

Some more effects of oxidation on everyday life

1. Combustion is the most common example for oxidation reactions.

   For example: burning of wood involves release of carbon dioxide, water vapour along with huge amount of energy.

2. Rising of dough with yeast depends on oxidation of sugars to carbon dioxide and water.

3. Bleaching of coloured objects using moist chlorine

   $$Cl_2 + H_2O \rightarrow HOCl + HCl$$

   $$HOCl \rightarrow HCl + [O]$$

   Coloured object + [O] → Colourless object.

Some times during rainy season the power supply to our home from the electric pole will be interrupted due to formation of the metal oxide layer on the electric wire. This metal oxide is an electrical insulator. On removing the metal oxide layer formed on the wire with a sand paper, supply of electricity can be restored.

4. Rancidity

- Have you ever tasted or smelt the fat/oil containing food materials left for a long time?

When fats and oils are oxidized they become rancid. Their smell and taste change.

Thus we can say that oxidation reactions in food material that were left for a long period are responsible for spoiling of food.

Rancidity is an oxidation reaction.

- How can we prevent the spoiling of food?

The spoilage of food can be prevented by adding preservatives like Vitamin C and Vitamin E.

Usually substances which prevent oxidation (Antioxidants) are added to food containing fats and oil. Keeping food in air tight containers helps to slow down oxidation process.

Manufacturers of potato chips flush bags of chips with nitrogen gas to prevent the chips from getting oxidized.

Key words

Law of conservation of mass, Law of constant proportion. Atom, Symbol, Atomic mass, Atomic mass unit (amu), Unified mass (u), Molecule, Molecules of elements, Molecules of compounds, Formula, Ion (cation, anion), Atomicity, Valency, Molecular mass, Formula unit mass, Mole, Avogadro constant, Molar mass, Chemical combination, Chemical decomposition, Displacement reaction, Double Displacement reaction, Oxidation, Reduction, Corrosion, Rancidity, Antioxidants.

What we have learnt

- The total mass of the products formed in a chemical reaction is exactly equal to the mass of the reactants. This is known as the law of conservation of mass.
- In a chemical substance the elements are always present in fixed proportions by mass. This is known as the law of constant proportion.
- An atom is the smallest particle of an element that can participate in a chemical reaction and retain all its properties.
- A molecule is the smallest particle of an element or a compound that is capable of independent existence and retains all the properties of that substance.
- Symbols represents atoms and formula represents molecules and compounds.
- Scientists use the relative atomic mass scale to compare the masses of different atoms of elements.
- The number of times one atom of a given element is heavier than $1/12^{th}$ part of mass of carbon -12 atom is called its atomic mass.
- By using criss - crosss method we can write the chemical formula of a compound.
- The number of particles present in one mole of any substance is called Avogadro constant (N_A). It is a fixed value of 6.022×10^{23}.
- Mass of one mole of a substance is called its molar mass.
- In a combination reaction two or more substances combine to form a new single substance.
- In a decomposition reaction a single substance decomposes to give two or more substances.
- Reactions in which heat energy is absorbed by the reactants are endothermic reactions.

- In exothermic reaction heat energy is released by the reactants.
- A displacement reaction occurs, when an element displaces another element from its compound.
- Two different atoms or ions are exchanged in double displacement reactions.
- Oxidation is the gain of Oxygen or loss of Hydrogen.
- Loss of oxygen or gain of Hydrogen is Reduction.
- Corrosion causes damage to iron appliances.
- When fats and oils are oxidized, they become rancid.
- Precipitate is an insoluble substance.

Let us Improve our learning

M5I5L3

Reflections on concepts

1. Explain the process and precautions in verifying law of conservation of mass. (AS-3)
2. In a class, a teacher asked students to write the molecular formula of oxygen Shamita wrote the formula as O_2 and Priyanka as O. which one is correct? State the reason. (AS-1)
3. Find out the chemical names and formulae for the following common household substances. (AS-1)

   a) common salt b) baking soda c) washing soda d) vinegar
4. Calculate the mass of the following (AS-1)

   a) 0.5 mole of N_2 gas. b) 0.5 mole of N atoms.

   c) 3.011×10^{23} number of N atoms. d) 6.022×10^{23} number of N_2 molecules.
5. Convert into mole (AS-1)

   a) 12g of O_2 gas. b) 20g of water. c) 22g of carbon dioxide.
6. Write the valencies of Fe in $FeCl_2$ and $FeCl_3$ (AS-1)
7. Calculate the molar mass of Sulphuric acid (H_2SO_4) and glucose ($C_6H_{12}O_6$)(AS-1)
8. Which has more number of atoms - 100g of sodium or 100g of iron? Justify your answer. (atomic mass of sodium = 23u, atomic mass of iron = 56u) (AS-1)

9. Fill the following table

Sl.No.	Name	Symbol/formula	Molar mass	Number of particles present in molar mass.
1	Oxygen Atom		16g	6.022×10^{23} atoms of oxygen
2	Oxygen molecule			
3	Sodium			
4	Sodium ion		23g	
5	Sodium chloride			6.022×10^{23} units of sodium chloride
6	water			

10. Write an equation for decomposition reaction where energy is supplied in the form of Heat / light / electricity. (AS-1)
11. How chemical displacement reactions differ from chemical decomposition reaction? Explain with an example for each. (AS-1)
12. Name the reactions taking place in the presence of sunlight? (AS-1)
13. Give two examples for oxidation-reduction reaction. (AS-6)
14. Draw the digarm to show the experimental setup to verify the law of conservation of mass. (AS-5)

Application of concepts

1. Why do we apply paint on iron articles? (AS-1)
2. What is the use of keeping food in air tight containers? (AS-6)

Higher Order Thinking Questions

1. 15.9g. of copper sulphate and 10.6g of sodium carbonate react together to give 14.2g of sodium sulphate and 12.3g of copper carbonate. Which law of chemical combination is obeyed? How? (AS-1)
2. Carbon dioxide is added to 112g of calcium oxide. The product formed is 200g of calcium carbonate. Calculate the mass of carbon dioxide used. Which law of chemical combination will govern your answer. (AS-1)
3. Imagine what would happen if we do not have standard symbols for elements?(AS-2)

Multiple choice questions

1. $Fe_2O_3 + 2Al \rightarrow Al_2O_3 + 2 Fe$. [ ]

   The above reaction is an example of:

   a) Combination reaction b) Decomposition reaction

   c) Displacement reaction d) Double decomposition reaction

2. What happens when dil. hydrochloric acid is added to iron filings? Choose the correct answer.

   a) Hydrogen gas and iron chloride are produced. [ ]

   b) Chlorine gas and iron hydroxide are produced.

   c) No reaction takes place.

   d) Iron salt and water are produced.

3. $2 PbO_{(s)} + C_{(s)} \rightarrow 2Pb_{(s)} + CO_{2(g)}$ [ ]

   Which of the following statements are correct for the above chemical reaction?

   a) Lead oxide is reduced b) Carbon dioxide is oxidized

   c) Carbon is oxidized d) (a) and (c) are correct

4. The chemical equation $BaCl_2 + Na_2SO_4 \rightarrow BaSO_4 + 2NaCl$ represents following type of chemical reaction. [ ]

   i) displacement ii) combination

   iii) decomposition iv) double-displacement

5. The reaction of formation hydrogen chloride from hydrogen and chloride represents following type of chemical reaction [ ]

   i) decomposition ii) displacement

   iii) combination iv) double-displacement

Suggested Experiments

1. Do an experiment to understand the changes in weight of reactants and products in a chemical reaction, write a report.

Suggested Project

1. Collect the information about the symbols, atomic weights of first thirty elements in the periodic table and write a report.