Students' Learning Outcomes

After completing this chapter, the students will be able to:

- Describe the structure of an atom.
- Differentiate between atomic and mass number.
- Draw diagrams of the atomic structure of the first eighteen elements in the periodic table.
- Define valency.
- Explain formation of ions.
- Differentiate between cations and anions.
- Describe isotopes and their uses in medicine and agriculture.
- Identify the types and number of elements present in simple molecules and compounds.
- Make chemical formulae from list of anions and cations.
- State the law of constant composition and give examples.

Everything is made up of different kinds of atoms.

We have learnt in class VI that **atom** is the smallest particle of matter that cannot exist independently. Everything in the universe is made up of atoms. Our body is also composed of several trillions of atoms. A Greek philosopher Democritus gave the idea of atom for the first time. Then, in 19th century John Dalton from England presented the first atomic model. According to him, all matter is composed of atoms. Atoms can neither be created nor destroyed.

6.1: Structure of an Atom

Is there any particle smaller than atom? Sure, there is. Atoms are made of even smaller particles called electrons, protons and neutrons. The central part of the atom is called the **nucleus**.Protons and neutrons are present in the nucleus.

Electrons revolve around the nucleus. An electron has negative charge. Its mass is extremely small.

A **proton** has positive charge. The number of protons in an atom is equal to the number of electrons revolving around the nucleus. It has a mass 1837 times greater than that of electron.

A **neutron** has no charge. This neutral particle is also found in the nucleus of an atom. The mass of a neutron is almost equal to the mass of a proton.

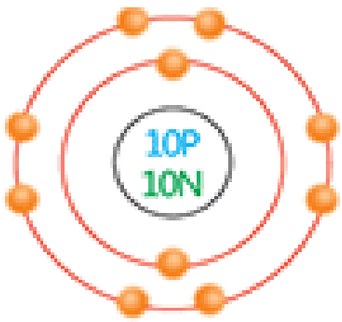


Fig 6.1: structure of neon atom

Extend Your Thinking

How protons, neutrons and electrons are alike and different?

Why is atom neutral?

Although electrons and protons in an atom have charges, but atom as a whole has no charge. In an atom, the number of protons is equal to the number of electrons. As a result, the total positive charge of protons balances the total negative charge of electrons. Because of it, the atom is neutral.

6.2: Atomic and Mass Numbers

Atomic Number (Z)

The number of protons present in the nucleus of an atom is called the **atomic number.** It is represented by Z.

The hydrogen atom has one proton in its nucleus; its atomic number is 1. Carbon atom has six protons in the nucleus; its atomic number is 6. An oxygen atom has 8 protons in the nucleus. What will be the atomic number of oxygen?

Each element has its own atomic number. We can identify an element by its atomic number.

Mass Number (A)

The sum of protons and neutrons in the nucleus of an atom is called its **mass number**. It is represented by A. The hydrogen atom has only one proton in its nucleus, its mass number is also 1. Carbon has 6 protons and 6 neutrons. Its mass number is 12. We can use atomic numbers and mass numbers to find the number of neutrons in atoms.

Mass number (A) = Number of protons (Z) + Number of neutrons (N)

General symbolic representation of an element is thus given as:

$^{A}_{Z}X$ Where **X** denotes any element.

Example: Oxygen atom has atomic number 8 and mass number 16. What would be the number of neutrons in its nucleus?

Extend Your Thinking

Tungsten is an element with 74 protons and 109 neutrons. What is tungsten's atomic number? How many electrons does tungsten have?

Activity 6.1

Calculate the number of protons, electrons and neutrons in a sodium atom ($^{35}_{17}Na$).

6.3: Distribution of Electrons in Shells

We know that electrons revolve around the nucleus of an atom. The paths of movement of electrons around the nucleus are called shells. Electrons are distributed in different shells. Shells are also called as energy levels. These shells are labeled as K, L, M, N, O, P, Q, etc. K is the first shell. We can calculate the number of electrons in a shell using the formula:

Number of electrons in a shell = $2n^2$ ('n' is the number of shell)

Shell number	Maximum number of electrons
Shell number 1 or K-shell	$2n^2 = 2(1)^2 = 2$
Shell number 2 or L-shell	$2n^2 = 2(2)^2 = 8$
Shell number 3 or M-shell	$2n^2 = 2(3)^2 = 18$

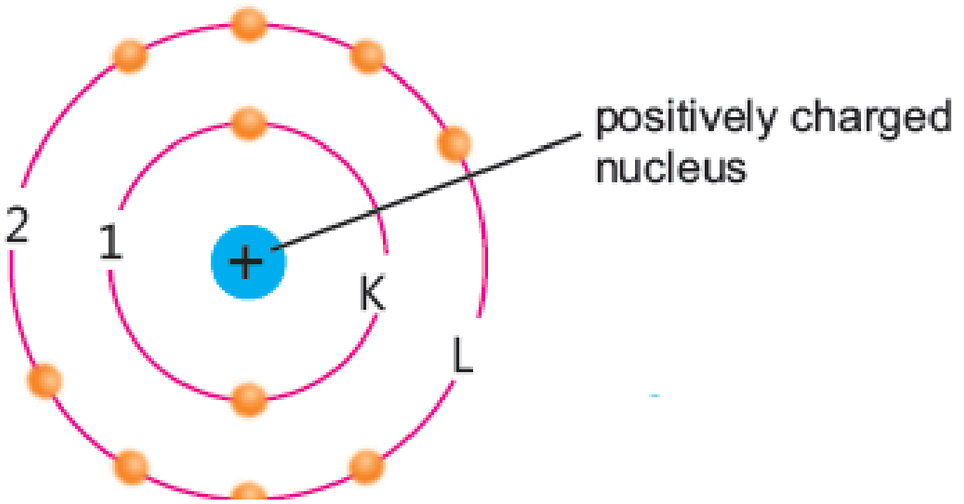
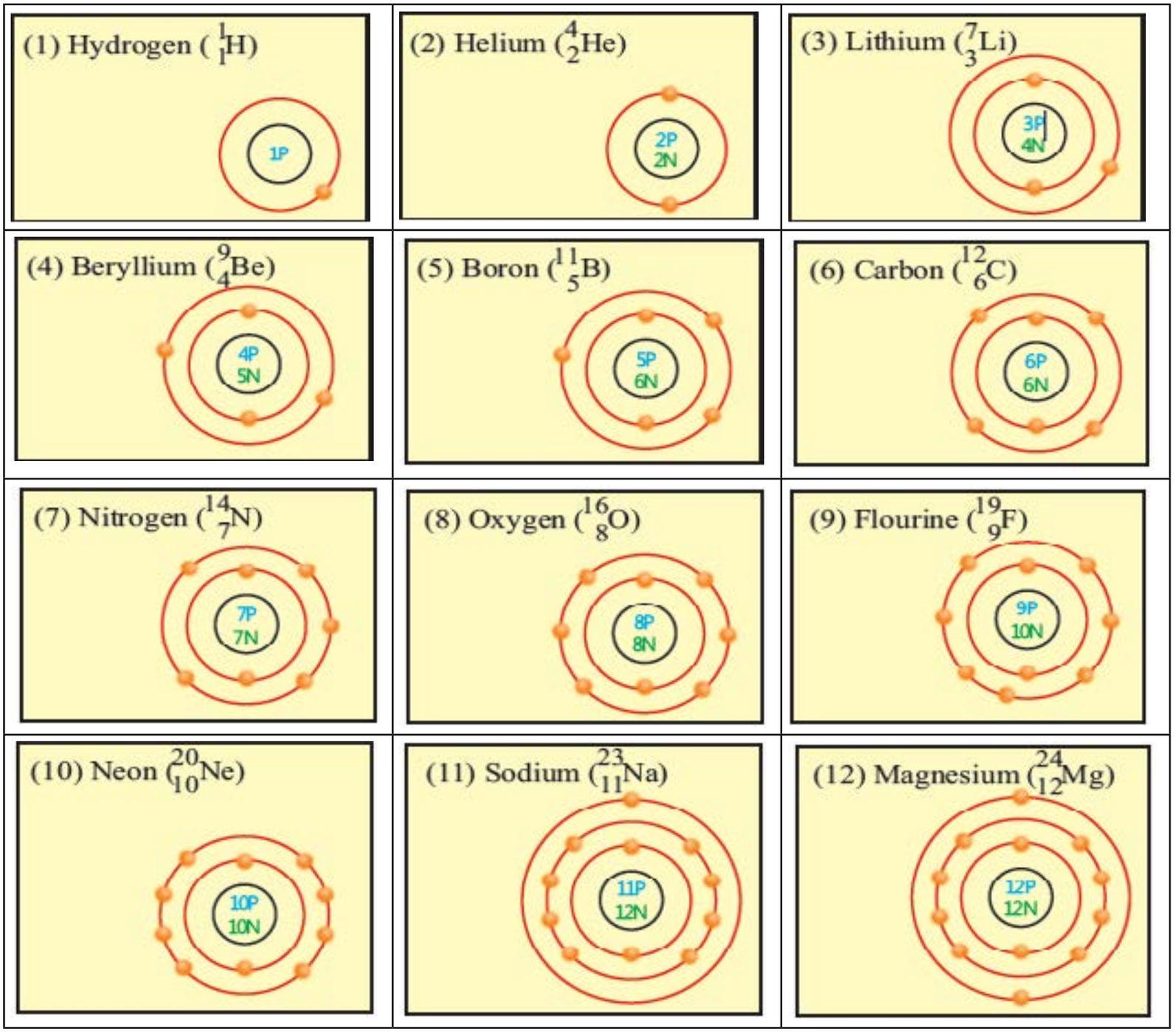
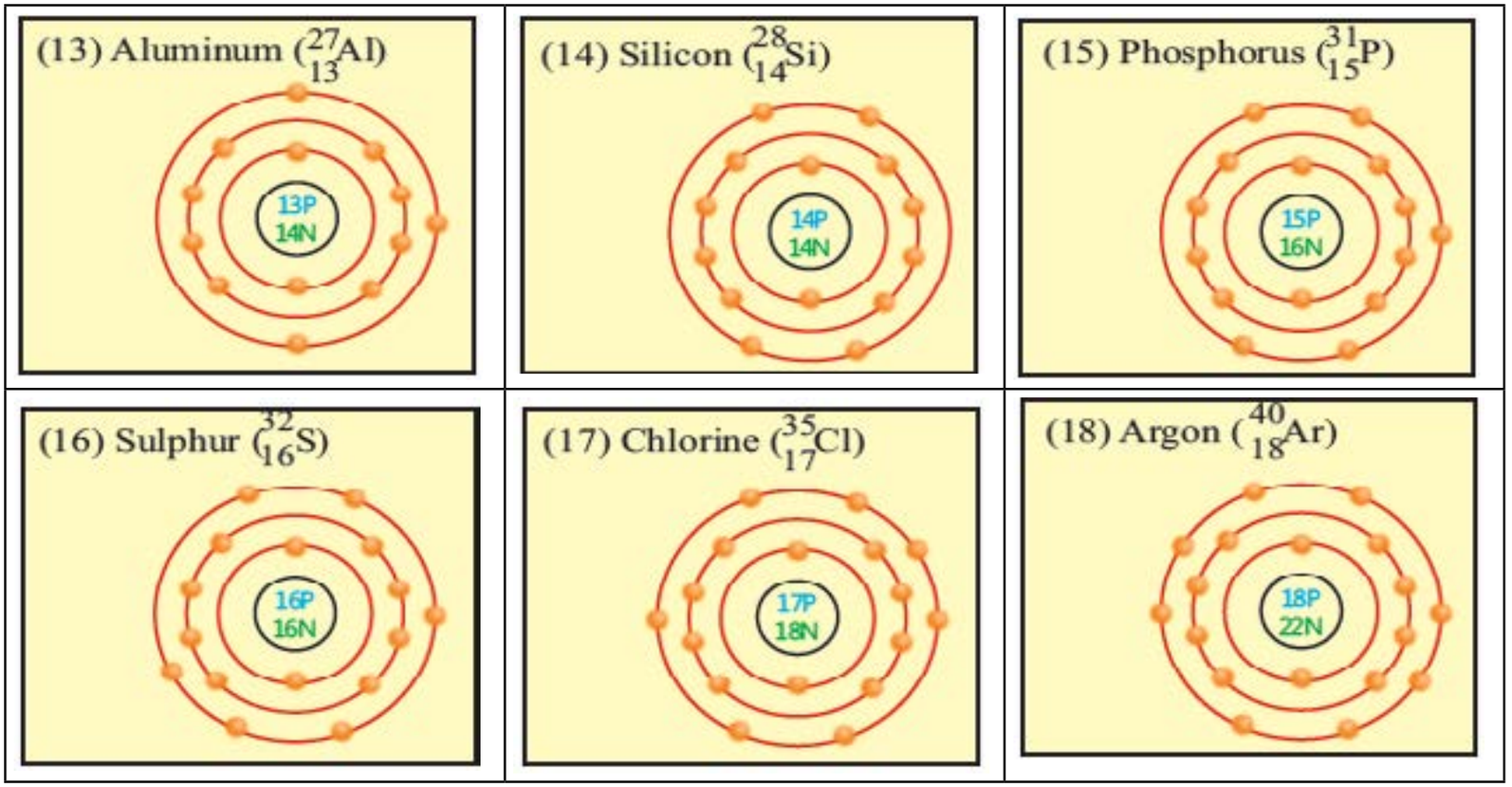


Fig. 6.2: Shells in an atom

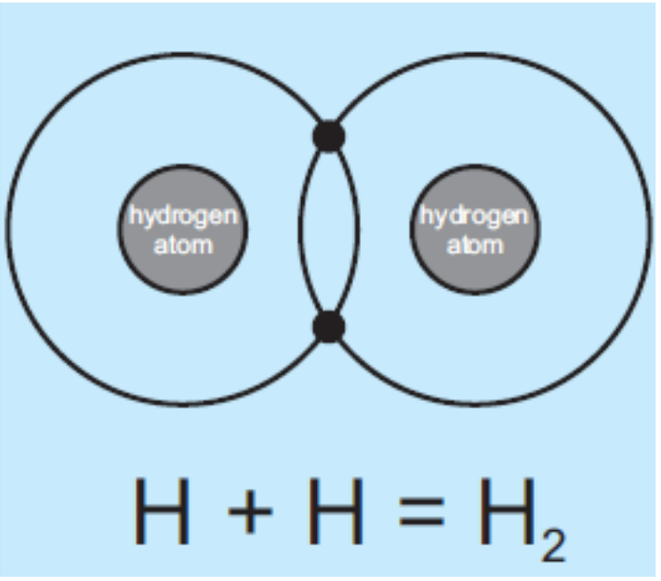
ATOMIC STRUCTURE OF THE FIRST EIGHTEEN ELEMENTS





Why do atoms combine?

Atoms combine with other atoms but they stop reacting with other atoms (become stable) when their outermost shell is complete having 8 electrons, or they have only one shell (K-shell) with 2 electrons. For this purpose an atom can lose, gain or share its electrons with other atoms. Two hydrogen atoms combine to form a hydrogen molecule (H_2) by sharing electrons.



6.4: Valency and Ions

Valency

Valency is the capacity of an atom to combine with the other atom. Valency can also be defined as follows. "The number of electrons that an atom wants to lose, gain or share is called its valency." For example, sodium atom (Na) loses one electron. It's valency is '1'. Fluorine atom (F) gains one electron. Its valency is '1'. Hydrogen (H) shares one electron. Its valency is also '1'. Copper, magnesium, oxygen, etc. have valency number '2'. The valency of aluminium and nitrogen is '3'. The valency of carbon atom is '4'.

Ion

An atom with positive or negative charge is called an **ion**. For example, sodium ion (Na^{+}), chloride ion (Cl^{-}), oxide ion O^{2-}, copper ion (Cu^{2+}), etc. When an atom releases its one or more electrons from the outermost shell, the number of protons more than that of electrons. It becomes a positive ion or **cation.** When an atom absorbs one or more electrons in its outermost shell, the number of electrons increases. It becomes a negative ion or **anion**. Positive ions and negative ions attract each other to form compounds. See the table 6.1.

Table 6.1: Some Common Ions

H^{1+}	Hydrogen	F^{1-}	Fluoride
Na^{1+}	Sodium	Cl^{1-}	Chloride
Ag^{1+}	Silver	O^{2-}	Oxide
Mg^{2+}	Magnesium	S^{2-}	Sulfide
Al^{3+}	Aluminum	P^{3-}	Phosphide

Extend Your Thinking

When a glass rod is rubbed with silk, the rod becomes positively charged. What type of particle in the atoms in the rod has been removed?

How is sodium chloride (NaCl) formed?

1 One electron transfers from sodium atom to chlorine atom. Sodium atom has 1 electron in its outermost shell. Chlorine atom has 7 electrons in its outermost shell.

2 After losing one electron, sodium atom becomes sodium ion (Na^+). The chlorine atom gains one electron to become chloride ion (Cl^-).

3 Negative and positive ions attract each other to form sodium chloride (NaCl).

Sodium chloride (table salt)

Activity 6.2

The valency of each element shows the number of electrons that the atom releases or gains. Find the number of electrons released or gained for each element.

Elements	Valency	Number of electrons released	Number of electrons gained
Potassium	1+		
Oxygen	2-		
Calcium	2+		
Chlorine	1-		

6.5: Isotopes and their Uses

All atoms of an element always have the same number of protons. However, the number of neutrons may be different in some of these atoms. It means some atoms of the same element may have different mass number than the others. The atoms of the same element having same atomic number but different mass numbers are called isotopes.

Hydrogen (H) has three isotopes. An atom of hydrogen may have zero, one or two neutrons in its nucleus. Protium ($^{1}_{1}H$), Deuterium($^{2}_{1}H$) and Tritium($^{3}_{1}H$) are three isotopes of hydrogen.

Carbon (C) has three isotopes, i.e.

$^{12}_{6}C$ $^{13}_{6}C$ $^{14}_{6}C$

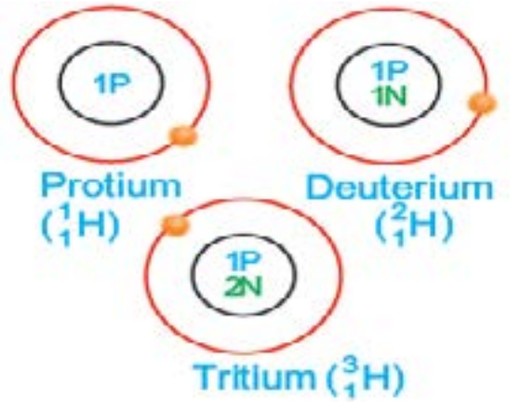


Fig. 6.3: Hydrogen has three naturally occurring isotopes.

Isotopes are of great importance in the fields of medicine and agriculture.

1. **Carbon–14** is used to calculate the age of plants.
2. **Nitrogen–15** is used to study the effects of nitrogenous fertilizers in plants.
3. **Sodium–24** is used to study circulation of blood.
4. **Phosphorus–32** is used in treatment of blood cancer and bone diseases.
5. **Chromium–51** is used to study red blood cells in patients with blood deficiency.
6. **Iron-59** is used to study absorption of iron in human body.
7. **Cobalt–60** is used in cancer treatment.
8. **Iodine–131** is used to treat a disease called goiter.

6.6: Molecules and Chemical Formulae

6.6.1: Molecule

A **molecule** is the smallest particle of an element or a compound that can exist independently and shows all the properties of that element or compound. It may be a monoatomic molecule such as helium (He), neon (Ne), etc. Two or more atoms can also be present in a molecule. For example, water (H_2O), hydrogen gas (H_2), glucose ($C_6H_{12}O_6$), etc.

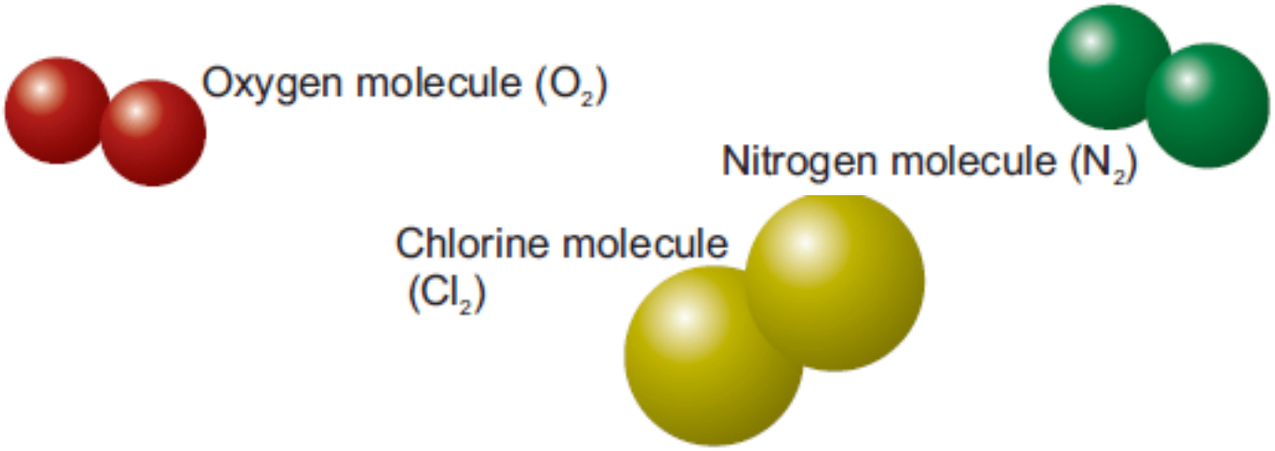


Fig. 6.4: Atoms of the same kind combine to make a molecule of that element.

Animation: 6.2 Molecules
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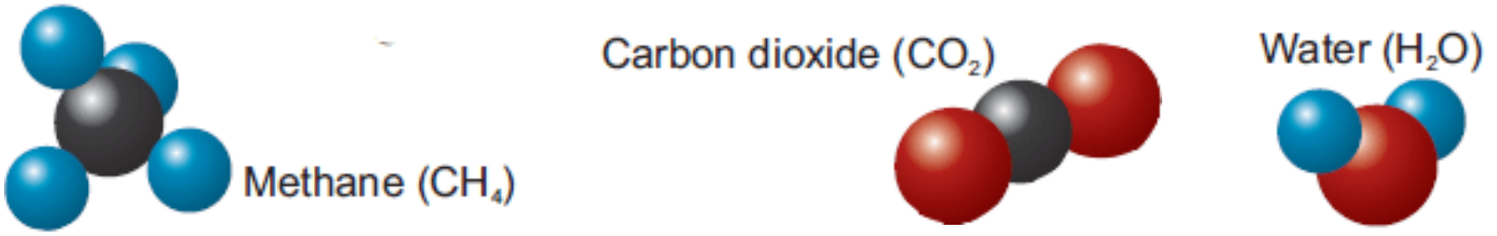


Fig. 6.5: Atoms of different kinds combine to make a molecule of a compound.

Activity 6.3

Write the number and types of atoms present in each of the following:

(a) Carbon tetrachloride (CCl_4)
(b) Sodium hydroxide (NaOH)
(c) Calcium carbonate ($CaCO_3$)
(d) Ammonia (NH_3)

6.6.2: Chemical Formula

Describing a molecule in the form of symbols and valencies is called the **chemical formula.** The chemical formula of a molecule shows:

1. kinds of elements in the molecule
2. number of atoms of each element

For example, H_2 represents a molecule of hydrogen gas. It contains two hydrogen atoms. Similarly, CO_2 is the formula of carbon dioxide gas which shows that two atoms of oxygen combine with one carbon atom.

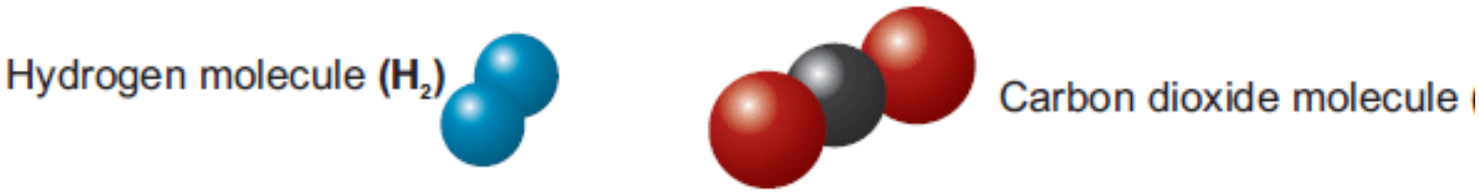


Fig. 6.6: H_2 is the chemical formula of hydrogen molecule and CO_2 is that of carbon dioxide.

Writing a Chemical Formula

The chemical formula of a molecule of an element is denoted by the symbol of that element with a subscript .The subscript tells the number of atoms present in the molecule.

Fig:6.7: Nitrogen molecule (two atoms of nitrogen)

Fig:6.8: Ozone molecule (three atoms of oxygen)

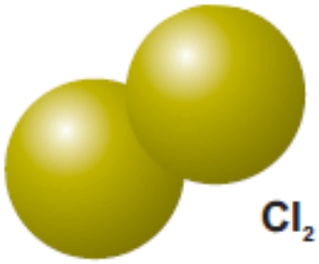


Fig:6.9:Chlorine molecule (two atoms of chlorine)

The chemical formula of a molecule of a compound is denoted by the symbols of all elements present in that molecule. A subscript is given, when two or more atoms of an elements are present. When no subscript is given, the number of atom is assumed as 'I' .

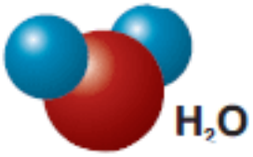


Fig:6.10: Water molecule (One oxygen atom combines with two hydrogen atoms.)

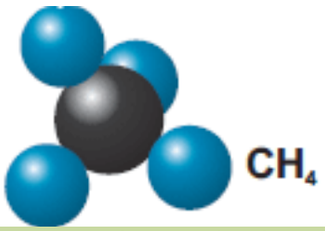


Fig:6.11: Methane molecule (One carbon atom combines with four hydrogen atoms.)

How to pronounce a formula?

You can pronounce a chemical formula as follows:

H_2O (water) is pronounced as: H two O

$C_{12}H_{22}O_{11}$ (sugar) is pronounced as: C twelve H twenty two O eleven.

6.6.3 MAKING CHEMCAL FORMULA OF IONIC COMPOUNDS

When a positive ion (cation) attracts a negative ion (anion), **an ionic compound** is formed. Sodiam chloride (NaCl), magnesium chloride ($MgCl_2$) are examples of ionic compounds. To write the formula of an ionic compound, follow these steps:

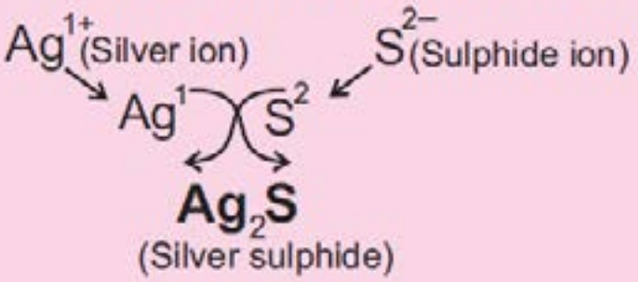
Step-1: Write the symbol of positive ion(cation) on the left and symbol of negative ion(anion) on the right. You may use table 6.1.

Step-2: Put the valency number of each ion with its charge on its top right side.

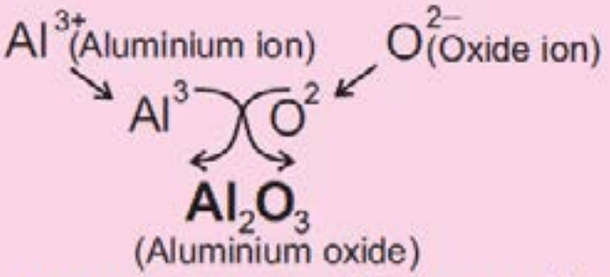
Step-3: Interchange the valency numbers of both ions and write them on lower right side of each ion. Omit the +ve and –ve signs which cancel each other. Remember that number '1' is also omitted. This method of writing chemical formulae is called **crisscross method.**

Examples

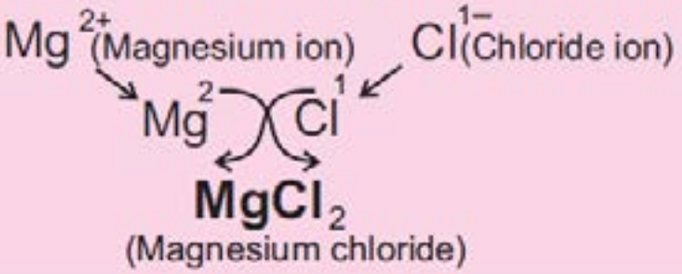
1. Write the formula for a compound of silver and sulphur ions, i.e. silver sulphide.



2. Write the formula for the compound composed of aluminium and oxygen ions.



3. Write the formula for the compound composed of magnesium and chlorine ions.



Activity 6.4

Make chemical formulae for the following ionic compounds:

Sodium chloride Magnesium iodide	Potassium bromide Calcium chloride	Aluminium chloride Copper oxide

6.7: Law of Constant Composition

Composition refers to the type and number of atoms present in a substance. In the late1700, a French scientist Joseph Proust studied the chemical compounds and presented The Law of Constant Composition. The law states that **the composition of a compound is always the same regardless of how the compound was made or obtained.**

Fig. 6.12: Joseph Proust (1754-1826) was a French chemist. In 1794, he presented "The Law of Constant Composition".

1. Water can be obtained from many sources (river, well, sea, etc.), but its composition is always the same. There are 2 atoms of hydrogen and 1 atom of oxygen present in a molecule of water (H_2O).

Water (H_2O)

2. Carbon dioxide (CO_2) is produced in a number of ways, but its one molecule always consists of one carbon atom and two oxygen atoms.

Science, Technology and Society

An isotope is one of two or more atoms having the same atomic number but different mass numbers. Some isotopes release radiation all the time. These isotopes are called radioisotopes. Radioisotopes can be used for human welfare. Food irradiation is a method to make food safer for a long time. The radiation from a radioisotope kills microorganisms (bacteria, etc.) present in the food. Find some more uses of radioisotopes.

Key Points

- An atom is made of smaller particles called electrons, protons and neutrons.
- Atomic number is the number of protons in an atom, while mass number is the sum of protons and neutrons in the nucleus of an atom.
- Electrons of an atom revolve around the nucleus in specific orbits or shells.
- Valency is the capacity of an atom to combine with the other atom.
- An ion is the atom with positive or negative charge.
- When an atom releases its one or more electrons, it becomes a positive ion (cation).
- When an atom absorbs electrons in its outermost shell, it becomes a negative ion (anion).
- Isotopes are the atoms of the same element, having same atomic number, but different mass numbers. Isotopes are used in medicines and industries.
- A chemical formula is the description of a molecule in the form of symbols and valencies.
- The Law of Constant Composition states that the composition of a compound is always the same, regardless of how the compound was made or obtained.

Questions

1. Complete each of the following sentences by writing the correct term.

- Two or more atoms of the same element with a different number of neutrons
- The atomic particle with no charge
- It is the number of protons in an atom
- An atom with positive or negative charge
- A molecule having one atom in it

3. Give short answers.

i. What does give the positive charge to the nucleus of an atom?
ii. Define a cation and an anion?
iii. What is chemical formula?
iv. List the names, charges and locations of three kinds of particles that make up an atom.
v. How are the isotopes of an element alike and how are they different?
vi. A chlorine atom has 17 protons and 18 neutrons. What is its mass number?
What is its atomic number?
vii. Why the electrical charge on an atom is zero, or neutral?