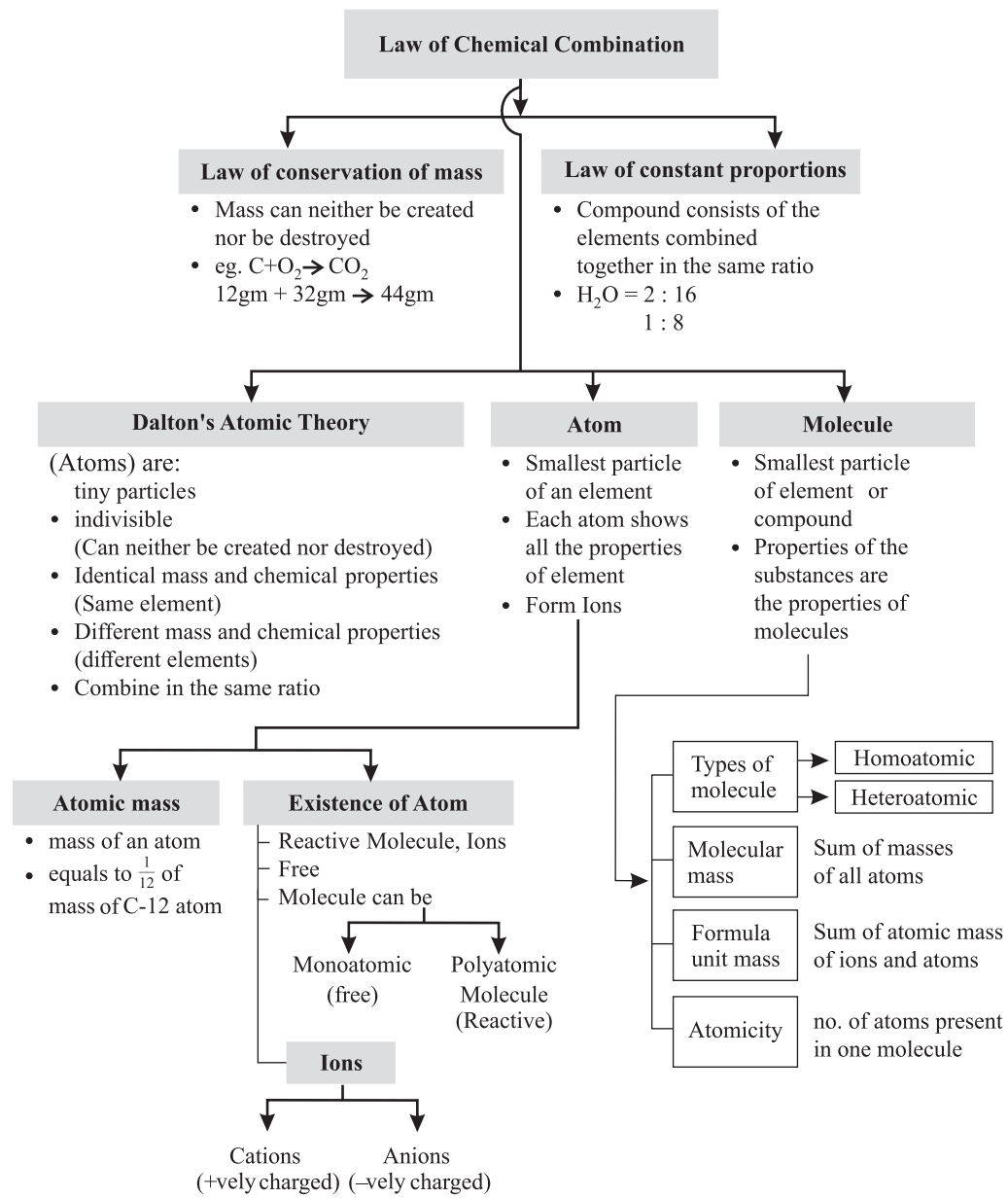


Chapter - 3

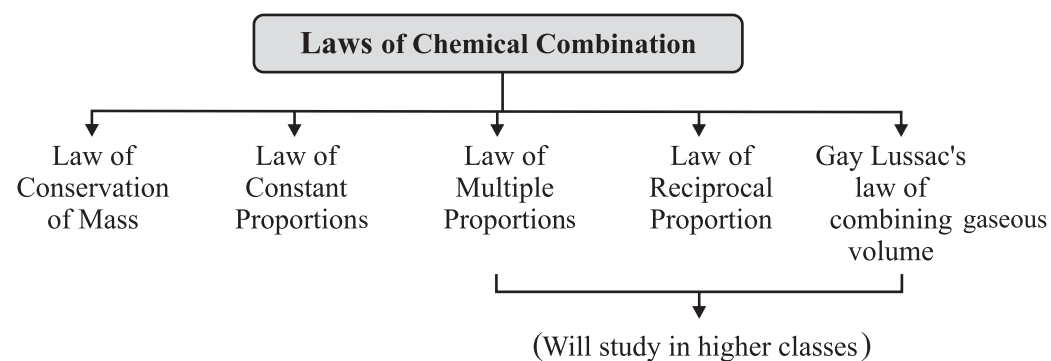
Atoms And Molecules

CONCEPT MAPPING



Laws of Chemical Combination :

The chemical reaction between two or more substances giving rise to products is governed by certain laws. These laws are called 'Laws of Chemical Combination'.



Law of Conservation of Mass

According to this law, "Mass can neither be created nor destroyed."

In a chemical reaction, this law can be understood in the following way:

"During a chemical reaction total mass of reactants will be equal to total mass of products."

For example,



Reactant Product

Then,

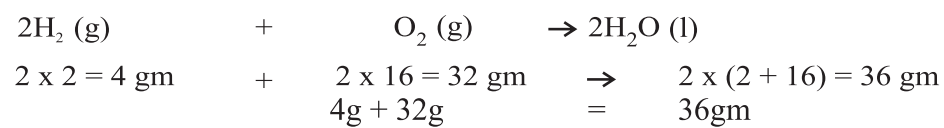
$$m_A + m_B = m_{AB}$$

where,

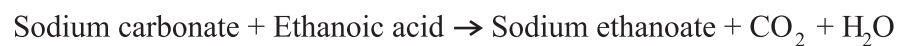
$$m_A = \text{Mass of A}$$

$$m_B = \text{Mass of B}$$

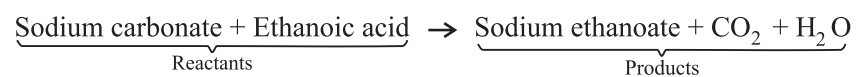
$$m_{AB} = \text{Mass of AB}$$



Example : In a reaction 5.3 gm of sodium carbonate reacted with 6 gm of ethanoic acid. The products were 2.2 gm of CO_2 , 0.9 gm of H_2O and 8.2 gm of sodium ethanoate. Show that these observations are all in agreement with law of conservation of mass.



Solution :



Now, according to the law of conservation of mass :

Mass of sodium carbonate + Mass of ethanoic acid = Mass of sodium ethanoate + Mass of CO₂ + Mass of H₂O

Putting values of masses from the equation :

$$5.3 \text{ gm} + 6.0 \text{ gm} = 8.2 \text{ gm} + 2.2 \text{ gm} + 0.9 \text{ gm}$$

Or $11.3 \text{ gm} = 11.3 \text{ gm}$

Since, LHS = RHS

Law of conservation of mass is in agreement with the given values in equation.

Law of Constant Proportions

According to this law, "A pure chemical compound always contains the same elements combined together in the same proportion by mass irrespective of the fact from where the sample has been taken or from which procedure has it been produced."

For example :

- 18 gm of H₂O ⇒ 16 gm of oxygen + 2 gm of hydrogen,
i.e., $m_{\text{H}}/m_{\text{O}} = 2/16 = 1/8$
- 36 gm of H₂O ⇒ 32 gm of oxygen + 4 gm of hydrogen,
i.e., $m_{\text{H}}/m_{\text{O}} = 4/32 = 1/8$
- 9 gm of H₂O ⇒ 8 gm of oxygen + 1 gm of hydrogen,
i.e., $m_{\text{H}}/m_{\text{O}} = 1/8$

From the above three cases, differently weighing H, O samples were taken but the ratio of mass of 'H' to mass of 'O' comes out to be '1/8' is same, proving law of constant proportion.

Likewise, if a sample of 'H₂O' was taken from anywhere *i.e.*, from well, pond, lake or anywhere the ratio of masses of 'H' to 'O' will come out to be same as '1/8'.

Example : Hydrogen and oxygen combine in the ratio 1 : 8 by mass to form water. What mass of oxygen gas would be required to react completely with 3.0 gm of hydrogen gas ?

Solution : $\frac{m_H}{m_O} = \frac{1}{8}$ (Given in equation For H₂O)

But, $m_H = 3.0 \text{ gm}$ (given)

Or $\frac{3}{m_O} = \frac{1}{8}$

Or $m_O = 24 \text{ gm}$

∴ Mass of oxygen will be 24 gm.

Or it will be a sample of 27 gm of H₂O where 3 gm of hydrogen is present with 24 gm of oxygen.

Dalton's Atomic Theory

Based upon laws of chemical combination, Dalton's Atomic Theory provided an explanation for the Law of Conservation of Mass and Law of Constant Composition.

Postulates of Dalton's atomic theory are as follows :

- All matter is made up of very tiny particles called 'Atoms' .
- Atom are indivisible particles, which can't be created or destroyed in a chemical reaction. (Proves 'Law of Conservation of Mass')
- Atoms of an element have identical mass and chemical properties.
- Atoms of different elements have different mass and chemical properties.
- Atom combine in the ratio of small whole numbers to form compounds. (Proves 'Law of Constant Proportion')
- The relative number and kinds of atoms are constant in a given compound.

Atom

- According to modern atomic theory, an atom is the smallest particle of an element which takes part in chemical reaction such that during the chemical reaction, the atom maintains its identity, throughout the chemical or physical change.
- Atoms are very small and hence can't be seen even through a very powerful microscope.
- Atomic radius of smallest atom of Hydrogen is $0.37 \times 10^{-10} \text{ m}$ or 0.037 nm.

Such that, $1 \text{ nm} = 10^{-9} \text{ m}$

**IUPAC (International Union of Pure and Applied Chemistry)
Symbols of Atoms of Different Elements**

Element	Symbol	Element	Symbol
Aluminium	Al	Iodine	I
Argon	Ar	Iron	Fe
Barium	Ba	Lead	Pb
Calcium	Ca	Nitrogen	N
Carbon	C	Oxygen	O
Chlorine	Cl	Potassium	K
Cobalt	Co	Silicon	Si
Copper	Cu	Silver	Ag
Fluorine	F	Sulphur	S
Gold	Au	Zinc	Zn
Hydrogen	H		

Atomic Mass

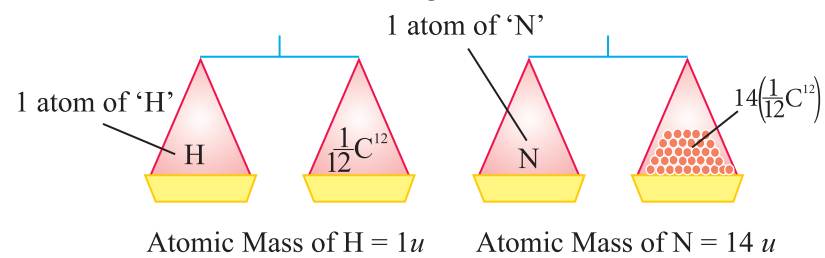
- The mass of an atom of an element is called its atomic mass.
- In 1961, IUPAC have accepted 'atomic mass unit' (u) to express atomic and molecular mass of elements and compounds respectively.

Atomic Mass Unit

The atomic mass unit is defined as the quantity of mass equal to 1/12 of mass of an atom of Carbon-12.

$$1 \text{ amu or } u = \frac{1}{12} \times \text{Mass of an atom of C-12}$$

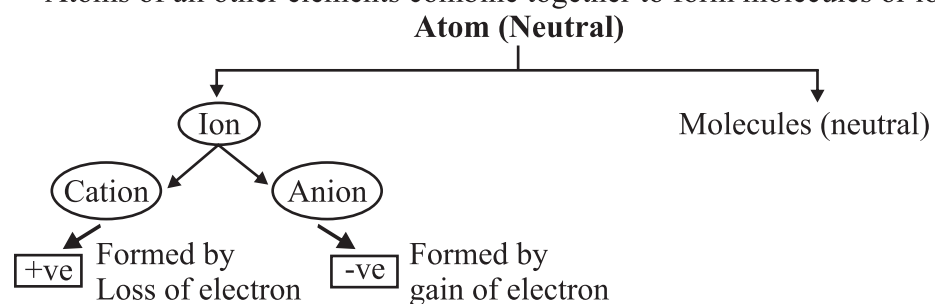
$$1 u = 1.66 \times 10^{-27} \text{ kg}$$



Atomic Mass of some elements					
Element	Symbol	Atomic Mass	Element	Symbol	Atomic Mass
Hydrogen	H	1u	Sodium	Na	23u
Helium	He	4u	Magnesium	Mg	24u
Lithium	Li	7u	Aluminium	Al	27u
Beryllium	Be	9u	Silicon	Si	28u
Boron	B	11u	Phosphorous	P	31u
Carbon	C	12u	Sulphur	S	32u
Nitrogen	N	14u	Chlorine	Cl	35.5u
Oxygen	O	16u	Potassium	K	39u
Fluorine	F	19u	Calcium	Ca	40u
Neon	Ne	20u	Iron	Fe	56u

How do atoms exist ?

- Atoms of most of the elements are very reactive and do not exist in free state.
- Only the atoms of noble gases (such as He, Ne, Ar, Kr, Xe and Rn) are chemically unreactive and can exist in the free state as single atom.
- Atoms of all other elements combine together to form molecules or ions.



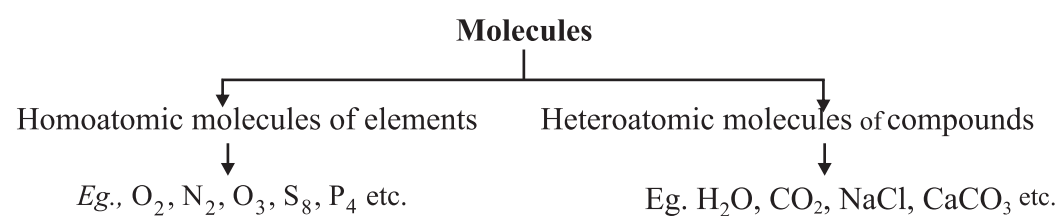
Molecule

- A molecule is a group of two or more atoms which are chemically bonded with each other.
- A molecule is the smallest particle of matter (except element) which is capable of an independent existence and show all properties of that substance.

E.g., 'H₂O' is the smallest particle of water which shows all the properties of water.

- A molecule may have atom of same or different elements, depending upon this, molecule can be categorized into two categories :

Homoatomic molecules (containing atoms of same element) and
Heteroatomic molecules (containing atoms of different elements)



Molecules of some compounds	
Compound	Combining Elements
Water (H ₂ O)	Hydrogen, Oxygen
Ammonia (NH ₃)	Nitrogen, Hydrogen
Carbon Dioxide (CO ₂)	Carbon, Oxygen
Hydrogen Chloride (HCl)	Hydrogen, Chlorine
Methane (CH ₄)	Carbon, Hydrogen
Ethane (C ₂ H ₆)	Carbon, Hydrogen
Sodium Chloride (NaCl)	Sodium, Chlorine
Copper Oxide (CuO)	Copper and Oxygen

Atomicity

The number of atoms present in one molecule of an element is called its atomicity.

Name	Formula	Atomicity	
1. Argon	Ar	Monoatomic (1)	} Noble gases constitute monoatomic molecules
2. Helium	He	Monoatomic (1)	
3. Oxygen	O ₂	Diatomic (2)	
4. Hydrogen	H ₂	Diatomic (2)	
5. Phosphorus	P ₄	Tetratomic (4)	
6. Sulphur	S ₈	Polyatomic (8)	
7. Ozone	O ₃	Triatomic (3)	

Chemical formulae

It is the symbolic representation of the composition of a compound.

Characteristics of chemical formulae

- The valencies or charges on ion must balance.
- When a compound is formed of metal and non-metal, symbol of metal comes first. *E.g.*, CaO, NaCl, CuO.
- When polyatomic ions are used, the ions are enclosed in brackets before writing the number to show the ratio. *E.g.*, Ca(OH)₂, (NH₄)₂SO₄

Molecular Mass

It is the sum of atomic masses of all the atoms in a molecule of that substance. It is also expressed in Atomic mass units.

e.g., Molecular mass of H₂O = 2 x Atomic mass of Hydrogen + 1 x Atomic mass of Oxygen

So, Molecular mass of H₂O = 2 x 1 + 1 x 16 = 18 *u*

Formula Unit Mass

It is the sum of atomic mass of all atoms present in formula for a compound.

e.g., In NaCl, Na = 23u and Cl = 35.5u

So, Formula unit mass = 1 x 23 + 1 x 35.5 = 58.5 *u*

Rules of writing chemical formulae :

Rule 01:

- Write symbols of atoms of element.
- Then write their valencies / charges below the symbols.
- Now crossover the valencies of constituent atoms.
- As a result, the first atom gets valency of second atom and the second atom gets the valency of the first atoms.
- By crossover chemical formula is formed.

Rule 02 :

- If valency is 1, it is not written below.

Rule 03 :

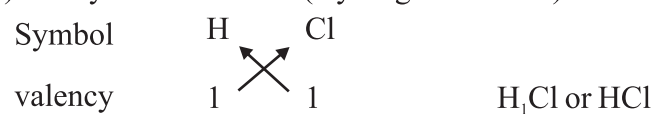
- In case we have two or more same polyatomic ions, we use brackets and then write subscript.

Examples:

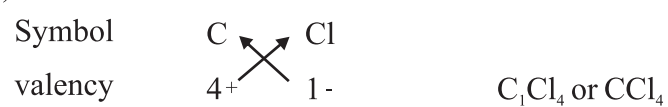


[Take 2 common and divide the formula by 2]

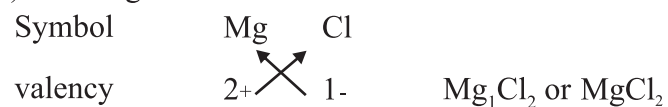
(iii) For Hydrochloric acid (Hydrogen chloride)



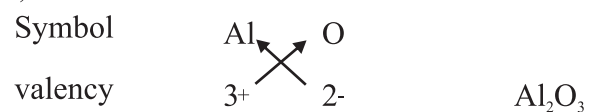
(iv) For Carbon tetrachloride



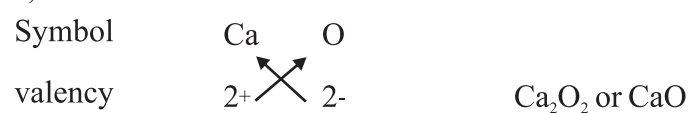
(v) For Magnesium chloride



(vi) For aluminium oxide

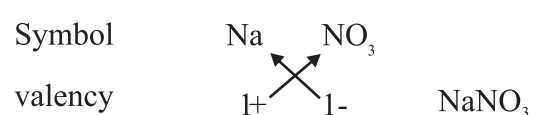


(vii) For Calcium oxide



[Take 2 common and divide the formula by 2]

(viii) For Sodium nitrate

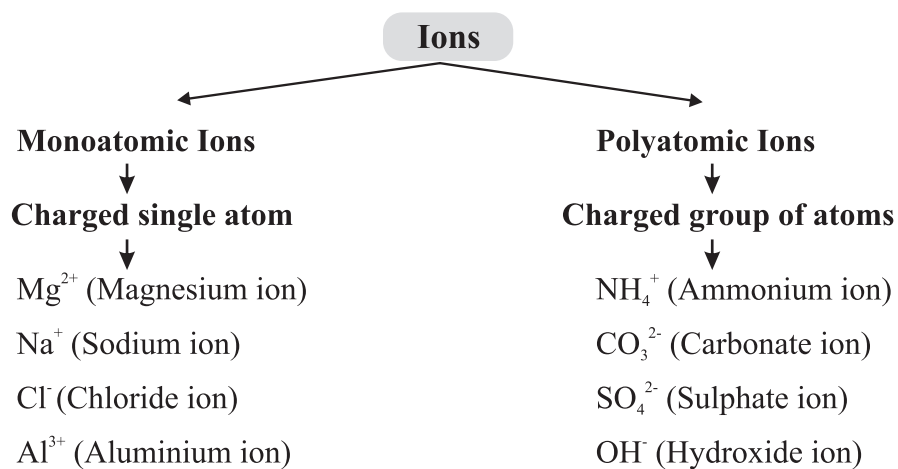


Ions

An ion may be defined as an atom or group of atoms having positive or negative charge.

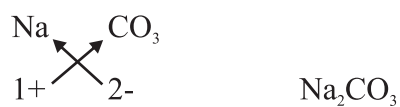
Some positively charged ions : Na^+ , K^+ , Ca^{2+} , Al^{3+} etc.

Some negatively charged ions : Cl^- (chloride ion), S^{2-} (sulphide ion), OH^- (hydroxide ion), SO_4^{2-} (sulphate ion) NO_3^- (Nitrate ion)



Chemical Formulae of Ionic Compounds (Polyatomic ions)

(i) Sodium carbonate



(ii) Aluminium sulphate



(iii) Calcium hydroxide



(iv) Ammonium sulphate



(v) Magnesium hydroxide



QUESTIONS

VERY SHORT ANSWER TYPE QUESTIONS

1. What do you understand by valence electrons?
2. Name the anion and cation that constitute the molecule of calcium oxide.
3. An element 'X' has atomic number 13. Write the formula of its oxide.
4. Write the names of elements present in common salt.
5. If 'K' and 'L' shells of an atom are completely filled with electrons then what will be the total number of electrons in that atom ?
6. Name any two elements that exist as independent atoms.
7. Identify polyatomic ion in MgCO_3 .
8. State the law of constant proportion.

SHORT ANSWER TYPE QUESTIONS

1. Write the chemical formulae of-
 - (a) Calcium chloride
 - (b) Magnesium bicarbonate
 - (c) Aluminum sulphate
 - (d) Sodium carbonate
 - (e) Lead Nitrate
 - (f) Calcium Phosphate
 - (g) Iron (II) sulphide
 - (h) Mercury (I) chloride.
2. Write the molecular formulae of all the compounds that can be formed by the combination of following ions.
 $\text{Cu}^{2+}, \text{Na}^+, \text{Fe}^{3+}, \text{Cl}^-, \text{SO}_4^{2-}, \text{PO}_4^{3-}$
3. Write the cations (Positively charged ions) and anions (negatively charged ions) Present in the following compounds.
 - (a) NaCl
 - (b) H_2SO_4
 - (c) NH_4NO_3
 - (d) $\text{Ca}(\text{HCO}_3)_2$

4. Give the formulae of the compounds formed from the following sets of elements
- | | |
|---------------------------|-------------------------|
| (a) Calcium and fluorine | (d) Sulphur and Oxygen |
| (b) Nitrogen and Hydrogen | (e) Carbon and Oxygen |
| (c) Nitrogen and Oxygen | (f) Carbon and Chlorine |
5. Classify each of the following elements or compounds on the basis of their atomicity.
- | | | | | |
|-----------------|------------|------------|-----------|--------------|
| (a) F_2 | (b) NO_2 | (c) CH_4 | (d) P_4 | (e) H_2O_2 |
| (f) P_4O_{10} | (g) O_3 | (h) HCl | (i) He | (j) Ag |
6. Write postulates of Dalton's atomic theory (at least three).
7. What is the difference between the molecule of an element and molecule of a compound? Give one example of each.
8. What is the difference between $2H$ and H_2 ? (at least two differences)

LONG ANSWER TYPE QUESTIONS

- Atoms are very tiny particles, but it is important to know about them, why?
 - What is the full form of IUPAC?
 - State the rules given by IUPAC for writing symbols of elements.
- An element X has multiple valency of 2 and 3 both. It is a metal. What will be the chemical formula of :
 - Oxide
 - Chloride
 - Sulphate formed by X.
- Find the mass ratio of elements present in the given compounds.
 - Calcium Oxide
 - Magnesium Sulphide
 - Sodium Chloride
 - Carbon Dioxide
 - Ammonia

OBJECTIVE TYPE QUESTIONS

1. Which of the following statements is not true about an atom?
 - a. Atoms are not able to exist independently
 - b. Atoms are the basic units from which molecules and ions are formed
 - c. Atoms are always neutral in nature
 - d. Atoms aggregate in large numbers to form the matter that we can see, feel or touch
2. The chemical symbol for nitrogen gas is
 - a. Ni
 - b. N₂
 - c. N⁺
 - d. N
3. The chemical symbol for sodium is
 - a. So
 - b. Sd
 - c. NA
 - d. Na
4. Give the chemical formulae of the compounds formed from the following sets of elements.
 - a. Calcium and fluorine
 - b. Hydrogen and sulphur
 - c. Nitrogen and hydrogen
 - d. Carbon and chlorine
 - e. Sodium and oxygen
 - f. Carbon and oxygen
5. Write the molecular formulae for the following compounds
 - a. Copper (II) Bromide.
 - b. Aluminium (III) nitrate.
 - c. Calcium (II) phosphate
 - d. Iron (III) sulphide
 - e. Mercury (II) chloride
 - f. Magnesium (II) chloride

6. An element 'X' forms an oxide X_2O_3
- State the valency of X
 - Write the chemical formula for chloride of X.
7. Write the molecular formulae of the compounds that can be formed by the combination of following ions
- Cu^{2+} and Cl^-
 - Na^+ and NO_3^-
 - Fe^{3+} and SO_4^{2-}
 - Fe^{2+} and Cl^-
8. Classify each of the following on the basis of their atomicity.

Elements	Atomicity
F_2	
NO_3	
NO_2	
P_4	
H_2O_2	
He	
Ag	
CH_4	
P_4O_{10}	
C_4H_{10}	

9. Fill in the blanks
- In a chemical reaction, the sum of the masses of the reactants and products remains unchanged. This is called
 - A group of atoms carrying a fixed charge on them is called
 - The formula unit mass of $Ca_3(PO_4)_2$ is
 - Formula of sodium carbonate is and that of ammonium sulphate is

Assertion and reason type questions:-

Two statements are given one labelled assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below:

- (a) Both A and R are true and R is the correct explanation of A.
- (b) Both A and R are true but R is not the correct explanation of A.
- (c) A is true but R is false.
- (d) A is false but R is true.

1. Assertion (A): Sulphates are polyatomic ions.

Reason (R) : The sulphate ion consists of one sulphur atom and four oxygen atom and carries an overall charge of 2-

Answer: (a) The Sulphate ion is SO_4^{2-} . The atoms of a polyatomic ion are tightly bonded together and so the entire ion behaves as a single unit.

2. Assertion (A) : Magnesium and chlorine ions are represented by Mg^{2+} and Cl^- respectively.

Reason (R) : The chemical formula of Magnesium Chloride is Mg_2Cl .

Answer : (C) The correct formula of Magnesium Chloride is MgCl_2 .