Revision Notes on Atoms and Molecules

The invisible and unknown form of matter

The idea of divisibility by Indian philosophers

Maharishi Kanad – He postulated that if we keep on dividing the matter (called as 'padarth') we will get smaller and smaller particles. And soon we will achieve the smallest of particles (called as 'parmanu') which may not divide further.

Pakudha Katyayama – He postulated that there are various forms of matter because the particles of matter exist together in combinations.

The idea of divisibility by Greek philosophers

Democritus and Leucippus – They suggested that when we keep on dividing the matter there comes a time when no more division of particles can take place. Such particles are called atoms which means being invisible.

But all these ideas were not backed up by many experimental pieces of evidence until Antoine L. Lavoisier provided two laws of chemical combination.

Laws of Chemical Combination

1. Law of conservation of mass – mass can neither be created nor destroyed in a chemical reaction

2. Law of constant proportion/Law of definite proportion – the elements are always present in definite proportions by mass in a chemical substance

For example, Hydrogen and oxygen are present in water in a ratio of 1:8. So if we decompose 9g of water we will obtain 1g of hydrogen and 8g of oxygen.

The Atomic Theory

John Dalton proposed an atomic theory which acted as an explanation of the above two laws. As per the theory, all matter whether it is an element, a compound or a mixture consists of tiny invisible particles called 'atoms'.

The postulates of the atomic theory by John Dalton

1. The matter is made up of tiny particles called atoms that cannot be divided.

2. Atoms are never formed or destroyed during a chemical reaction.

3. Atoms of an element exhibit same nature. They have the same size, mass, and character.

4. Atoms of different elements exhibit variant nature. They do not have same characteristics.

5. Atoms form compounds by combining in a ratio of whole numbers.

6. A compound contains a constant number and kinds of atoms

Atoms

We can call atoms as the building blocks of matter. Just like bricks are the building blocks of a building.

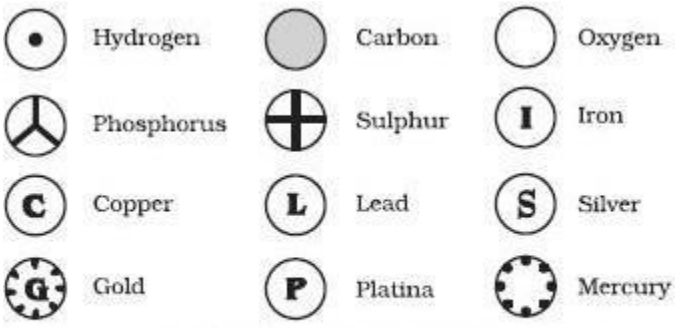
What is the size of an atom?

Atoms are extremely small. Their size is measured in nanometers where 1nm = 1/109 m.

Atomic radius is measured in nanometers **1/109 = 1nm** **1m = 109 nm**	
Relative Sizes	
Radii (in m)	**Example**
10^{-10}	Atom of hydrogen
10^{-9}	Molecule of water
10^{-8}	Molecule of haemoglobin
10^{-4}	Grain of Sand
10^{-2}	Ant
10^{-1}	Watermelon

Symbols for Atoms

Here are some examples of the symbols that are used to represent different atoms



Symbols for some elements as proposed by Dalton

The symbols for representing an atom are generated from the first two letters of the element's name. The first letter is always in uppercase (capital letter) while the second letter is written in lowercase. Here are some examples –

Element	Symbol	Element	Symbol	Element	Symbol
Aluminium	Al	Copper	Cu	Nitrogen	N
Argon	Ar	Fluorine	F	Oxygen	O
Barium	Ba	Gold	Au	Potassium	K
Boron	B	Hydrogen	H	Silicon	Si
Bromine	Br	Iodine	I	Silver	Ag
Calcium	Ca	Iron	Fe	Sodium	Na
Carbon	C	Lead	Pb	Sulphur	S
Chlorine	Cl	Magnesium	Mg	Uranium	U
Cobalt	Co	Neon	Ne	Zinc	Zn

The Atomic Mass

The Dalton's Atomic Theory suggested that each element has a distinguishing atomic mass. With this theory, the law of constant proportions could be explained easily.

But it is indeed difficult to evaluate the mass of an atom since the size of an atom is relatively small.

Therefore scientists started evaluating the mass of an atom by comparing it with the mass of a standard atom.

Earlier 1/16 of the mass of an oxygen atom was used as a standard for calculating the mass of other elements. Now, carbon - 12 is considered a standard atom for calculating the mass.

Its atomic mass is 12u (12 atomic mass units). Thus we can say that one atomic mass unit is the mass of 1/12 the mass of a carbon-12 atom. Here is a list of atomic masses of a few elements.

Element	Atomic Mass
Hydrogen	1 µ
Carbon	12 µ
Nitrogen	14 µ
Oxygen	16 µ
Sodium	23 µ
Magnesium	24 µ
Sulphur	32 µ
Chlorine	35.5 µ
Calcium	40 µ

Can atoms exist independently?

Atoms cannot survive independently. So, atoms join together and form molecules or ions.

Molecule

- A molecule is a collection of various atoms that combine chemically with each other.
- These atoms are bound together by certain forces of attraction.
- Atoms of the same elements or different elements can bind together to form molecules.
- Therefore, a molecule is the smallest particle of a substance that can exist independently and shows all the properties of that substance.

Molecules of Elements

- The molecules of an element are formed by combinations of similar types of atoms. For example, Helium (He) is made up of only one atom while oxygen is made up of two atoms.
- **Atomicity** – the number of atoms in a molecule of an element is called its atomicity. For example, helium is monoatomic and oxygen is diatomic.
- **Monoatomic** – when an element comprises of a single atom. Example – all metals
- **Diatomic** – when an element comprises of two atoms. Example – all gases
- **Triatomic** – when an element comprises of three atoms
- **Tetra-atomic** – when an element comprises of four atoms
- **Poly-atomic** – when an element comprises of more than two atoms

Here a few examples of atomicity of elements –

Atomicity of some Elements		
Name	**Atomicity**	**Formula**
Argon	Monoatomic	Ar
Helium	Monoatomic	He
Oxygen	Diatomic	O_2
Hydrogen	Diatomic	H_2
Nitrogen	Diatomic	N_2
Chlorine	Diatomic	Cl_2
Phosphorous	Tetra – atomic	P_4
Sulphur	Poly – atomic	S_8

Molecules of Compounds

Molecules of compounds constitute atoms of different elements that combine together in a fixed proportion. For example, water comprises of two atoms of hydrogen and one atom of oxygen.

Molecules of some compounds :-

Compound	Combining elements	Number of atoms of each elements
Water – H_2O	Hydrogen, Oxygen	2 - Hydrogen, 1 - Oxygen
Ammonia – NH_3	Nitrogen, Hydrogen	1 - Nitrogen, 3 - Hydrogen
Carbon dioxide CO_2	Carbon, Oxygen	I - Carbon, 2 - Oxygen
Hydrochloric acid HCl	Hydrogen, Chlorine	1 - Hydrogen, 1 - Chlorine
Nitric acid HNO_3	Hydrogen, Nitrogen, Oxygen	1 - Hydrogen, 1 - Nitrogen, 3 - Oxygen
Sulphuric acid H_2SO_4	Hydrogen, Sulphur, Oxygen	2 - Hydrogen, 1 - Sulphur, 4 - Oxygen

Ions

- Compounds contain metals as well as non-metals. These elements include charged species which are known as ions.
- Thus, ion is a particle that has a positive or negative charge.
- **Anion** – negatively charged ion
- **Cation** – positively charged ion
- There can be a single charged atom in an ion or there may be a group of charged atoms in an ion that have a net charge on the compound.
- When a group of atoms carries a charge in a compound it is called as a **polyatomic ion.**

Chemical Formula

We use a chemical formula to represent the composition of a compound in the form of symbols. To write a chemical formula you must know two things –

1. Symbols of elements

2. Valency

Valency – it is also known as the combining capacity of an element. In other words, valency explains how atoms of one element will mix with atoms of another element. For example, the hydrogen ion is represented as H+ which means that its valency is 1. Similarly, the oxygen ion is represented as O2- which means that its valency is 2. Here is a list of valancies of various elements.

Name of the Element	Symbol	Valency	Ion.
Hydrogen	H	1	H^+
Helium	He	0	–
Lithium	Li	1	Li^+
Beryllium	Be	2	Be^{2+}
Boron	B	3	B^{3+}
Carbon	C	4 (Shares electrons)	–
Nitrogen	N	3	N^{3-}
Oxygen	O	2	O^{2-}
Fluorine	F	1	F^-
Neon	Ne	0	–
Sodium	Na	1	Na^+
Magnesium	Mg	2	Mg^{2+}
Aluminium	Al	3	Al^{3+}

Rules of writing a Chemical Formula

- Valencies of on the ions must balance.
- In a case where both metal and non-metal substances are present in a compound, the name of the metal is always written first in the chemical formula. For example, Sodium Chloride is written as NaCl
- In case of polyatomic ions, the ion is written in brackets before writing the number of ions associated to it. In case of a single ion, there is no need to mention the ion in brackets

Writing the Formulae of Simple Compounds

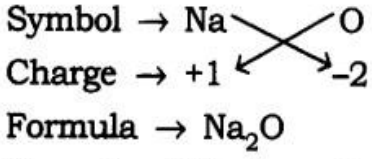
Binary compounds – compounds that consist of two different elements

How to write a Formula of a Compound

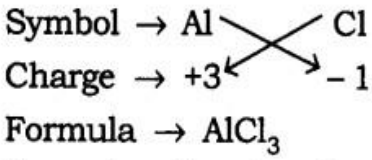
- Write the symbols of the corresponding elements of the compound as explained above
- Write the valencies of the elements of the compound
- Crossover the valencies of the elements

Here are a few examples of writing the chemical formula

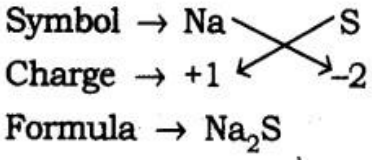
(i) Formula of Sodium Oxide



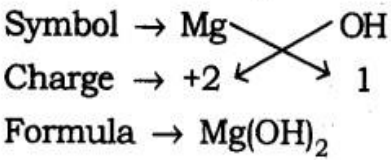
(ii) Formula of aluminium chloride



(iii) Formula of Sodium Oxide



(iv) Formula of magnesium hydroxide



Molecular Mass and the Mole Concept

Molecular Mass – summation of all the atomic masses in a molecule

Molecular mass is expressed in atomic mass units (amu).

For example, the molecular mass of HNO3 can be calculated as:

Atomic mass of H =1u

Atomic mass of N =14u

Atomic mass of O =16u

Molecular mass of HNO3 = 1 + 14 + (16*3) = 63u

Formula Unit Mass

The sum of atomic masses of all atoms in a formula unit of a compound is called as its formula unit mass. The formula unit mass is used in case of substances that constitute ions. For example, formula unit mass of Sodium Chloride (NaCl) can be calculated as: (1*23) + (1*35.5) = 58.5u

Formula unit mass of ZnO

= 1 × atomic mass of Zn + 1 × atomic mass of O

= 1 × 65 u + 1 × 16 u = **81 u**

Formula unit mass of Na_2O

= 2 × atomic mass of Na + 1 × atomic mass of O

= 2 × 23 u + 1 × 16 u = **62 u**

Formula unit mass of K_2CO_3

= 2 × atomic mass of K + 1 × atomic mass of C + 3 × atomic mass of O

= 2 × 39 u + 1 × 12 u + 3 × 16 u

= 78 u + 12 u + 48 u = **138 u**