1 ELEMENTS AND COMPOUNDS : ATOMS AND MOLECULES

In This Chapter You Will Learn :

- Elements, symbols and their significance
- Atomicity and molecular formulae of elements
- Molecular formulae of compounds
- Atoms and molecules
- Compounds

INTRODUCTION

There are millions of substances in this world. These substances differ from each other in their composition, properties and uses because they all are made up of different kinds of matter. They can be pure or impure. To study these substances accurately and conveniently, they need to be classified under three categories : elements, compounds and mixtures on the basis of some similarities and dissimilarities.

All substances are made up of very tiny particles called **molecules**. Molecules are formed from even smaller particles called atoms. **Atoms** and molecules are so small that they can only be seen through a powerful microscope.

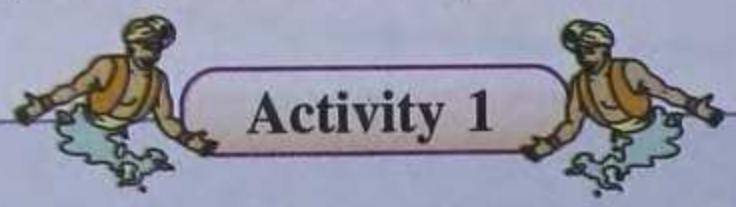
SUBSTANCES

- **Pure substances** (Homogeneous)
  - **Elements**
    - **Metals** — *e.g. :* Copper, Iron
    - **Non-metals** — *e.g. :* Hydrogen, Oxygen Carbon
    - **Metalloids** — *e.g. :* Silicon, Arsenic
    - **Noble gases** — *e.g. :* Helium, Neon
  - **Compounds**
    - **Inorganic** — *e.g. :* Water, Salt
    - **Organic** — *e.g. :* Sugar, Proteins
- **Impure substances**
  - **Mixtures**
    - **Homogeneous Mixtures** — *e.g. :* Air, Salt, Water, etc.
    - **Heterogeneous Mixtures** — *e.g. :* Sand and Water, Oil and Water, etc.

Pure substances : Pure substances are made up of same kind of atoms or molecules and have a definite set of properties. They are all homogeneous *i.e.*, their composition is uniform throughout the bulk. **Both elements and compounds are pure substances.** Elements are made up of same kind of atoms and compounds are made up of the same kind of molecules.

Impure substances : Impure substances are made up of two or more pure substances

mixed together in any proportions. They do not have any definite set of properties but they retain the properties of constituent substances. They may be homogeneous or heterogeneous, *i.e.*, their composition is not uniform throughout the bulk, *e.g.* : air, sugar solution, sand and stone, etc.



Activity 1

Make a list of five mixtures which you use in your daily life and give reason why those substances should be considered as mixtures.

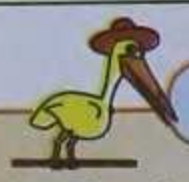
1.1 ELEMENTS

Elements are the limited number of basic substances from which millions of more substances are made.

An element is the simplest pure substance. Each element is made up of only one kind of atom, which differs from the atom of any other element.

Oxygen, hydrogen, sulphur, carbon, iron, gold, silver, *etc*. are some examples of elements.

The smallest unit of an element is atom.



Do You Know ?

Robert Boyle was the first scientist to use the term element in 1661.

Antoine Laurent Lovoisier (1743-94) was the first to establish experimentally useful definition of an element.

He defined an element as a basic form of matter that cannot be broken down into simpler substances by chemical reactions.

Examples **:** A piece of aluminium sheet contains only aluminium atoms and oxygen contains atoms of oxygen only. Atoms of oxygen and aluminium are different. Thus, each element has its own unique properties.

At present 118 *elements are known. Of these,* 90 *are natural elements (most of them are in combined state in the earth's crust) while rest* 28 *have been artificially created.* Some elements are solids, some are liquids and some are gases.

Do You Know ?

Of the 118 elements, known to us, some are radioactive in nature, because they emit radiations which may be harmful.

1.2 CLASSIFICATION OF ELEMENTS

Based on their properties, elements are classified into :

(i) metals (ii) non-metals

(iii) metalloids (iv) noble (or inert) gases.

Metals : Most of the elements known to us are metals.

1. They are usually lustrous and hard solids. [*Exceptions* :- Mercury and gallium are liquids. Sodium and potassium are soft.]
2. Metals are malleable and ductile [Zinc is brittle].

   Note : Malleable (can be beaten into thin sheets).

   Ductile (can be drawn into wire without breaking).
3. They have high melting and boiling points.
4. They are good conductors of heat and electricity.
5. They are sonorous substances because they produce a specific sound when struck.

Examples **:** Gold, silver, copper, aluminium, zinc, iron, tin, *etc*.

Do You Know ?

- Chalk, milk and our bones contain a common metal **calcium**.
- Chlorophyll contains **magnesium** which helps to capture the energy from sunlight for photosynthesis by plants.
- In mammals iron is found in red blood cells in haemoglobin which carries oxygen in the body.

Non-metals :

1. Non-metals are elements with a dull surface, *i.e.*, they do not shine.
2. They are fewer in number as compared to metals. They are either soft solids or gases, except bromine, which is a liquid.
3. Non-metallic solids are brittle in nature.
4. They are all bad conductors of heat and electricity. [Except carbon in the form of graphite and gas carbon].
5. They have low melting and boiling points [*Exception: Carbon in the form of Graphite has a high melting point*].
6. They are neither malleable nor ductile.
7. They are not sonorous.
8. They display a variety of colours.

Examples : Sulphur, phosphorus, carbon, oxygen, hydrogen, chlorine, nitrogen, *etc*.

Do You Know ?

- Sulphur, phosphorus and iodine are soft solids.
- Carbon exists as soft solid in the form of charcoal, coal and soot but in the form of **diamond** it is the hardest naturally occurring solid.
- Graphite is another form of carbon which is soft, lustrous and a good conductor of heat and electricity.
- Diamond, due to its brilliant shine is used as a gem for making jewelleries.
- Oxygen, hydrogen, chlorine and nitrogen are all gases.

Metalloids : These elements show some properties of metals and some properties of non-metals. They are hard solids.

Examples : boron, silicon, germanium, arsenic, antimony, *etc*.

Inert or noble gases : These elements do not react chemically with other elements or compounds, so they are known as noble (or inert) gases. They are found in air, in traces. There are only six noble gases — helium, neon, argon, krypton, xenon and radon.

1.3 SYMBOLS OF ELEMENTS

1. Each element is denoted by a symbol which is usually the first letter of its name in English or Latin [written in capital].

Example : Oxygen is an element. It is denoted by the symbol 'O'. Similarly, hydrogen is denoted by a symbol 'H'. Now-a-days, IUPAC (International Union of Pure and Applied Chemistry) approves names of elements.

2. However, when the first letter of more than one element is same, the symbol is denoted by two letters, first letter is written in capital while the second is written in small letter.

Example : Carbon, cobalt and copper are the elements whose first letter is 'C'. *Carbon* is denoted by the symbol 'C'. *Cobalt* is denoted by two letters 'Co'. *Copper* is denoted by the symbol 'Cu' [taken from its Latin name **cuprum**]. Chromium is denoted by Cr while chlorine by Cl.

3. These symbols also represent an atom of that element.

Example :

(i) 'H' represents the element hydrogen as well as one atom of hydrogen.

(ii) 'C' represents the element carbon as well as one atom of carbon.

4. Other symbols have been taken from the names of elements in Latin, German or Greek.

Example : The symbol of iron is Fe from its latin name Ferrum, sodium is Na from Natrium, potassium is K from Kalium. Therefore, each element has a name and a unique chemical symbol.

Table 1.1 : Names and symbols of some elements derived from latin and greek languages.

Name in English	*Name in Latin/Greek*	*Symbol*
Sodium	Natrium	Na
Potassium	Kalium	K
Magnesium	Magnesia	Mg
Aluminium	Alumen	Al
Calcium	Calx	Ca
Iron	Ferrum	Fe
Copper	Cuprum	Cu
Zinc	Zinke	Zn
Silver	Argentum	Ag
Gold	Aurum	Au
Mercury	Hydragyrum	Hg
Lead	Plumbum	Pb
Hydrogen	—	H
Nitrogen	—	N
Oxygen	—	O
Chlorine	—	Cl
Carbon	—	C
Sulphur	—	S
Phosphorus	—	P
Boron	—	B
Silicon	—	Si
Helium	—	He
Neon	—	Ne
Argon	—	Ar

Table 1.2 : Names and symbols

Name in English	*Symbol*	*Name in English*	*Symbol*
Chromium	Cr	Manganese	Mn
Cobalt	Co	Nickel	Ni
Tin	Sn	Barium	Ba
Tungsten	W	Platinum	Pt
Radium	Ra	Uranium	U
Fluorine	F	Bromine	Br
Iodine	I	Germanium	Ge
Arsenic	As	Antimony	Sb
Krypton	Kr	Xenon	Xe
Radon	Rn		

Compounds : "A compound is a pure substance formed by the chemical combination of two or more elements in a fixed ratio by mass."

A compound can be broken down into simpler substances. *For example :* table salt is a compound which can be broken down into two elements (more simple substances) sodium and chlorine.

Some common compounds are water, carbon dioxide, sugar, common salt, chalk, washing soda, alcohol, *etc*.

The smallest unit of a compound is molecule

1.4 CHARACTERISTICS OF COMPOUNDS

1. Compounds are homogeneous.
2. The properties of compounds are entirely different from those of its constituent elements.
3. Compounds can be broken down into their constituent elements only by chemical means, not by physical means.
4. Compounds have fixed composition of their own.
5. Energy is either absorbed or liberated during the formation of a compound.
6. A compound can be represented by a formula.

Activity 2

What do we get when two or more elements are combined ?

- Divide the class into two groups. Give 5g of iron fillings and 3g of sulphur powder in a china dish to both the groups.

Group I

- Mix and crush iron fillings and sulphur powder.

Group II

- Mix and crush iron fillings and sulphur powder. Heat this mixture strongly till red hot. Remove from flame and let the mixture cool.

Group I and II

- Check for magnetism in the material obtained. Bring a magnet near the material and check if the material is attracted towards the magnet.
- Compare the texture and colour of the material obtained by the groups.
- Add carbon disulphide to one part of the material obtained. Stir well and filter.
- Add dilute sulphuric acid or dilute hydrochloric acid to the other part of the material obtained.
- Perform all the above steps with both the elements (iron and sulphur) separately.
- The gas obtained by group I is hydrogen. (Colourless, odourless, combustable).
- The gas obtained by group II is hydrogen sulphide. (It is a colourless gas with the smell of rotten eggs).

You must have observed that the products obtained by both the groups are different, though the starting materials were the same. Group I has carried out the activity involving a physical change whereas in case of group II, a chemical change has taken place.

- The material obtained by group I is a mixture of the two substances. The substances given are the elements — iron and sulphur.
- The properties of the mixture are the same as that of its constituents.
- The material obtained by group II on heating the two elements strongly we get a compound, which has totally different properties compared to the combining elements.
- The composition of a compound is the same throughout. We can also observe that the texture and the colour of the compound are the same throughout.

Note : The experiment should be done very carefully under the observation of the concerned teacher.

EXERCISE – I

1. Write the symbols of helium, silver, krypton, antimony, barium.
2. Write the names of the following elements Na, C, Kr, U, Ra, Fe, Co.
3. Define :
   (a) Elements (b) Compounds
4. What do you understand by :
   (a) metalloids (b) noble gases
5. List four differences between metals and non-metals.
6. Name the main metal present in the following:
   (a) Haemoglobin (b) Chalk
   (c) Chlorophyll (d) Chocolate wrappers
   (e) Hammer (f) Door-knob
   (g) Electric wires
7. Which element exists as a soft solid as well as a hard solid ? Give one example for each type of solid in which it exists.

You have studied in the beginning of the chapter that all substances are made up of very minute particles called **atoms** and **molecules**. Will you not like to know about them in detail ?

1.5 AN ATOM

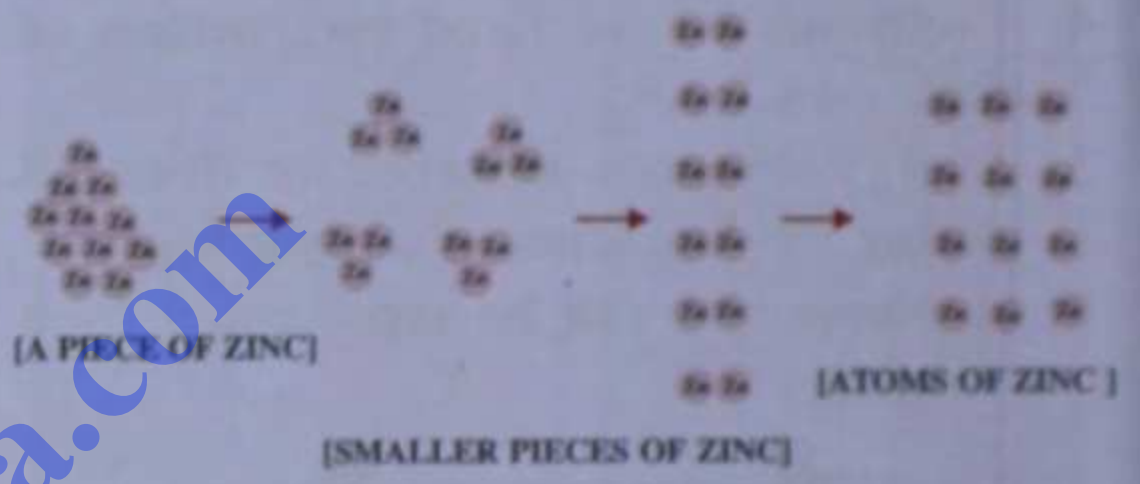
*"An atom is the smallest particle of an element that exhibits all the properties of that element. It **may or may not exist** independently but can take part in every chemical reaction.*

Example : Take a small piece of zinc and grind it into smaller pieces. All these pieces show properties of zinc. On grinding them further they break up into very fine particles which still show the properties of zinc. But, there comes a stage when the particles cannot be further subdivided into particles exhibiting properties of zinc. These indivisible particles are the atoms of zinc.

"In other words atoms are the smallest possible units of an element".

Atoms of same element are all identical. They differ from the atoms of other elements.

That is why different elements differ in their properties.



Do You Know ?

Atoms are so small that it would take millions of them, just to cover a full stop.

1.6 A MOLECULE

"A molecule is the smallest particle of a pure substance (element or compound) which has independent existence. It exhibits all the properties of that pure substance" or a molecule is a group of two or more atoms that are chemically bonded together by attractive forces.

Molecules are of *two* types :

1. Molecules of an element.
2. Molecules of a compound.

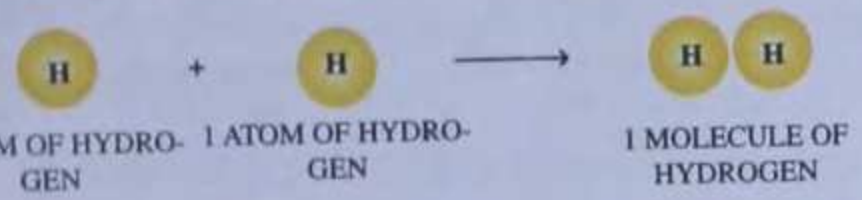
1.6.1 Molecules of an element

Two or more atoms of the same element combine to form a molecule of an element. The

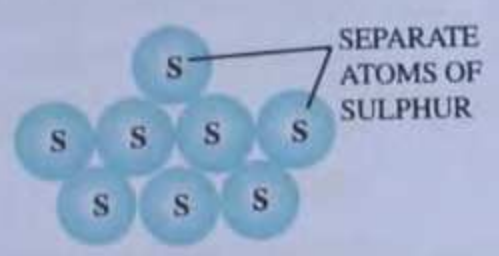
atoms of certain elements, like oxygen, nitrogen, chlorine, *etc.*, cannot exist independently. So they join to form molecules that have independent existence. To form molecules, atoms always join in whole numbers.

Examples :

1. Two atoms of hydrogen join to form one molecule of the element hydrogen.



2. Eight atoms of sulphur join to form a molecule of sulphur.



1.6.2 Atomicity

The number of atoms of an element that join together to form a molecule of that element is known as the *atomicity* of that molecule. Depending upon the atomicity, the molecules of elements can be divided into :

(a) monoatomic molecules
(b) diatomic molecules
(c) triatomic molecules
(d) polyatomic molecules.

Monoatomic molecules : They contain only one atom. Atoms of metals and metalloids do not combine with their own types of atoms. So, their atoms are regarded as their molecules too. Similarly, atoms of inert gases exist freely under all conditions. All these elements are said to have *monoatomic molecules.*

Examples : Na, Zn, Mg, *etc.*, noble gases : He, Ne, Ar, Xe, *etc.*

Diatomic molecules of an element contains two atoms of the same type.

Examples : H_2, O_2, N_2, Cl_2, *etc.*

Triatomic molecules contains three atoms.

Examples : Ozone O_3.

Polyatomic molecules contain more than three atoms.

Examples : Phosphorus (P_4), sulphur (S_8), *etc.*

1.6.3 Molecular formula of an element

The molecular formula of an element is the symbolic representation of its molecule. It indicates the number of atoms present in it.

Example : A molecule of chlorine is represented by 'Cl_2' which indicates that two atoms of chlorine join to form one molecule of chlorine. It also shows that the atomicity of chlorine is 2.

Table 1.5 : Names, symbols and state of the molecules of common elements

Name of element	*Symbol of molecules*	*Number of atoms in one molecule*	*State*
Hydrogen	H_2	2	Gas
Nitrogen	N_2	2	Gas
Oxygen	O_2	2	Gas
Fluorine	F_2	2	Gas
Chlorine	Cl_2	2	Gas
Bromine	Br_2	2	Liquid
Iodine	I_2	2	Solid
Ozone	O_3	3	Gas
Phosphorus	P_4	4	Solid
Sulphur	S_8	8	Solid

From the above it is clear that :

(i) 'H' represents one atom of hydrogen and 'H_2' represents one molecule of hydrogen.

(ii) '2H' represents two atoms of hydrogen and $2H_2$ represents two molecules of hydrogen.

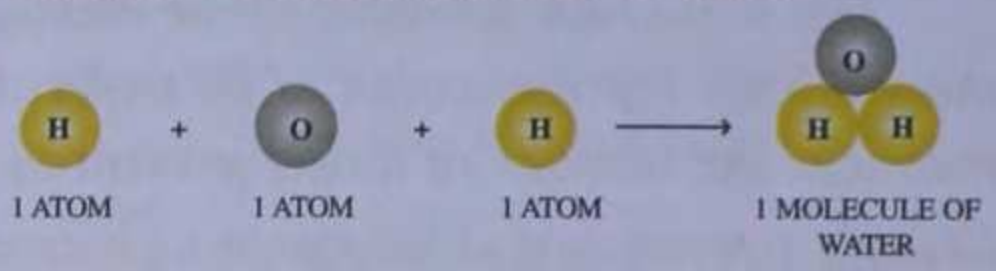
If a numeral is written on the left hand side of a symbol it represents the number of atoms or molecules.

1.7 MOLECULES OF COMPOUNDS

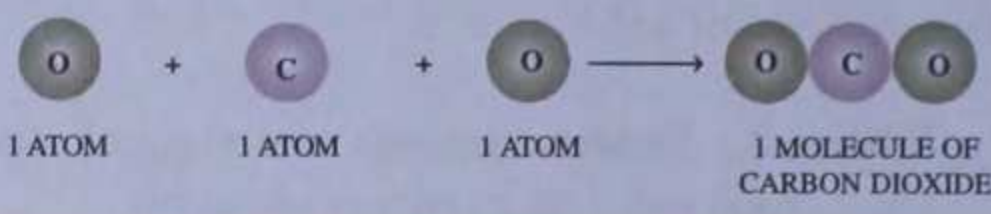
When atoms of two or more elements join together a molecule of a compound is formed.

Examples :

1. Two atoms of hydrogen and one atom of oxygen combine to form a molecule of water.



2. One atom of carbon combines with two atoms of oxygen to form a carbon dioxide molecule.



The smallest unit of a compound is its molecule. It exhibits all the properties of that compound. Every compound has its own specific molecules, which are same in all respects but differ in their properties from the atoms of which they are made.

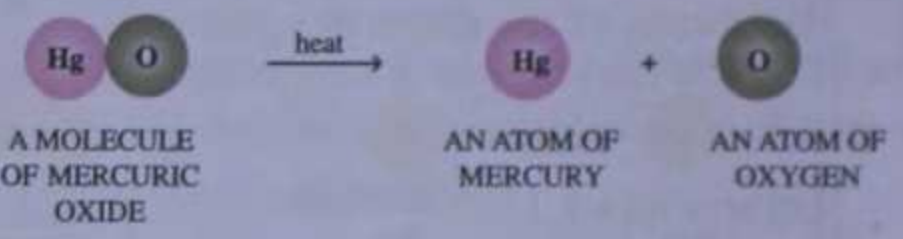
Accordingly, a water molecule is a liquid, but hydrogen and oxygen atoms are gaseous.

Similarly, carbon dioxide is a gaseous compound but carbon is a solid element.

A molecule of a compound can be broken into its constituent elements.

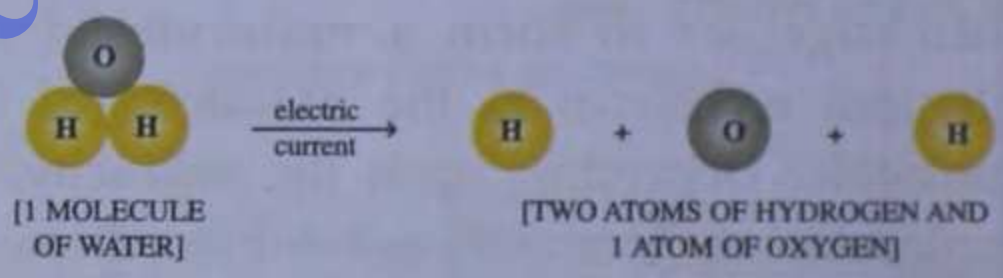
Examples :

1. Mercuric oxide is a solid compound. When it is heated, it decomposes to give mercury and oxygen, which are elements.



2. When electric current is passed through acidulated water it ionises to give hydrogen and oxygen gases in the ratio of 2 : 1 [by volume].

From whatever source water is taken and ionised, the ratio of gases hydrogen and oxygen is found to be the same.



Note : Molecules of different compounds show different properties. *E.g.* :- Water molecules and sugar molecules are different.

Of the 118 elements known to mankind, till now, millions of compounds are formed.

RECAPITULATION

- Pure substances are broadly classified into elements and compounds.
- Elements are made up of same kind of atoms.
- Compounds are made up of different kinds of atoms.
- Atoms are the smallest unit of elements.
- Molecules are the smallest unit of compounds.
- Symbols represent not only the elements but also their atoms.
- A formula represents the molecule of element or compound indicating the number of atoms present in them.

EXERCISE – II

1. Define :
   (a) Atom (b) Molecule
   (c) Atomicity
2. Give an example for each of the following and also give their formulae :
   (a) A diatomic molecule of an element
   (b) A polyatomic molecule of an element
   (c) A diatomic molecule of a gaseous compound.
   (d) A triatomic molecule of a liquid compound
   (e) A diatomic molecule of a solid compound.
3. Why is the molecular formula of sodium is Na, while that of oxygen is O_2 ?
4. What does each of the following represent.
   (a) 3O (b) H_2
   (c) 5Cl (d) $2Cl_2$
   (e) H_2O (f) H_2O_2
5. Which of the following substances fall in the category of a "pure substance" ?

   Ice, milk, iron, hydrochloric acid, calcium oxide, mercury, brick, wood, air.

OBJECTIVE TYPE QUESTIONS

1. Fill in the blanks :
   (a) ..... are malleable and ductile.
   (b) A non-metal which is a good conductor of heat and electricity is .....
   (c) ..... and ..... are pure substances.
   (d) A water molecule contains ..... and ..... elements.
   (e) 2H represents ..... of hydrogen.
   (f) ..... on heating gives two elements ..... and .....
   (g) The formation of a compound involves a change in .....
   (h) The smallest unit of a compound is .....
   (i) The atomicity of helium is .....
2. Give one words for the following :
   (a) Molecules consisting of two atoms of an element.
   (b) The smallest unit of an element.
   (c) The elements which do not react chemically.
   (d) The elements which resembles both metals and non-metals in their properties.
3. Write **true** or **false** for the following statements:
   (a) Molecule is the smallest particle of matter .....
   (b) Atoms of same element are all alike .....
   (c) 2O represents two molecules of oxygen .....
   (d) Both chalk and bones contain calcium .....
   (e) Compounds are made up of same kind of atoms. .....

MULTIPLE CHOICE QUESTIONS

1. The smallest particle of a compound showing all its properties is
   (a) an atom (b) an element
   (c) a molecule (d) none of these
2. A molecule of ozone has atomicity
   (a) one (b) two
   (c) three (d) four
3. A water molecule contains hydrogen and oxygen in the ratio (by volume)
   (a) 1 : 2 (b) 2 : 1
   (c) 2 : 2 (d) 1 : 1
4. A liquid non-metal is
   (a) Mercury (b) Germanium
   (c) Neon (d) Bromine

PROJECT

Select five articles made up of different metals and write five properties of each of them.