MOLE CONCEPT

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An element is a pure substance that contains only one kind of particles which may be atom or molecule.

ATOMS: An atom is the smallest particle of an element which may or may not be capable of independent existence.

For example: Iron, copper, silver, gold etc. can exist freely. Hydrogen, oxygen, nitrogen etc. cannot exist freely but they exit as H_2, O_2, and N_2

MOLECULE: A molecule is the smallest particle of an element or a compound which can exist freely. For example: Molecules of elements N_2 , H_2 , O_2 can exist freely. Molecules of compounds—H_2O , NH_3 , CO_2 etc. exist freely .

Atomic Mass: The atomic masses of all the elements were obtained by comparing with the mass of hydrogen taken as 1 (because it was the lightest element). But by doing so, the atomic masses of most of the elements come out to be fractional. Hence, the reference was changed from hydrogen to oxygen taken as 16. However, a still better reference which now is widely accepted, has been found to be carbon taken as 12. On this basis, the relative mass of hydrogen comes out to 1.008 and that of oxygen as 15.9994 or 16. Hence atomic mass of an element may be defined as follows:

"The atomic mass of an element is the number of times an atom of that element is heavier than an atom of carbon taken as 12".

Atomic masses are expressed as relative masses i.e., with reference to mass of a standard atom. These masses on the atomic mass scale are expressed in terms of "atomic mass unit"(amu).

"One atomic mass unit is equal to $1/12^{th}$ of the mass of an atom of carbon-12 isotope".

Now-a-days, all atomic masses are expressed on the ${}^{12}_{6}C$ scale, taking mass of this isotope as exactly 12. This scale is called unified scale. Symbol 'μ' is used instead of 'amu' The atomic masses of the element have been determined accurately during the recent years using an instrument called 'mass spectrometer'. It is found that in a number of cases, atoms of the same element posses different masses (isotopes). In such cases, the atomic mass of the element is taken as the average value. For example—ordinary chlorine is a mixture of two isotopes with atomic masses 35μ and 37μ . They are present in the ratio of 3:1. Hence, average mass of chlorine would be $35x3+37x1\div3+1=35.5\mu$

"The atomic mass of an element is the average relative mass of its atoms as compared with an atom of carbon-12 taken as 12".

GRAM ATOMIC MASS: The atomic mass of an element expressed in grams is called gram atomic mass. This amount of the element is also called one gram atom.

For example: Atomic mass of oxygen =16amu, Gram atomic mass of oxygen=16g or one gram atom of oxygen=16g

MOLECULAR MASS: Molecular mass of a substance refers to the relative mass of its molecule.

"The molecular mass of a substance (element or compound) is the number of times of molecules of substance is heavier than $1/12^{th}$ the mass of an atom of carbon -12 isotope."

OR,

" The molecular mass of a substance is the average relative mass of its molecules as compared with an atom of carbon -12 isotope taken as 12".

For example: Molecular mass of H_2SO_4 is equal to:

2x at. mass of H + at. mass of S + 4x at. mass of O

$2x1 +32.0 + 4x\ 16=98.0\mu$

GRAM MOLECULAR MASS: The molecular mass of a substance expressed in grams is called it gram molecular mass. This amount of the substance is also called one gram molecule.

For example: Molecular mass of H_2SO_4=98.0u, Gram molecular mass of H_2SO_4 = 98 .0g OR one gram molecule of H_2SO_4.

FORMULA MASS AND GRAM FORMULA MASS: Ionic compounds such as NaCl, KNO_3, Na_2CO_3 etc. do not consist of molecule i.e., single entities but exist as ions closely packed together in three dimensional space. Each ion is surrounded by a number of oppositely charged ions. For example – in NaCl, each Na^+ ion is surrounded by six Cl^- ions and vice versa. Hence in such cases, the formula is used to calculate the formula mass instead of molecular mass.

For example: Formula mass of NaCl = At. Mass of Na + At. Mass of Cl =23.0 +35.5 = 58.5u, mass of one formula unit = 58.5u .

Gram formula mass is expressed in grams e.g. gram formula mass of NaCl = 58.5g

MOLE: Quite commonly, we use different units for counting such as dozen for 12 articles, score for 20 articles and gross for 144 articles, irrespective of their nature. In a similar way, chemists use the unit 'mole' for counting atoms, molecules, ions etc. A mole is a collection of $6.022x10^{23}$particle.

A mole represents $6.022x10^{23}$particles.

The number $6.022x10^{23}$ is called Avogadro number denoted by 'N'.

For example:

1 mole of hydrogen atoms = $6.022x10^{23}$ hydrogen atoms

1mole of hydrogen molecules = $6.022x10^{23}$ hydrogen molecules.

1 mole of sodium ions = $6.022x10^{23}$ sodium ions.

1 mole of electrons = $6.022x10^{23}$ electrons

Mole in terms of mass

A mole is defined as the amount of substance that contains the same number of entities (atoms, molecules, ions, or other particles), as the number of atoms present in 12g of the carbon-12 isotope . Number of atoms in 1 mole of C-12 = 12g/mole of C-12 ÷ 1.992648×10^{-23}g/atoms of C $=6.022137x10^{23}$atom/mole for simplicity $=6.022x10^{23}$ atoms / mole.

Mass of one carbon atom $=1.992648x10^{-23}$g

Mass of $6.022x10^{23}$ atoms (or one mole atoms) of any element in grams is equal to its gram atomic mass or one gram atom.

Mass of $6.022x10^{23}$ atoms of oxygen= 16g

Mass of $6.022x10^{23}$ atoms of sodium= 23g

Mass of $6.022x10^{23}$ atoms of Argon= 40g

One mole of atoms ≡ $6.022x10^{23}$ atoms ≡ Gram atomic mass of the element

No. of mole = given no. of particles ÷ $6.022x10^{23}$

Mole and Gram molecular Mass: Mass of $6.022x10^{23}$ molecules (or 1 mole molecules) of any substance in gram is equal to its gram molecule mass or one gram molecule.

For example: The mass of 1 mole molecules ($6.022x10^{23}$ molecules) of water is equal to 18g.

One gram mole molecules of oxygen = 32g

One gram mole molecules of CO_2 = 44g

$6.022x10^{23}$ molecules of CO_2 = 44g

One mole of molecules ≡ $6.022x10^{23}$ molecules ≡ Gram molecular mass

Mass of $6.022x10^{23}$ formula units (or one mole formula units) of any ionic substance in grams is equal to its gram formula mass.

For example: A mole of NaCl = 58.5 = $6.022x10^{23}$ formula units of NaCl OR $6.022x10^{23}$ Na^+ ions and $6.022x10^{23}$ Cl^- ions

1 mole of $CaCl_2$ = 111g = $6.022x10^{23}$ Ca^{+2} ions and 2x $6.022x10^{23}$ Cl^- ions

The mass of 1 mole of a substance is called its molar mass.

For example: Molar mass of sodium atoms=mass of 1 mole of sodium atoms =23g/mole =$6.022x10^{23}$ sodium atoms.

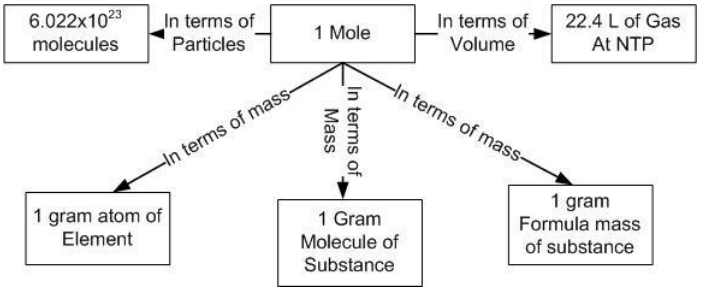
Molar mass of H_2O molecules = mass of 1 mole of H_2O molecules = 18g mol^{-1} = $6.022x10^{23}$ H_2O molecules

Molar mass of NaCl= mass of 1mole of NaCl formula unit =58.5g mol^{-1} =$6.022x10^{23}$ formula units of NaCl

Mole in terms of volume

Mole is also related to the volume of the gaseous substance. Volume of one mole of any substance is called its molar volume. One mole of an ideal gas occupies 22.4L at N.T.P ($O^{\circ}C$ and 1 atm. Pressure). i.e., $6.022x10^{23}$ molecules.

For example: 1 mole of Hydrogen gas at N.T.P = 22.4 L , 1 mole of CO_2 gas at N.T.P = 22.4 L Molecular mass = Molar Volume x Density



One mole of atoms = $\frac{mass\,of\ an\,element}{atomic\ mass}$

Mass of one atom = $\frac{atomic\ mass}{6.022x10^{23}}$

Mole of a compound = $\frac{mass\,of\ compound}{molecular\ mass}$

Mass of one molecules = $\frac{molecular\ mass}{6.022x10^{23}}$

One mole of gas at N.T.P = 22.4 L

Calculate the number of moles in each of the following :

(1) 392g of sulphuric acid (H_2SO_4) , (2) 44.8L of CO_2 at N.T.P,

(3) $6.022x10^{23}$ molecules of oxygen, (4) 9.0g of aluminium

Solution:

(1) 1 mole of H_2SO_4 = 98g (M. mass = 2x1+32+4x16 = 98g)

Thus, 98g of H_2SO_4 =1 mole of H_2SO_4

∴ 392g of H_2SO_4 = 1x392/ 98 = 4 mole of H_2SO_4

(2) 1 mole of CO_2 = 22.4L at N.T.P

22.4L of CO_2 at N.T.P = 1 mole

$\therefore$ 44.8 L of CO_2 at N.T.P = 1x44.8/22.4 = 2 mole of CO_2

(3) $6.022x10^{23}$ molecules of O_2 = 1 mole of O_2 molecules

(4) 1 mole of Al =27g of Al (At. Mass of Al = 27u)

27g of Al =1 mole of Al

9g of Al = 1x9/27 = 0.33 mole of Al

Assignment

(1) One mole of CO_2 contains

(a) $6.022x10^{23}$ atoms of C (b) $6.02x10^{23}$ atoms of O

(c) $18.1x10^{23}$ molecules of CO_2 (d) 3g atoms of CO_2

(2) The mass of one molecule of oxygen is

(a) 32g (b) $32/6.02x10^{23}$g (c) $16/6.02x10^{23}$g (d) 0.32g

(3) 1 mole of methane (CH_4) contains

(a) $6.02x10^{23}$ atoms of H (b) 4g atoms of hydrogen

(c) $1.81x10^{23}$ molecules of methane (d) 3.0g of carbon

(4) Avogadro number is the number of molecules present in:

(a) 1L of a gas at N.T.P (b) 1 ml of a gas at N.T.P

(c) 22.4 of a gas at N.T.P (d) 1 ml of a gas at 0°C and 1 atm. Pressure

(5) The mass of an atom of carbon is

(a) 1g (b) 1/12g

(c) $1.99x10^{-23}$ g (d) $1.99x10^{23}$g

Answers

(1) a (2) b (3) b (4) c (5) c

Author is M.Sc. (Chem.), M.Ed. and Advanced Diploma in German Language (Gold Medallist). She retired as a Principal, Govt. School Haryana, has 3-1/2 years' experience in teaching Chemistry and distance teaching through lectures on Radio and Videos. She has volunteered to complement mentoring of students for Chemistry through Online Web-enabled Classes of this initiative.
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