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CHAPTER 3

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CHAPTER – 3

ATOMS AND MOLECULES

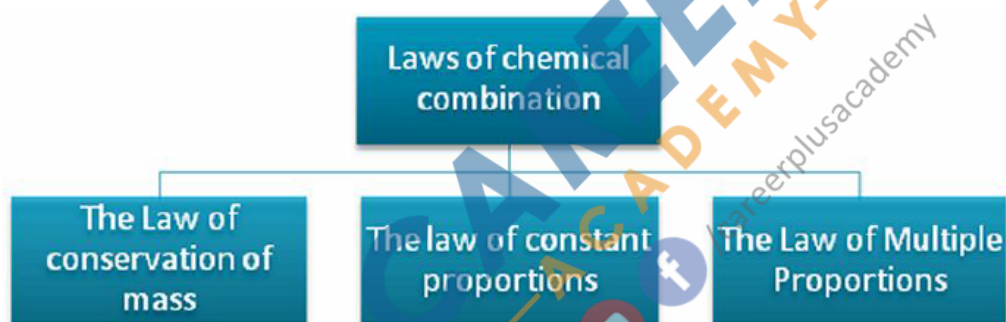
ATOMS AND MOLECULES

LAWS OF CHEMICAL COMBINATIONS

Before Dalton concept of atom was mere philosophical. Dalton explained about atom on the basis of Laws of Chemical Combinations.

There are three laws of chemical combination.

1. Law of Conservation of Mass
2. Law of Constant Proportions
3. Law of Multiple Proportions



LAW OF CONSERVATION OF MASS

Antoine L. Lavoisier, a French scientist, established the theory of Law of Conservation of Mass. The law of conservation of mass states, “**Mass can neither be created nor destroyed in a chemical reaction**”.

All matters in the universe exist in three states. There are two ways of classification of matter.

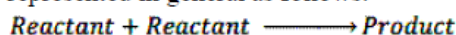
1. According to physical state as solid, liquid or gas.
2. According to its composition as element, compound or mixture.

According to this law mass of an isolated system will remain constant over time. This means when mass is enclosed in a system and none is allowed in or out, its quantity will never change. That is mass will be conserved, and hence this is called Law of Conservation of Mass. This means total mass of products is always equal to the total mass of reactants. As there is no loss of mass of substances, i.e. mass is conserved, that's why Lavoisier called this the law of conservation of mass.

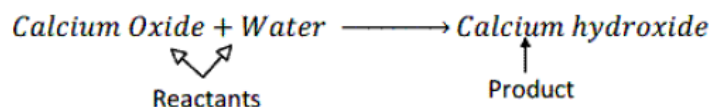
REACTANTS AND PRODUCTS:

In a chemical reaction the substances that combine or react are known as reactants and the new substance/substances formed are called product or products.

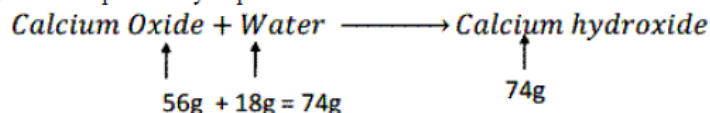
A chemical reaction can be represented in general as follows:



Example: When calcium oxide is dissolved in water calcium hydroxide is formed. The reaction involve in this can be written as:



In this reaction calcium oxide and water are reactants while calcium hydroxide is product. In this reaction 74 g of calcium hydroxide is obtained when 56 g of calcium oxide reacts with 18 g of water, which is proved by experiment.



Here the total mass of reactants, i.e. calcium oxide and water is equal to 74 g. And the mass of product, i.e. calcium hydroxide is also equal to 74g. This proves that the total mass of reactants is always equal to the total mass of product, which proves the Law of Conservation of Mass.

A simple experiment to demonstrate the LAW of CONSERVATION OF MASS

LAW OF CONSTANT PROPORTIONS

Law of Constant Proportion states that a chemical compound always contains exactly the same proportion of elements by mass.

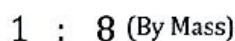
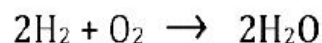
This law is also known as Law of definite proportions. Joseph Louis Proust gave this law hence, this law is also known as Proust's Law.

Explanation of the law:-

Compounds are formed by the combination of two or more elements. In a compound the ratio of the atoms or element by mass remains always same irrespective of the source of compound. This means a certain compound always formed by the combination of atoms in same ratio by mass. If the ratio of mass of constituent atoms will be altered the new compound is formed.

Examples:-

Water is formed by the combination of hydrogen and oxygen. The ratio of masses of hydrogen and oxygen is always in 1:8 in water irrespective of source of water. Whether you collect the water from a well, river, pond or from anywhere the ratio of their constituent atoms by mass will always same.

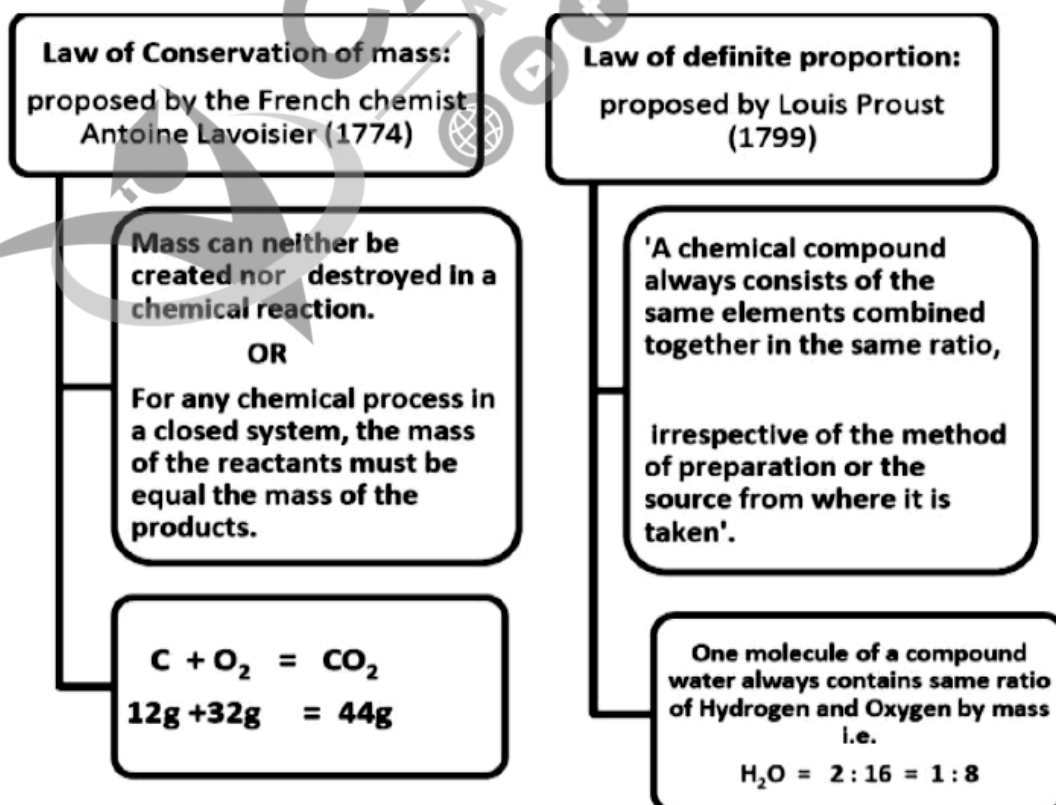


Nitrogen dioxide is a compound, which is formed by the combination of nitrogen and oxygen. The ratio of nitrogen and oxygen by mass in nitrogen dioxide is in 7:16.

Nitrous oxide is a compound which is also formed by the combination of nitrogen and oxygen. The ratio of nitrogen and oxygen in nitrous oxide is in 28:16.

Nitric oxide is a compound, which is also formed by the combination of nitrogen and oxygen. The ratio of nitrogen and oxygen in nitric oxide is in 7:8.

From the above three examples it is clear that if the ratio of the atoms by mass is altered then the new compound is formed, such as in the case of nitrogen dioxide, nitrous oxide, nitric oxide. These three compounds are formed by the combination of same atoms but because of combination of the constituent atoms in different ratios by mass new compound is formed.



DALTON'S ATOMIC THEORY

John Dalton, a British Chemists and scientists gave the Atomic Theory in 1808. This theory is popularly known as Dalton's Atomic Theory in the honour of John Dalton. He gave the theory on the basis of Laws of Chemical Combination and explains them properly. In his theory he explains about atom.

Hence, the given observations are in agreement with the law of conservation of mass.

Q2. Hydrogen and oxygen combine in the ratio of 1:8 by mass to form water. What mass of oxygen gas would be required to react completely with 3 g of hydrogen gas?

Answer:

It is given that the ratio of hydrogen and oxygen by mass to form water is 1:8.

Then, the mass of oxygen gas required to react completely with 1 g of hydrogen gas is 8 g.

Therefore, the mass of oxygen gas required to react completely with 3 g of hydrogen gas is $8 \times 3 \text{ g} = 24 \text{ g}$.

Q3. Which postulate of Dalton's atomic theory is the result of the law of conservation of mass?

Answer:

The postulate of Dalton's atomic theory which is a result of the law of conservation of mass is:

Atoms are indivisible particles, which can neither be created nor destroyed in a chemical reaction.

Q4. Which postulate of Dalton's atomic theory can explain the law of definite proportions?

Answer:

The postulate of Dalton's atomic theory which is a result of the law of conservation of mass is:

Atoms are indivisible particles, which can neither be created nor destroyed in a chemical reaction.

ATOMS

On the basis of Dalton's Atomic Theory atom can be defined as the smallest particles of matter are called atoms.

Characteristics of atoms:

- Atom is the smallest particle of matter.
- All elements are made of tiny particles called atom.
- Atoms are very small in size and cannot be seen through naked eyes.
- Atom does not exist in free-state in nature. But atom takes part in a chemical reaction.
- The properties of a matter depend upon the characteristics of atoms.
- Atoms are the building block of an element similar to a brick which combine together to make a building.
- The size of atoms is indicated by its radius.
- In ancient time atoms was considered indivisible.













SYMBOLS OF ATOMS OF ELEMENTS

Dalton was the first scientist to use the symbols for elements in a very specific sense. When he used a symbol for an element he also meant a definite quantity of that element, that is, one atom of that element. Berzilius suggested that the symbols of elements be made from one or two letters of the name of the element.

Many of the symbols are the first one or two letters of the element's name in English. The first letter of a symbol is always written as a capital letter (uppercase) and the second letter as a small letter (lowercase).

For convenience elements are represented by unique symbols. For example: Hydrogen is represented by 'H'. Oxygen is represented 'O'. Nitrogen is represented by 'N'. Iron is represented by 'Fe'. Elements are represented by unique symbols. For example: Hydrogen is

represented by 'H'. Oxygen is represented 'O'. Nitrogen is represented by 'N'. Iron is represented by 'Fe'.

	Hydrogen		Carbon		Oxygen
	Phosphorus		Sulphur		Iron
	Copper		Lead		Silver
	Gold		Platina		Mercury

His worked proved as boon to science. For his marvelous work Berzilius, together with John Dalton, Antoine Lavoisier, and Robert Boyle is considered as the Father of Modern Chemistry.

Symbol and Name of some elements					
Element	Symbol	Element	Symbol	Element	Symbol
Hydrogen	H	Sodium	Na	Cromium	Cr
Helium	He	Magnesium	Mg	Mangese	Mn
Lithium	Li	Aluminium	Al	Iron	Fe
Beryllium	Be	Silicon	Si	Cobalt	Co
Boron	B	Phosphorous	P	Nickel	Ni
Carbon	C	Sulphur	S	Copper	Cu
Nitrogen	N	Chlorine	Cl	Zinc	Zn
Oxygen	O	Argon	Ar	Silver	Ag
Fluorine	F	Potassium	K	Gold	Au
Neon	Ne	Calcium	Ca	Mercury	Hg

Symbol of many elements are taken from their English name, while symbol of many elements are taken from their Greek or Latin names.

Symbol of some element which are derived from their Latin name

Several elements are named after the place where they discovered, such as 'Copper' which was taken from Cyprus. Some elements are named after their colour, such as 'Gold' which means yellow.

The atomic mass of hydrogen atom = 1u.

This means one hydrogen atom is 1 times heavier than $1/12^{\text{th}}$ of the carbon atom.

The atomic mass of oxygen is 16u, this means one atom of oxygen is 16 times heavier than $1/12^{\text{th}}$ of carbon atom.

Absolute mass or Actual atomic mass:

It is found that, the actual atomic mass of a carbon-12 atom is equal to 1.9926×10^{-23} g.

$$\text{Therefore, } 1u = \frac{1.9926 \times 10^{-23}}{12} \text{ g} = 1.6605 \times 10^{-24} \text{ g}$$

Thus by multiplying the relative atomic mass with 1.6605×10^{-24} g we can get the absolute or actual mass of an atom.

Example -1 - Find the absolute mass oxygen.

Solution:

The atomic mass of oxygen is 16u

We know $1u = 1.6605 \times 10^{-24}$ g

Therefore, Absolute mass of oxygen = $1.6605 \times 10^{-24} \times 16$ g

= $26.568 \times 10^{-24} = 2.6568 \times 10^{-23}$ g

Example - 2 - Find the absolute mass of Sodium.

Solution:

The atomic mass of Sodium is 23u

We know $1u = 1.6605 \times 10^{-24}$ g

Therefore, Absolute mass of Sodium = $1.6605 \times 10^{-24} \times 23$ g

= $38.191 \times 10^{-24} = 3.8191 \times 10^{-23}$ g

Example - 3 - Calculate the absolute mass of hydrogen atom.

Solution:

The atomic mass of hydrogen is 1u

We know $1u = 1.6605 \times 10^{-24}$ g

Therefore, Absolute mass of hydrogen = $1.6605 \times 10^{-24} \times 1$ g = 1.6605×10^{-24} g

Example - 4 - Calculate the absolute or actual mass of Nitrogen atom.

Solution:

The atomic mass of Nitrogen is 14u

We know $1u = 1.6605 \times 10^{-24}$ g

Therefore, Absolute mass of hydrogen = $1.6605 \times 10^{-24} \times 14$ g

= $23.247 \times 10^{-24} = 2.3247 \times 10^{-23}$ g

EXISTENCE OF ATOMS

Atoms of most of the elements exist in the form of molecule or ion, since they are most reactive. For example, hydrogen, oxygen, chlorine, etc. However, atoms of some elements, which are non-reactive, exist in free-state in nature. For example helium, neon, argon, etc.

Usually atoms are exist in following two forms -

- In the form of molecules
- In the form of ions

INTEXT QUESTIONS PAGE NO. 35

Q1. Define the atomic mass unit.

Answer:

Mass unit equal to exactly one-twelfthth $\left(\frac{1}{12^{th}}\right)$ the mass of one atom of carbon-12 is called one atomic mass unit. It is written as 'u'.

Q2. Why is it not possible to see an atom with naked eyes?

Answer:

The size of an atom is so small that it is not possible to see it with naked eyes. Also, the atom of an element does not exist independently.

MOLECULE

Molecule is the smallest particle of a compound.

Atoms exist in free states in the form of molecule.

- A molecule may be formed by the combination of two or more similar atoms of an element, such as oxygen molecule is formed by the combination of two oxygen atoms, molecule of hydrogen which is formed by the combination of two hydrogen atoms.
- Molecules may be formed by the combination of atoms of two or more different elements. For example molecule of water. It is formed by the combination of two atoms of hydrogen and one atom of oxygen. Molecule of Nitric oxide or nitrogen monoxide. It is formed by the combination of one nitrogen atom and one oxygen atom.
- A molecule takes part in chemical reaction.

Most of the atoms exist in the form of molecule. Molecules are formed by the combination of two or more elements.

Example: Molecule of hydrogen (H_2), Molecule of oxygen (O_2), Molecule of nitrogen (N_2), etc.

- Molecules of elements
- Molecules of Compounds

MOLECULES OF ELEMENTS

When two or more atoms of same element combine to form a molecule these are called molecules of element.

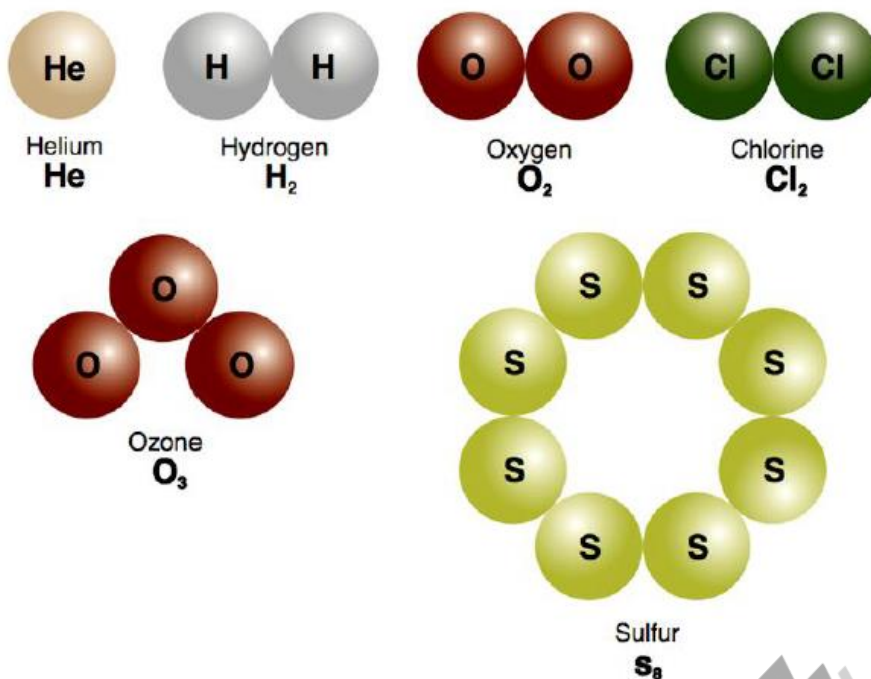
Example:

Hydrogen molecule (H_2). Hydrogen molecule (H_2). Molecule of hydrogen is formed by the combination of two hydrogen atoms.

Oxygen molecule (O_2). Molecule of oxygen is formed by the combination of two oxygen atoms.

Sulphur molecule (S_8). Molecule of sulphur is formed by the combination of eight sulphur atoms.

Phosphorous molecule (P_4). Molecule of phosphorous is formed by the combination of four phosphorous atoms.



Molecules of some non-reactive elements are formed by single atom. For example – helium, neon, argon, etc. molecules: Molecules of metals formed as big cluster of atoms. They are represented by their symbols simply. For example: Iron (Fe), Copper (Cu), Zinc (Zn), etc. These molecules are known as giant molecules.

Carbon is a non-metal, but it also exists as giant molecule and represented by its symbol 'C'.

ATOMICITY

Monoatomic:

When molecule is formed by single atom only, it is called monoatomic molecule. Generally noble gas forms monoatomic molecules. For example: Helium (He), Neon (Ne), Argon (Ar), Kr (Krypton), Xenon (Xe), Randon (Rn).

Diatomic

When molecule is formed by the combination of two atoms of it is called diatomic molecule. For example: Hydrogen (H₂), Oxygen (O₂) Nitrogen (N₂), Chlorine (Cl₂), etc.

Triatomic

When molecule is formed by the combination of three atoms it is called triatomic molecule. For example: molecule of ozone (O₃)

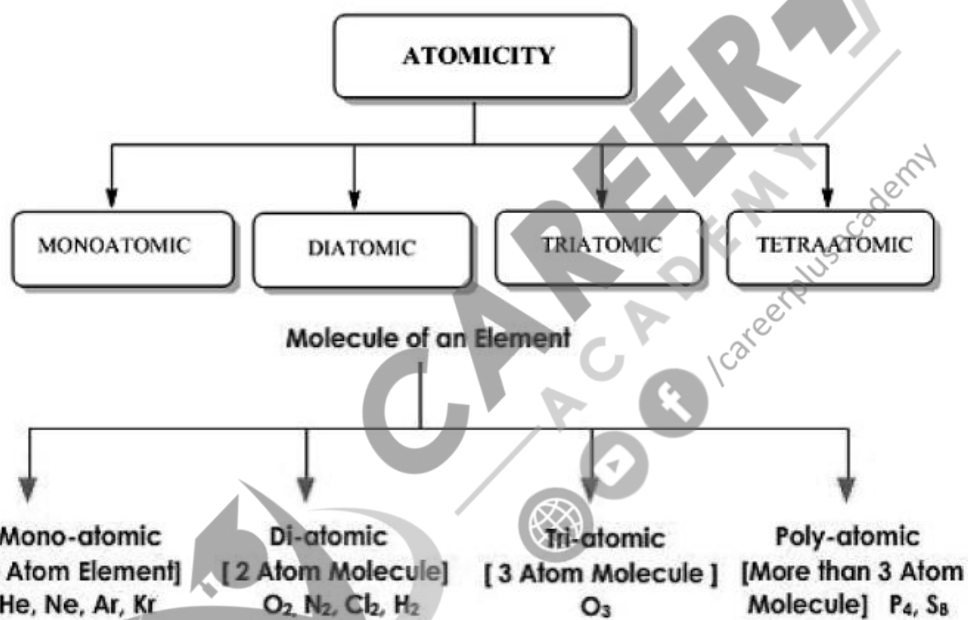
Tetra-atomic

When molecule is formed by the combination of four atoms it is called tetra-atomic molecule. For example: Phosphorous molecule (P₄)

Polyatomic

When molecule is formed by the combination of more than two atoms, it is called polyatomic molecule. For example: Sulphur molecule (S₈)

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

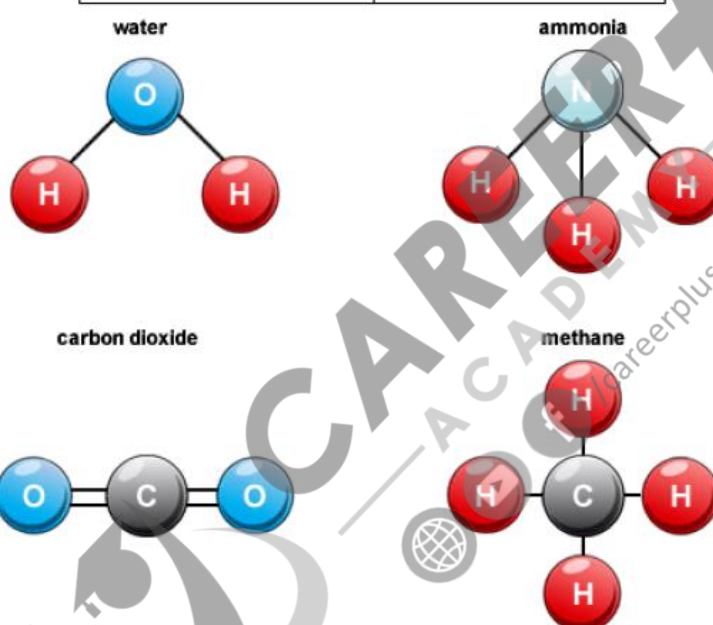


MOLECULES OF COMPOUNDS

When molecule is formed by the combination of two or more atoms of different elements, it is called the molecule of compound.

Example: Molecule of water (H₂O). Molecule of water is formed by the combination of two hydrogen and one oxygen atoms.

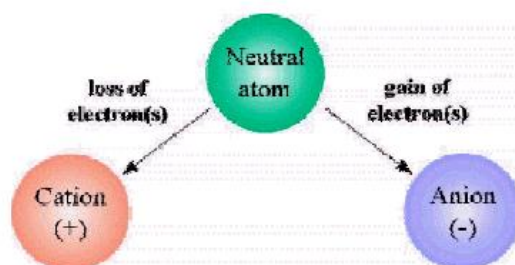
Molecules of some compounds	
Compound	Combining Elements
Water (H ₂ O)	Hydrogen, Oxygen
Ammonia (NH ₃)	Nitrogen, hydrogen
Carbon dioxide(CO ₂)	Carbon, oxygen
Hydrogen Chloride (HCl)	Hydrogen, Chlorine
Methane (CH ₄)	Carbon, Hydrogen
Ehtane (C ₂ H ₆)	Carbon, hydrogen
Sodium chloride (NaCl)	Sodium, chlorine.
Copper oxide (CuO)	Copper and oxygen



IONS

Atoms of several elements exists in the form of ion. Atoms or molecule with negative or positive charge over them are called ions.

For example: Sodium ion (Na^+), potassium ion (K^+), Chlorine ion (Cl^-), Fluoride ion (F^-) etc.



Cations:

Ions having positive charge over them are called cations.

For example: sodium ion (Na^+), potassium ion (K^+), etc

Anions:

Ions having negative charge over them are called anions.

For example: Chloride ion (Cl^-), Fluoride ion (F^-), etc

Monoatomic ions:

Ions formed by one atom are called monoatomic ions.

For example: sodium ion (Na^+), potassium ion (K^+), Chloride ion (Cl^-), Fluoride ion (F^-), etc.

Polyatomic ions:

Ions formed by two or more atoms are called polyatomic ions. These are group of atoms of different elements which behave as single units, and are known as polyatomic ions.

For example: Ammonium ion (NH_4^+), Hydroxide ion (OH^-), etc

Some Common ions					
Cations		Anions		Polyatomic ions	
Lithium ion	Li^+	Chloride ion	Cl^-	Hydroxide	OH^-
Sodium ion	Na^+	Fluorine	F^-	Ammonium	NH_4^+
Potassium ion	K^+	Iodide	I^-	Nitrate	NO_3^-
Silver ion	Ag^+	Hydride	H^-	Bicarbonate or	HCO_3^-
Copper ion	Cu^+	Oxide ion	O^{2-}	Hydrogen carbonate	
Hydrogen ion	H^+	Sulphide	S^{2-}		
Magnesium ion	Mg^{++}	Nitride	N^{3-}	Sulphate	SO_4^{2-}
Calcium ion	Ca^{++}			Carbonate	CO_3^{2-}
Iron ion	Fe^{++}			Sulphite	SO_3^{2-}
Zinc ion	Zn^{++}			Phosphate	PO_4^{2-}
Copper ion	Cu^{++}				
Aluminium ion	Al^{+++}				

WRITING CHEMICAL FORMULA

Chemical formula of the compound is the symbolic representation of its composition. To write chemical formula of a compound, symbols and valencies of constituent elements must be known. The valency of atom of an element can be thought of as hands or arms of that atom.

Points to remember

- The symbols or formulas of the component radicals of the compound are written side by side.
- Positive radicals are written left and negative radicals on the right.
- The valencies of the radicals are written below the respective symbols.
- The criss-cross method is applied to exchange the numerical value of valency of each radical. It is written as subscript of the other radical.

- The radical is enclosed in a bracket and the subscript is placed outside the lower right corner.
- The common factor is removed.
- If the subscript of the radical is one, it is omitted.

The rules that you have to follow while writing a chemical formula are as follows:

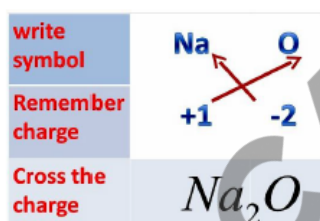
- the valencies or charges on the ion must balance.
- when a compound consists of a metal and a non-metal, the name or symbol of the metal is written first. For example: calcium oxide (CaO), sodium chloride (NaCl), iron sulphide (FeS), copper oxide (CuO) etc., where oxygen, chlorine, sulphur are non-metals and are written on the right, whereas calcium, sodium, iron and copper are metals, and are written on the left.
- in compounds formed with polyatomic ions, the ion is enclosed in a bracket before writing the number to indicate the ratio.

The simplest compounds, which are made up of two different elements are called binary compounds. While writing the chemical formulae for compounds, we write the constituent elements and their valencies as shown below. Then we must crossover the valencies of the combining atoms.

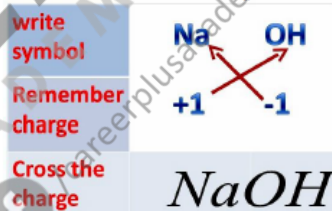
The formulae of ionic compounds are simply the whole number ratio of the positive to negative ions in the structure. For magnesium chloride, we write the symbol of cation (Mg^{2+}) first followed by the symbol of anion (Cl^-). Then their charges are criss-crossed to get the formula.

EXAMPLES

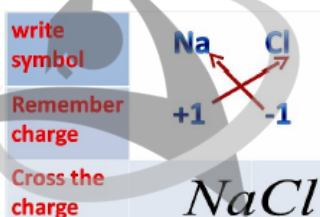
Formula of Sodium oxide



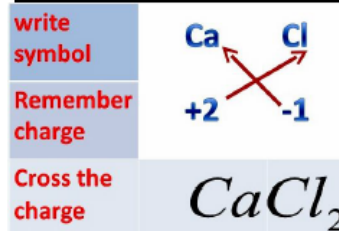
Formula of Sodium hydroxide



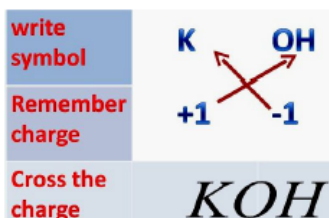
Formula of Sodium Chloride



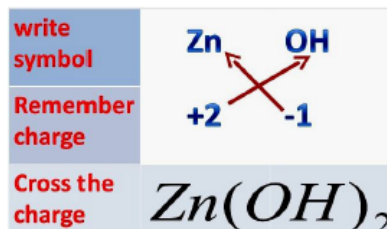
Formula of Calcium chloride



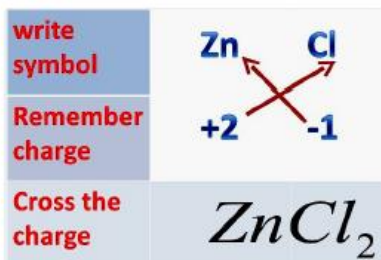
Formula of Potassium hydroxide



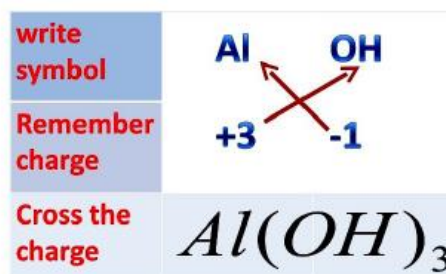
Formula of Zinc hydroxide



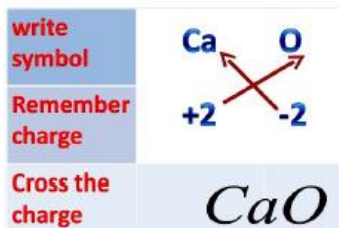
Formula of Zinc chloride



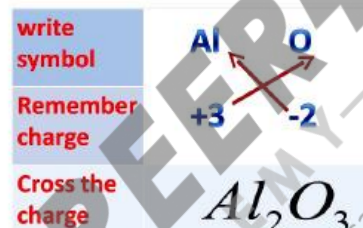
Formula of Aluminium hydroxide



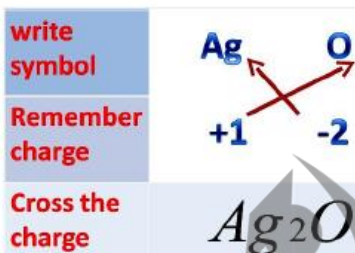
Formula of Calcium oxide



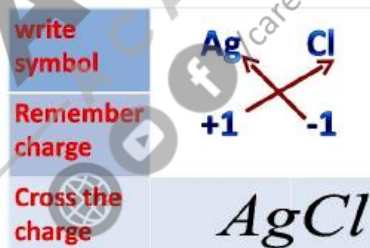
Formula of Aluminium oxide



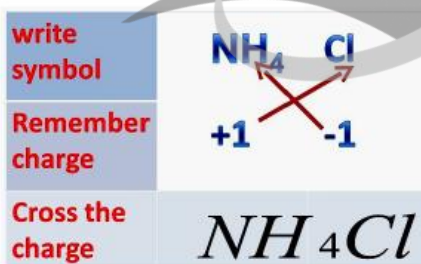
Formula of Silver oxide



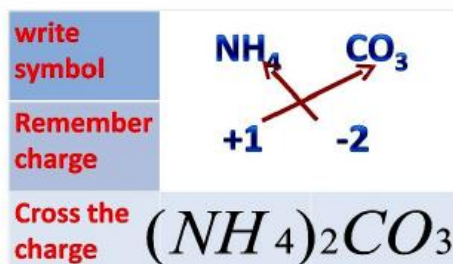
Formula of Silver chloride



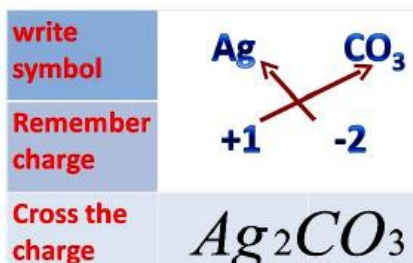
Formula of Ammonium Chloride



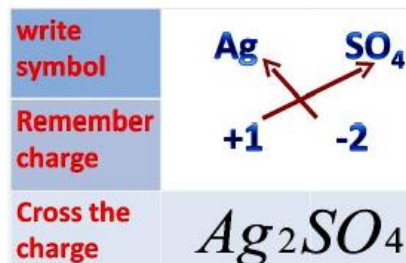
Formula of Ammonium carbonate



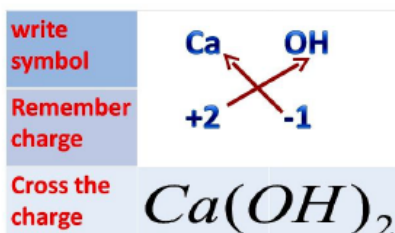
Formula of Silver Carbonate



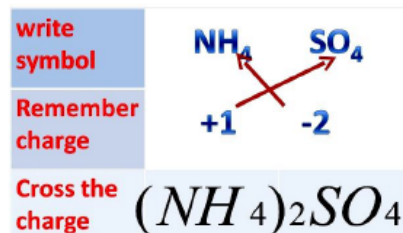
Formula of Silver Sulphate



Formula of Calcium hydroxide



Formula of Ammonium sulphate



INTEXT QUESTIONS PAGE NO. 39

Q1. Write down the formulae of

- (i) sodium oxide
- (ii) aluminium chloride
- (iii) sodium sulphide
- (iv) magnesium hydroxide

Answer:

- (i) Sodium oxide $\rightarrow \text{Na}_2\text{O}$
- (ii) Aluminium chloride $\rightarrow \text{AlCl}_3$
- (iii) Sodium sulphide $\rightarrow \text{Na}_2\text{S}$
- (iv) Magnesium hydroxide $\rightarrow \text{Mg}(\text{OH})_2$

Q2. Write down the names of compounds represented by the following formulae:

- (i) $\text{Al}_2(\text{SO}_4)_3$
- (ii) CaCl_2
- (iii) K_2SO_4
- (iv) KNO_3
- (v) CaCO_3 .

Answer:

- (i) $\text{Al}_2(\text{SO}_4)_3$ \rightarrow Aluminium Sulphate
- (ii) CaCl_2 \rightarrow Calcium Chloride
- (iii) K_2SO_4 \rightarrow Potassium sulphate
- (iv) KNO_3 \rightarrow Potassium nitrate
- (v) CaCO_3 . \rightarrow Calcium carbonate

Q3. What is meant by the term chemical formula?

Answer:

The chemical formula of a compound means the symbolic representation of the composition of a compound. From the chemical formula of a compound, we can know the number and kinds of atoms of different elements that constitute the compound.

For example, from the chemical formula CO_2 of carbon dioxide, we come to know that one carbon atom and two oxygen atoms are chemically bonded together to form one molecule of the compound, carbon dioxide.

Q4. How many atoms are present in a

- (i) H_2S molecule and
- (ii) PO_4^{3-} ion?

Answer:

- (i) In an H_2S molecule, three atoms are present; two of hydrogen and one of sulphur.
- (ii) In a PO_4^{3-} ion, five atoms are present; one of phosphorus and four of oxygen.

MOLECULAR MASS

Atomic mass: The atomic mass of an element is the mass of one atom of that element in atomic mass units or (u).

Atomic mass unit (amu): $1/12^{\text{th}}$ of the mass of an atom of carbon-12 is called atomic mass unit. It is a unit of mass used to express atomic masses and molecular masses.

Molar mass: The molar mass of an element is equal to the numerical value of the atomic mass. However, in case of molar mass, the units change from 'u' to 'g'. The molar mass of an atom is also known as gram atomic mass.

For example, the atomic mass of carbon = 12 atomic mass units. So, the gram atomic mass of carbon = 12 grams.

Molecular mass of the molecule: The sum of the atomic masses of all the atoms in a molecule of a substance is called the molecular mass of the molecule.

Molecular mass - calculation: Generally we use relative atomic masses of atoms for calculating the molecular mass of 1 mole of any molecular or ionic substances.

Example: Molecular mass of H_2SO_4

Atomic mass of Hydrogen = 1

Atomic mass of sulphur = 32

Atomic mass of oxygen = 16

Molecular mass of H_2SO_4 = 2(Atomic mass of Hydrogen) + 1 (Atomic mass of sulphur) + 4 (Atomic mass of oxygen) = $2 \times 1 + 32 + 4 \times 16 = 98$ u.

Calculation of molecular mass of hydrogen chloride:

Atomic mass of hydrogen + Atomic mass of chlorine = $1 + 35.5 = 36.5$ u.

FORMULA UNIT MASS

The formula unit mass of a substance is the sum of the atomic masses of all atoms in a formula unit of a compound. The term 'formula unit' is used for those substances which are made up of ions.

Formula unit mass of NaCl: $1 \times \text{Atomic mass of Na} + 1 \times \text{Atomic mass of Cl}$
 $1 \times 23 + 1 \times 35.5 = 58.5$ atomic mass units.

Formula unit mass of ZnO:

= $1 \times \text{Atomic mass of Zn} + 1 \times \text{Atomic mass O}$

= $1 \times 65 + 1 \times 16 = 81$ u.

INTEXT QUESTIONS PAGE NO. 40

Q1. Calculate the molecular masses of H_2 , O_2 , Cl_2 , CO_2 , CH_4 , C_2H_6 , C_2H_4 , NH_3 , CH_3OH .

Answer:

Molecular mass of O_2 = $2 \times \text{Atomic mass of O} = 2 \times 16 = 32$ u

Molecular mass of Cl_2 = $2 \times \text{Atomic mass of Cl} = 2 \times 35.5 = 71$ u

Molecular mass of CO_2 = Atomic mass of C + $2 \times \text{Atomic mass of O} = 12 + 2 \times 16 = 44$ u

Molecular mass of CH_4 = Atomic mass of C + $4 \times \text{Atomic mass of H} = 12 + 4 \times 1 = 16$ u

Molecular mass of C_2H_6 = $2 \times \text{Atomic mass of C} + 6 \times \text{Atomic mass of H} = 2 \times 12 + 6 \times 1 = 30$ u

Molecular mass of C_2H_4 = $2 \times \text{Atomic mass of C} + 4 \times \text{Atomic mass of H} = 2 \times 12 + 4 \times 1 = 28$ u

Molecular mass of NH_3 = Atomic mass of N + 3 × Atomic mass of H = $14 + 3 \times 1 = 17$ u
Molecular mass of CH_3OH = Atomic mass of C + 4 × Atomic mass of H + Atomic mass of O
= $12 + 4 \times 1 + 16 = 32$ u

Q2. Calculate the formula unit masses of ZnO , Na_2O , K_2CO_3 , given atomic masses of Zn = 65 u, Na = 23 u, K = 39 u, C = 12 u, and O = 16 u.

Answer:

Formula unit mass of ZnO = Atomic mass of Zn + Atomic mass of O = $65 + 16 = 81$ u

Formula unit mass of Na_2O = 2 × Atomic mass of Na + Atomic mass of O

= $2 \times 23 + 16 = 62$ u

Formula unit mass of K_2CO_3 = 2 × Atomic mass of K + Atomic mass of C + 3 × Atomic mass of O = $2 \times 39 + 12 + 3 \times 16 = 138$ u

MOLE CONCEPT

Mole: Mole is the measurement in chemistry. It is used to express the amount of a chemical substance.

One mole is defined as the amount of substance of a system which contains as many entities like, atoms, molecules and ions as there are atoms in 12 grams of carbon - ^{12}C .

Avogadro number: The number of the particles present in one mole of any substance is equal to 6.022×10^{23} . This is called avogadro's number or avogadro's constant.

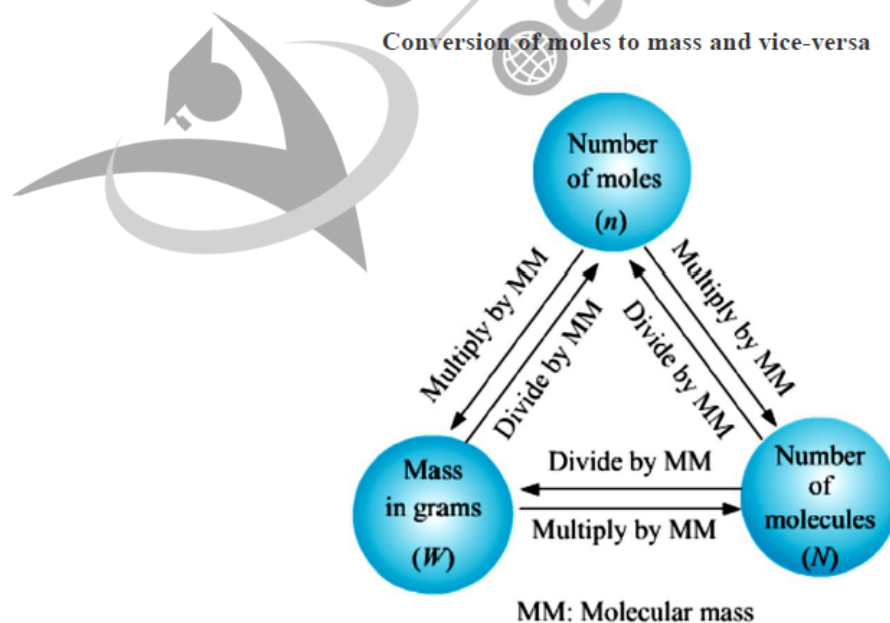
Number of particles in 1 mole:

1 mole of hydrogen atoms represents 6.022×10^{23} hydrogen atoms.

1 mole of hydrogen molecules represents 6.022×10^{23} hydrogen molecules.

1 mole of water molecules represents 6.022×10^{23} water molecules.

Conversion of moles to mass and vice-versa



The key concept used in these kind of problems is that a mole of any substance contains gram formula mass or molecular mass of that substance i.e. molecular mass of Hydrogen is 2 a.m.u.

so mass of 1 mole of hydrogen which is also known as molar mass will be 2 gram. Similarly if we have 2 moles of hydrogen, it will weigh 2×2 grams which is equal to 4 grams.

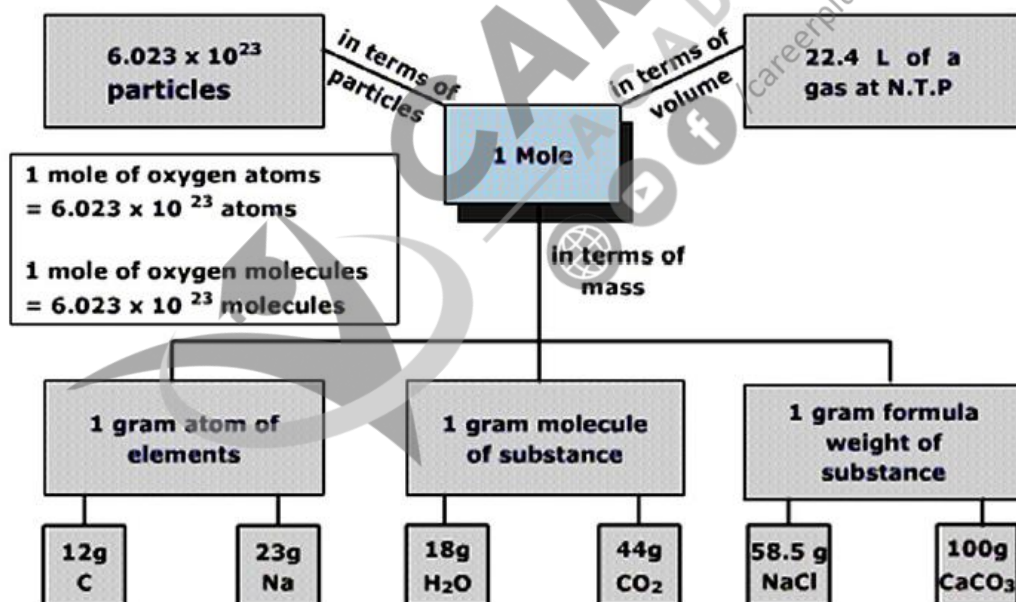
MOLE CONCEPT CALCULATION

This is the most basic and the most used calculation that a student comes across while solving a mole concept problem. Most of the times, moles or number of atoms or molecules are given in the question and the mass is needed to be calculated. In that case proceed as shown in the above example. In rest of the cases, mass will be given and moles or number will be needed to be calculated. In those questions also, proceed by:

STEP 1:- Establishing relationship between molar mass and the number (N_A) or moles of that particular entity (atom, molecule or ion).

STEP 2:- Use unitary method to calculate what is asked in the question.

NOTE: – When we say oxygen gas weighs 32 gram then we mean to say that 1 mole of oxygen molecule (O_2) weighs 32 grams and not 1 mole of oxygen atom which is O. This is because in natural form, oxygen exists as O_2 molecule.



PROBLEMS (BASED ON MOLE CONCEPT)

1. When the mass of the substance is given:

$$\text{Number of moles} = \frac{\text{given mass}}{\text{atomic mass}}$$

Example 1. Calculate the number of moles in 81g of aluminium

$$\text{Number of moles} = \frac{\text{given mass}}{\text{atomic mass}} = \frac{81}{27} = 3 \text{ moles of aluminium}$$

Example 2. Calculate the mass of 0.5 mole of iron
Solution: mass = atomic mass x number of moles
= 55.9 x 0.5 = 27.95 g

2. Calculation of number of particles when the mass of the substance is given:

$$\text{Number of particles} = \frac{\text{Avogadro number} \times \text{given mass}}{\text{gram molecular mass}}$$

Example 1. Calculate the number of molecules in 11g of CO₂
Solution: gram molecular mass of CO₂ = 44g

$$\text{Number of particles} = \frac{6.023 \times 10^{23} \times 11}{44} = 1.51 \times 10^{23} \text{ molecules}$$

3. Calculation of mass when number of particles of a substance is given:

$$\text{Mass of a substance} = \frac{\text{gram molecular mass} \times \text{number of particles}}{6.023 \times 10^{23}}$$

Example 1. Calculate the mass of 18.069 x 10²³ molecules of SO₂
Sol: Gram molecular mass SO₂ = 64g

$$\text{Mass of SO}_2 = \frac{64 \times 18.069 \times 10^{23}}{6.023 \times 10^{23}} = 192g$$

Example 2. Calculate the mass of glucose in 2 x 10²⁴ molecules
Gram molecular mass of glucose = 180g

$$\text{Mass of glucose} = \frac{180 \times 2 \times 10^{23}}{6.023 \times 10^{23}} = 597.7g$$

4. Calculation of number of moles when you are given number of molecules:

$$\text{Number of moles of atom} = \frac{\text{Number of molecules}}{\text{Avogadro Number}}$$

Example 1. Calculate number of moles in 12.046 x 10²² atoms of copper

$$\text{Number of moles of atom} = \frac{\text{Number of molecules}}{\text{Avogadro Number}} = \frac{12.046 \times 10^{22}}{6.023 \times 10^{23}} = 0.2 \text{ moles}$$

INTEXT QUESTIONS PAGE NO. 42

Q1. If one mole of carbon atoms weighs 12 gram, what is the mass (in gram) of 1 atom of carbon?

Answer:

One mole of carbon atoms weighs 12 g (Given)

i.e., mass of 1 mole of carbon atoms = 12 g

Then, mass of 6.022 x 10²³ number of carbon atoms = 12 g

$$\text{Therefore, mass of 1 atom of carbon} = \frac{12}{6.022 \times 10^{23}} \text{ g} = 1.9926 \times 10^{-23} \text{ g}$$

Q2. Which has more number of atoms, 100 grams of sodium or 100 grams of iron (given, atomic mass of Na = 23 u, Fe = 56 u)?

Answer:

Atomic mass of Na = 23 u (Given)

Then, gram atomic mass of Na = 23 g

Now, 23 g of Na contains = 6.022×10^{23} number of atoms

Thus, 100 g of Na contains = $\frac{6.022 \times 10^{23}}{23} \times 100 = 2.6182 \times 10^{24}$ number of atoms

Again, atomic mass of Fe = 56 u (Given)

Then, gram atomic mass of Fe = 56 g

Now, 56 g of Fe contains 6.022×10^{23} number of atoms

Thus, 100 g of Fe contains = $\frac{6.022 \times 10^{23}}{56} \times 100 = 1.0753 \times 10^{24}$ number of atoms

Therefore, 100 grams of sodium contain more number of atoms than 100 grams of iron.

EXERCISE QUESTIONS PAGE NO. 43, 44

Q1. A 0.24 g sample of compound of oxygen and boron was found by analysis to contain 0.096 g of boron and 0.144 g of oxygen. Calculate the percentage composition of the compound by weight.

Answer:

Mass of boron = 0.096 g (Given)

Mass of oxygen = 0.144 g (Given)

Mass of sample = 0.24 g (Given)

Thus, percentage of boron by weight in the compound = $\frac{0.096}{0.24} \times 100 = 40\%$

And, percentage of oxygen by weight in the compound = $\frac{0.144}{0.24} \times 100 = 60\%$

Q 2. When 3.0 g of carbon is burnt in 8.00 g oxygen, 11.00 g of carbon dioxide is produced. What mass of carbon dioxide will be formed when 3.00 g of carbon is burnt in 50.00 g of oxygen? Which law of chemical combination will govern your answer?

Answer:

Carbon + Oxygen → Carbon dioxide

3 g of carbon reacts with 8 g of oxygen to produce 11 g of carbon dioxide.

If 3 g of carbon is burnt in 50 g of oxygen, then 3 g of carbon will react with 8 g of oxygen.

The remaining 42 g of oxygen will be left un-reactive.

In this case also, only 11 g of carbon dioxide will be formed.

The above answer is governed by the law of constant proportions.

Q 3. What are polyatomic ions? Give examples.

Answer:

A polyatomic ion is a group of atoms carrying a charge (positive or negative). For example, ammonium ion (NH_4^+), hydroxide ion (OH^-), carbonate ion (CO_3^{2-}), sulphate ion (SO_4^{2-})

Q 4. Write the chemical formulae of the following.

- (a) Magnesium chloride
- (b) Calcium oxide
- (c) Copper nitrate
- (d) Aluminium chloride
- (e) Calcium carbonate.

Answer:

(a) Magnesium chloride → MgCl_2

- (b) Calcium oxide \rightarrow CaO
- (c) Copper nitrate \rightarrow Cu(NO₃)₂
- (d) Aluminium chloride \rightarrow AlCl₃
- (e) Calcium carbonate \rightarrow CaCO₃

Q 5. Give the names of the elements present in the following compounds.

- (a) Quick lime
- (b) Hydrogen bromide
- (c) Baking powder
- (d) Potassium sulphate.

Answer:

- (a) Quick lime

Chemical formula : CaO

Elements present: Calcium, Oxygen

- (b) Hydrogen bromide

Chemical formula : HBr

Elements present: Hydrogen, Bromine

- (c) Baking powder

Chemical formula : NaHCO₃

Elements present: Sodium, Hydrogen, Carbon, Oxygen

- (d) Potassium sulphate.

Chemical formula : K₂SO₄

Elements present: Potassium, Sulphur, Oxygen

Q 6. Calculate the molar mass of the following substances.

- (a) Ethyne, C₂H₂
- (b) Sulphur molecule, S₈
- (c) Phosphorus molecule, P₄ (Atomic mass of phosphorus = 31)
- (d) Hydrochloric acid, HCl
- (e) Nitric acid, HNO₃

Answer:

(a) Molar mass of ethyne, C₂H₂ = 2 × 12 + 2 × 1 = 26 g

(b) Molar mass of sulphur molecule, S₈ = 8 × 32 = 256 g

(c) Molar mass of phosphorus molecule, P₄ = 4 × 31 = 124 g

(d) Molar mass of hydrochloric acid, HCl = 1 + 35.5 = 36.5 g

(e) Molar mass of nitric acid, HNO₃ = 1 + 14 + 3 × 16 = 63 g

Q 7. What is the mass of _____

- (a) 1 mole of nitrogen atoms?
- (b) 4 moles of aluminium atoms (Atomic mass of aluminium = 27)?
- (c) 10 moles of sodium sulphite (Na₂SO₃)?

Answer:

(a) The mass of 1 mole of nitrogen atoms is 14 g.

(b) The mass of 4 moles of aluminium atoms is (4 × 27) g = 108 g

(c) The mass of 10 moles of sodium sulphite (Na₂SO₃) is

10 × [2 × 23 + 32 + 3 × 16] g = 10 × 126 g = 1260 g

Q 8. Convert into mole.

- (a) 12 g of oxygen gas
- (b) 20 g of water
- (c) 22 g of carbon dioxide.

Answer:

(a) 32 g of oxygen gas = 1 mole

Then, 12 g of oxygen gas = $\frac{12}{32}$ mole = 0.375 mole

(b) 18 g of water = 1 mole

Then, 20 g of water = $\frac{20}{18}$ mole = 1.11 moles (approx)

(c) 44 g of carbon dioxide = 1 mole

Then, 22 g of carbon dioxide = $\frac{22}{44}$ mole = 0.5 mole

Q 9. What is the mass of:

(a) 0.2 mole of oxygen atoms?

(b) 0.5 mole of water molecules?

Answer:

(a) Mass of one mole of oxygen atoms = 16 g

Then, mass of 0.2 mole of oxygen atoms = $0.2 \times 16 \text{ g} = 3.2 \text{ g}$

(b) Mass of one mole of water molecule = 18 g

Then, mass of 0.5 mole of water molecules = $0.5 \times 18 \text{ g} = 9 \text{ g}$

Q 10. Calculate the number of molecules of sulphur (S₈) present in 16 g of solid sulphur.

Answer:

1 mole of solid sulphur (S₈) = $8 \times 32 \text{ g} = 256 \text{ g}$

i.e., 256 g of solid sulphur contains = 6.022×10^{23} molecules

Then, 16 g of solid sulphur contains = $\frac{6.022 \times 10^{23}}{256} \times 16$ molecules

= 3.76×10^{22} molecules (approx)

Q 11. Calculate the number of aluminium ions present in 0.051 g of aluminium oxide.

(Hint: The mass of an ion is the same as that of an atom of the same element. Atomic mass of Al = 27 u)

Answer:

1 mole of aluminium oxide (Al₂O₃) = $2 \times 27 + 3 \times 16 = 102 \text{ g}$

i.e., 102 g of Al₂O₃ = 6.022×10^{23} molecules of Al₂O₃

Then, 0.051 g of Al₂O₃ contains = $\frac{6.022 \times 10^{23}}{102} \times 0.051$ molecules

= 3.011×10^{20} molecules of Al₂O₃

The number of aluminium ions (Al³⁺) present in one molecule of aluminium oxide is 2.

Therefore, the number of aluminium ions (Al³⁺) present in 3.011×10^{20} molecules (0.051 g) of aluminium oxide (Al₂O₃) = $2 \times 3.011 \times 10^{20} = 6.022 \times 10^{20}$

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- Avogadro's number represents the number of atoms in
 - 12g of Cl_2
 - 320g of sulphur
 - 32g of oxygen
 - 12.7g of iodine
- The number of moles of carbon dioxide which contain 8 g of oxygen is
 - 0.5 mol
 - 0.20 mol
 - 0.40 mol
 - 0.25 mol
- The total no of ions present in 111 g of CaCl_2 is
 - One mole
 - Two mole
 - Three mole
 - Four moles
- Which of the following weighs the most ?
 - one g-atom of nitrogen
 - One mole of water
 - One mole of sodium
 - One molecule of H_2SO_4
- 5.0 litre of 0.4 M H_2SO_4 Contains-
 - 2.0 Mole Of H_2SO_4
 - 0.4 mole H_2SO_4
 - 5.0 mole H_2SO_4
 - 2.0 moles H_2O
- Which of the following correctly represents 360 g of water?
 - 2 moles of H_2O
 - 20 moles of water
 - 6.022×10^{23} molecules of water
 - 1.2044×10^{25} molecules of water
 - (i) (b) (i) and (iv)
 - (ii) and (iii) (d) (ii) and (iv)
- Which of the following statements is not true about an atom?
 - Atoms are not able to exist independently
 - Atoms are the basic units from which molecules and ions are formed
 - Atoms are always neutral in nature
 - Atoms aggregate in large numbers to form the matter that we can see, feel or touch
- The chemical symbol for nitrogen gas is
 - Ni
 - N_2
 - N^+
 - N
- The chemical symbol for sodium is
 - So
 - Sd
 - NA
 - Na
- Which of the following would weigh the highest?
 - 0.2 mole of sucrose ($\text{C}_{12}\text{H}_{22}\text{O}_{11}$)
 - 2 moles of CO_2
 - 2 moles of CaCO_3
 - 10 moles of H_2O

11. Which of the following has maximum number of atoms?
(a) 18g of H₂O
(b) 18g of O₂
(c) 18g of CO₂
(d) 18g of CH₄
12. Which of the following contains maximum number of molecules?
(a) 1g CO₂
(b) 1g N₂
(c) 1g H₂
(d) 1g CH₄
13. Mass of one atom of oxygen is
(a) $\frac{16}{6.023 \times 10^{23}} \text{ g}$ (b) $\frac{32}{6.023 \times 10^{23}} \text{ g}$ (c) $\frac{1}{6.023 \times 10^{23}} \text{ g}$ (d) 8u
14. 3.42 g of sucrose are dissolved in 18g of water in a beaker. The number of oxygen atoms in the solution are
(a) 6.68×10^{23}
(b) 6.09×10^{22}
(c) 6.022×10^{23}
(d) 6.022×10^{21}
15. A change in the physical state can be brought about
(a) only when energy is given to the system
(b) only when energy is taken out from the system
(c) when energy is either given to, or taken out from the system
(d) without any energy change
16. Which of the following represents a correct chemical formula? Name it.
(a) CaCl (b) BiPO₄ (c) NaSO₄ (d) NaS
17. 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) acetate
18. Write the molecular formulae of all the compounds that can be formed by the combination of following ions
Cu²⁺, Na⁺, Fe³⁺, Cl⁻, SO₄²⁻, PO₄³⁻
19. Write the cations and anions present (if any) in the following compounds
(a) CH₃COONa
(b) NaCl
(c) H₂
(d) NH₄NO₃
20. Give the 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

21. Which of the following symbols of elements are incorrect? Give their correct symbols
- (a) Cobalt CO
 - (b) Carbon c
 - (c) Aluminium AL
 - (d) Helium He
 - (e) Sodium So
22. Give the chemical formulae for the following compounds and compute the ratio by mass of the combining elements in each one of them.
- (a) Ammonia
 - (b) Carbon monoxide
 - (c) Hydrogen chloride
 - (d) Aluminium fluoride
 - (e) Magnesium sulphide
23. State the number of atoms present in each of the following chemical species
- (a) CO_3^{2-}
 - (b) PO_4^{3-}
 - (c) P_2O_5
 - (d) CO
24. Find the ratio by mass of the combining elements in the compound – $\text{C}_2\text{H}_5\text{OH}$.
25. Give the formula of the compound formed by the elements calcium and fluorine.
26. What is the acid radical present in sodium peroxide?
27. Carbon and silicon have the same valency. What is the formula of sodium silicate?
28. What is the ratio by number of atoms in mercurous chloride?
29. Name the element whose Latin name is Stibium.
30. What is the valency of a sulphide ion?
31. How many atoms of oxygen are present in 50g of CaCO_3 ?
32. How many molecules are present in 1 ml of water?
33. What is the unit of measurement of atomic radius?
34. Name the international organization who approves names of elements.
35. How do we know the presence of atoms if they do not exist independently for most of the elements?
36. Give an example to show Law of conservation of mass applies to physical change also.
37. Explain with example that law of conservation of mass is valid for chemical reactions.
38. Is there any exception to law of conservation of mass?
39. In a reaction, 5.3 g of sodium carbonate reacted with 6 g of ethanoic acid. The products were 2.2 g of carbon dioxide, 0.9 g water and 8.2 g of sodium ethanoate. Show that these observations are in agreement with the law of conservation of mass.
- sodium carbonate + ethanoic acid \rightarrow sodium ethanoate + carbon dioxide + water
40. If 12 g of carbon is burnt in the presence of 32 g of oxygen, how much carbon dioxide will be formed?