MOLE CONCEPT (VIDEO)

Relative mass: It is the method of expressing mass of one atom in terms of mass of a standard atom. 1/12th mass of carbon-12 isotope is taken as the standard for stating mass of atoms. 1/12th mass of carbon –12 atom is called unified mass 'u'.

It is equivalent to 1.6606×10^{-27} kg .

For example relative atomic mass of nitrogen is 14. It means that mass of a nitrogen atom is 14 times heavier than 1/12th mass of a carbon – 12 atom.

A few elements and their atomic masses are given.

Element	Atomic mass (in u)
Hydrogen H	1
Helium He	4
Carbon C	12
Nitrogen N	14
Oxygen O	16
Phosphorous P	31
Chlorine Cl	35.5
Sulphur S	32

Gram atomic mass (GAM)

The mass of an element in gram equal to its atomic mass is called 1 gram atomic mass (one gram atom)

Example: 4 g He = 1 GAM Helium, 12 g C = 1 GAM Carbon,
16 g O_2 = 1 GAM Oxygen.

Gram atomic mass and Avogadro number

One gram atom of any element contains 6.022×10^{23} atoms. This number is known as **Avogadro number**.

That is, 4 gm of Helium, 12 g of Carbon, 16 g of oxygen and 35.5 g of chlorine contain the same number of atoms and is equal to 6.022×10^{23}

Finding number of atoms in certain amount of element.

Number of atoms = [mass of sample/GAM of the element] x Avogadro number.

Element	GAM of the element.	Mass of the sample	Number of atoms
H	1	20 g	$(20/1) \times 6.022 \times 10^{23} = 20 \times 6.022 \times 10^{23}$
He	4	40 g	$(40/4) \times 6.022 \times 10^{23} = 10 \times 6.022 \times 10^{23}$
O	16	48 g	$(48/16) \times 6.022 \times 10^{23} = 3 \times 6.022 \times 10^{23}$
C	12	120 g	$(120/12) \times 6.022 \times 10^{23} = 10 \times 6.022 \times 10^{23}$

Mole and One mole atom

The amount of any substance containing 6.022×10^{23} particles is called one mole.

Hence one mole atom means 6.022×10^{23} atoms.

So one mole atoms of carbon = 12 g

1 mole atoms of hydrogen = 1 g   1 mole atom of oxygen = 16 g

<u>Molecular mass</u>: Molecular mass is the total atomic masses of atoms present in one molecule.
Example: Molecular mass of water((H_2O) = 2x1 + 16 = 18
Molecular mass of methane (CH_4) = 1x12 + 4x1 = 12+4 = 16
Molecular mass of sulphuric acid (H_2SO_4) = 2x1+1x32+4x16 = 98

Gram molecular mass (GMM)

The mass in grams equal to the molecular mass of a substance is called gram molecular mass.
Example:i) 18 g water = 1 GMM water. ii)16 g methane(CH_4) = 1 GMM methane
iii) 98 g sulphuric acid = 1 GMM H_2SO_4.

Relation between GMM and number of molecules.

One gram molecular mass of any substance contains Avogadro Number of molecules.
That is, 18 g of water, 16 g of methane, 98 g of sulphuric acid contains same number of molecules and is equal to $6.022x10^{23}$

<u>Mole concept:</u> The amount of any substance containing $6.022x10^{23}$ particles is called one mole. The particle may be atom, molecules,ions etc.. So when we express the amount of substance in mole, the type of particles should be specified. For example, one mole water molecule, three moles of carbon atoms.

Finding number of moles from given number of particles or given mass.

Number of moles = number of particles/N_A = mass of the substance / GAM
= mass of the substance /GMM

<u>See the following examples</u>.

? How many moles of atoms are present in 4g hydrogen?
Number of moles of hydrogen atoms = mass of the sample/ GAM of hydrogen = 4/1 = 4 mole.
*?How many moles of molecules are there in 4g hydrogen?
Number of moles of hydrogen molecules = mass of hydrogen/ molecular mass of hydrogen
= 4/2 = 2 mole
?Find out the number of moles in 54 g of water.
Number of moles of molecules in 54 g water = mass of given water/molecular mass of water
= 54/18 = 3 mole.
? Find out the number of molecules in 220 g CO_2 . (Atomic mass C-12, O -16)
Molecular mass of CO_2 = 12+2x16 =44
Number of moles in 220 g CO_2 = 220/44 = 5
Therefore, number of molecules in 220 g CO_2 = $5x6.022x10^{23}$ = $30.11x10^{23}$
?Calculate number of moles of atoms, number of atoms, number of moles of molecules and number of molecules in 700 g of nitrogen (N_2).
Atomic mass of nitrogen = 14 Molecular mass of nitrogen= 2x14 =28
Number of moles of atoms**= 700/14 = 50**
Number of nitrogen atoms **= 50x $6.022x10^{23}$ = $301.1x10^{23}$**
Number of moles of molecules = **700/28 = 25**
Number of nitrogen molecules = $25x6.022x10^{23}$ = **$150.55x10^{23}$**
? How many atoms are present in 36 g of water?
Molecular mass water (H_2O) = 2x1+16 =18
Number of moles of molecules in 36 g water = 36/18 = 2
Number of molecules 36 g water = $2x6.022x10^{23}$
As there are three atoms in each molecules of water,
total number of atoms =3x**$2x6.022x10^{23}$** = $6x6.022x10^{23}$
? Calculate the mass of one sulphuric acid molecule (H_2SO_4)
Molecular mass of (H_2SO_4) = 2x1+1x32+4x16 = 98
Therefore mass of $6.022x10^{23}$ sulphuric acid molecules = 98 g

Then, mass of one sulphuric acid molecule = 98/6.022x10^{23} g
*?Calculate the number of atoms and molecules present in 90 g glucose ($C_6H_{12}O_6$)
Molecular mass of glucose ($C_6H_{12}O_6$) = 6x12+12x1+6x16 = 72+12+96 = 180
Number of molecules in 90 g glucose = mass of the sample/ molecular mass = 90/180 = ½
Therefore the number of molecules in 90 g glucose = ½ x N_A = ½x6.022x10^{23} = 3.011x10^{23}
As there are 24 atoms in each molecules, number of atoms in 90 g glucose
= 24 x3.011x10^{23} =72.264x10^{23}

<u>Relationship between volume of a gas and moles.</u> The volume of one mole of gas at a definite temperature and volume is called **molar volume**. At same temperature and pressure, molar volume of all gases will be same. At standard temperature and pressure 'STP' (at 1 atm pressure and 0°C temperature) molar volume of all gases is 22.4 litre. That is, **6.022x10^{23} molecules are present in 22.4 litre of any gas at STP.**

<u>Finding number of moles from volume at STP.</u>

Number of moles = volume at STP/ 22.4
? Carbon dioxide gas (CO_2) is stored in a cylinder of capacity 67.2 litre at 0°C temperature and atmospheric pressure. Calculate number of molecules, number of atoms and mass of the carbon dioxide gas in the cylinder.
Number of moles = Volume of gas at STP/22.4 = 67.2/22.4 = 3
Number of molecules in 3 moles = 3x 6.022x10^{23} =**18.006x10^{23}**
As there are three atoms in each CO_2 molecule,
Total number of atoms = 3x18.006x10^{23} =54.198x10^{23}
Mass of one mole of CO_2 = 44 g.
Therefore mass of 3 mole of CO_2 = 3x44 g = 132 g.
That is, mass of 67.2 litre carbon dioxide gas at STP will be 132 g.

ABSTRACT
One mole = Avogadro number of atoms = Avgadro number of molecules = 1 GAM = amount of substance equal to atomic mass in gram= 1GMM= amount of substance equal to molecular mass in gram = 22.4 litre of any gas at STP.
Number of moles = number of atoms/N_A = number of molecules/N_A = mass in gram /atomic mass = mass in gram/ molecular mass = volume in litre at STP/22.4
Mass of substance = number of moles x molecular mass **Volume of a gas at STP =number of moles x 22.4** **Number of molecules = number of moles x N_A**

PRACTICE QUESTIONS AND ANSWERS

1. Amount of a few substance are given. Find the number of GMMs present in each sample?
a. 100 g He. b. 200 g O_2. c. 70 g N_2. d. 1 g Ca.
(Hint: Atomic mass: He – 4, O – 16, N – 14, Ca – 40)
Answer:Helium: 100/4 = 25, Oxygen: 200/2x16 = 6.25, Nitrogen: 70/2x14 = 2.5,
Calcium: 1/40 = 0.025

2. Find the gram molecular mass of the following substances.
a. Nitric acid HNO_3 b. Calcium chloride $CaCl_2$. c. Sodium sulphate Na_2SO_4
d. Ammonium nitrate NH_4NO_3
(Hint : Atomic mass: H–1,N-14,O–16, Na -23, S – 32, Cl – 35.5, Ca -40)
Answer: a.HNO_3 : 1x1+1x14+3x16 = 1+14+48 = 63g
b. $CaCl_2$: 1x40+2x35.5 = 40+71 = 111 g
c.Na_2SO_4 : 2x23+1x32+4x16 = 142 g
d. NH_4NO_3 : 1x14+4x1+1x14+3x16 = 14+4+14+48 = 80 g

3. Some samples are given below.
i. 400 g of water(H_2O). ii. 400 g of carbon iii. 400 g of helium (He)
iv. 400 g of glucose ($C_6H_{12}O_6$)
a. Find number of moles in each sample. b. Write them in increasing order of mole number.
Answer: a.i. 400/18 = 22.22 a.ii. 400/12 = 33.33 a.iii. 400/4 = 40 a.iv. 400/180 = 2.22
b. 400 g glucose - 400 g water - 400 g carbon - 400 g helium

4. Find out the following.
a. Number of moles in 1 kg of water. b. Mole numbers in 500 g of $CaCO_3$.
c. Number of molecules and atoms present in 88 g of CO_2..
d. Volume of 170 g ammonia (NH_3) at STP.
e. Mass and number of molecules in 56 L CO_2 at STP.
Answer: a. Molecular mass of water (H_2O) = 2x1+16 = 18
Number of moles in 1 kg of water = 1000/18 = 55.56
b. Molecular mass of $CaCO_3$ = 1x40+1x12+3x16= 100
Number of moles in 500 g $CaCO_3$ = 500/100 = 5
c. Molecular mass of CO_2 = 1x12+2x16 = 44
Number of moles in 88 g CO_2 = 88/44 = 2
Number of molecules in 88 g CO_2 (in 2 mole CO_2) = $2x6.022x10^{23}$ = $12.044x10^{23}$
Number of atoms in 88 g CO_2 = $3x12.044x10^{23}$ = $36.132x10^{23}$
d. Molecular mass of ammonia = 1x14+3x1 =17
Number of moles in 170 g NH_3 = 170/17 =10
Volume of 170 g of ammonia at STP = 10x22.4 = 224 L
e. Number of moles in 56 L CO_2 = 56/22.4 = 2.5
Mass of 2.5 mole CO_2 = 2.5x44 = 110 g.
Number of molecules in 2.5 mole CO_2 = $2.5x6.022x10^{23}$ = $15.055x10^{23}$

5. Examine the samples given below.
P. 22.4 L NH_3. (at STP) Q.22 g CO_2. R.64 g SO_2.
S.4 g H_2. T. $6.022x10^{23}$ C atoms. U. 117 g NaCl. V. $3.011x10^{23}$ oxygen molecules.
a. Group the samples having same number of moles of molecules.
b. Which are the samples in which number of molecules are same?
c. Group the samples where number of atoms are same.
d. Calculate the mass of the sample P .

Answer:

substance	Number of moles of molecules	Number of molecules	Number of atoms	Volume(L)
P. 22.4 L NH_3	22.4/22.4 = 1	$6.022x10^{23}$	$4x6.022x10^{23}$	[redacted]
Q. 22 g CO_2	22/44 = ½	½ $x6.022x10^{23}$	3x½ $x6.022x10^{23}$	½x22.4 =11.2
R. 64 g SO_2	64/64=1	$6.022x10^{23}$	$3x6.022x10^{23}$	22.4
S. 4 g H_2	4/2=2	$2x6.022x10^{23}$	$2x2x6.022x10^{23}$	2x22.4=44.8
T.$6.022x10^{23}$ C	$6.022x10^{23}$ /$6.022x10^{23}$ =1	$6.022x10^{23}$	$6.022x10^{23}$	[redacted]
U. 117 g NaCl	117/58.5=2	$2x6.022x10^{23}$	$2x2x6.022x10^{23}$	[redacted]
V.$3.011x10^{23}$ O_2	$3.011x10^{23}/6.022x10^{23}$= ½	½ $x6.022x10^{23}$	$2x1/2x6.022x10^{23}$ $=6.022x10^{23}$	1/2x22.4 =11.2

a. P,R,T =1 Q,V = ½ S,U =2 b. P,R,T Q,V S,U c. P,S,U T,V
d. Mass of a substance = number of moles x molecular mass = 1x17=17 g.
6. Volume of a cylinder, that contains NH_3 at STP, is 5600 mL.
a. How many moles of ammonia are present in the cylinder?
b. What is the mass of the ammonia gas in it?
c. Find out the number of molecules and atoms in the cylinder?
Answer: a.Number of moles of ammonia = 5.6L/22.4 = 5.6/22.4 = ¼
b. Mass of the ammonia gas = ¼ x 17 = 4.25 g
c. Number ammonia molecules = Number of moles x Avgadro number = ¼ x $6.022x10^{23}$
Total number number of atoms = $4x¼x6.022x10^{23}$= $6.022x10^{23}$
7. The dimension of a room is 2mx3mx2m. If the room is filled with oxygen at 0°C of temperature and atmospheric pressure,
a. What will be the volume of oxygen? b. How many grams of oxygen are present in the room?
c. Calculate the number of molecules in the room.
Answer: a. Volume of oxygen = volume of the room = 2x3x2=$12m^3$ = 12000L.
b. Mass of the oxygen gas = number of moles x molecular mass of oxygen
= (12000/22.4) x 32 = 535.7 x 32 = 17142.4 g.
c. Number of oxygen molecules = number of moles x Avogadro number = 535.7 N_A.
8. Find out the odd one from the given sets.
a. 11.2 L NH_3 at STP, 22 g CO_2, $6.022x10^{23}$ water molecules, 9 g of water.
b. One mole water(H_2O), One mole CO_2, One mole ozone(O_3), one mole hydrogen(H_2)
c. $2N_A$ H_2 atoms, 2x 22.4 L H_2 at STP, 2 g H_2 gas, $6.022x10^{23}$ hydrogen molecules.
Answer:a. $6.022x10^{23}$ water molecules. (All others are ½ mole substances)
b. one mole hydrogen(H_2)- Number of atoms are equal in all other samples.
c. 2x 22.4 L H_2 at STP - Others are one mole .
9. Complete the second pair according to the first pair.
a. 1 GAM nitrogen : $6.022x10^{23}$ atoms
1 GMM nitrogen : …......... molecules.
b. 1GMM carbon: 12 g carbon; 1GAM carbon: …..........
c. 1 GAM chlorine: 35.5 g ; One GMM chlorine: …..... g.
Answer:a. $6.022x10^{23}$. b. 12 g of carbon. c. 71 g.
10. Chemical formula of ammonia is NH_3 . (Atomic mass: N-14, H-1)
a. Find molecular mass of ammonia.
b. How many moles of molecules are present in 51 gm of ammonia?
c. Calculate the number of molecules in 51 g of ammonia.

d. What is meant by standard temperature and pressure (STP)?
e. What will be the volume of 51 g of ammonia at STP?
Answer: a. Molecular mass of NH_3 = 1x14 + 3x1 = 17
b. Number of moles of molecules in 51 g of ammonia = 51/17 = 3
c. Number of molecules in 51 g of ammonia= $3x6.022x10^{23}$ =$18.066x10^{23}$
d. It is physical condition of 273 K (0°C) temperature and one atm pressure.
e. Volume of 51 g ammonia at STP = 3 x22.4 = 67.2 litre.
11. Some samples are given.
(I). 80 g of helium(He). (ii) 320 g of methane(CH_4). (iii) 140 g of nitrogen(N_2).
(Hint: Atomic mass: He – 4, C -12, H -1, N-14)
a. Calculate the number of atoms in the first sample.
b. How many molecules are there in the third sample?.
c. Find out the samples in which the number of molecules are same.
Answer: a. Number of moles of atoms in 80 g helium = 80/4 = 20
So the number of helium atoms = 20 N_A.
(Note: As helium is a mono atomic element, the number of atoms and molecules are the same)
b. The number of moles molecules in 140 g of nitrogen = 140/28= 5
There fore, the number of molecules in 140 g of nitrogen = $5xN_A$.
c. Number of molecules in 320 g of methane = $(320/16)xN_A$. = $20N_A$.
So the number of molecules in 1st and 2rd sample are same.
12. Some information about the three gases at STP are given below.
A. 16 g CH_4. B. 11.2 L CO_2. C. $6.022x10^{23}$ NH_3 molecules.
a. The number $6.022x10^{23}$ is called …..........
b. Find the number of moles of molecules in 16 g of CH_4
c. Write down the samples A,B &C in the increasing order of mass.
(Atomic mass : H=1 C=12 N=14,O=16)
Answer: a. Avogadro number.
b. Number of moles in 16 g of CH_4 = mass of the substance/molecular mass =16/16 = 1 mole.
Number of molecules in 16 g of CH_4 =1x $6.022x10^{23}$ = $6.022x10^{23}$
c. 11.2 L CO_2. = ½ mole of CO_2 = ½ x molecular mass of CO_2 = ½ x 44 = 22 g
$6.022x10^{23}$ number of NH_3 molecules = 1GMM of NH_3 = 17 g.
A,C,B is the increasing order of mass.
13.A,B and C are three cylinders of 11.2 L capacity. They are filled with the gases of H_2,O_2 and N_2 respectively at STP.
a. Find the number of moles of molecule of H_2 in cylinder A.
b. Calculate the number of O_2 molecules in the cylinder B.
c. If the volume of nitrogen gas in the cylinder C is doubled at STP, what will be the mass then? (Hint: Atomic mass: H=1, O=16,N=14)
Answer:a. Number of moles in 11.2 L of hydrogen at STP
= Volume at STP /22.4 = 11.2/22.4 =½ mole.
b. Number of moles in 11.2 L of O_2 at STP = ½
Number of oxygen molecules in ½ mole O_2 = ½ x $6.022x10^{23}$= $3.011x10^{23}$
c.Volume of nitrogen gas when it is doubled = 2x11.2 = 22.4 L = 1 mole.
Mass of 1 mole of nitrogen = 1x28 = 28 g.
14. Atomic masses : H-1,S-32,O-16
a. Calculate the molecular mass of sulphuric acid (H_2SO_4) .
b. Find out the number of moles in 49 gm of H_2SO_4 ?
c. How many molecules are present in 980 gm of H_2SO_4 ?
Answer: a. Molecular mass = 2x1+1x32+ 4x16 = 98
b. Number of moles in 49 g of H_2SO_4 = 98/49 = ½ mole.

c. Number of molecules in 980 g of H_2SO_4 = number of molesxAvogadro number
= (980/98)x $6.022X10^{23}$= =$6.022X10^{24}$
15. Mass, number of molecules and volume at STP in respect of four gases are given.
(Atomic mass: H-1,N-14,O-16,C-12) Find the values of A,B,C and D.

Gas	Mass (in g)	Volume (in L)	Number of molecules
H_2	4	44.8	…...A......
CO_2	220	112	…......B......
NH_3	…....C........	22.4	$6.022x10^{23}$.
CH_4	16	…....D....	$6.022x10^{23}$.

Answer: A = $2x6.022x10^{23}$ B = $5x6.022x10^{23}$ C =17 g D = 22.4
16.a. Chemical formula for a few compounds are given.
I.$CaCO_3$ ii. CO_2. (Hint: Atomic mass: Ca-40, C -12, O-16)
a. Find the molecular mass of the compounds.
b. (i)One mole of which of the above compound likely to have 22.4 L volume at STP?
(ii) How many moles will be present in 112 L of this compound?

Answer: a. $CaCO_3$ – 1x40+1x12+3x16 = 100. CO_2 – 1x12 +2x16 = 44
b. (i). CO_2 Because it is a gas. (ii) Number of moles in 112 L of CO_2 = 112/22.4 =5
17. $6.022x10^{23}$ carbon atoms are present in 12 g of carbon.
a. The number $6.022x10^{23}$ is known as …........
b. Calculate the number carbon atoms in 48 gm of C-12
c. Which weighs more, $6.022x10^{23}$ molecules of CO_2 or $6.022x10^{23}$ molecules of H_2O?
Answer: a. Avogadro number. b.48 g of C-12 =48/12 = 4 mole = 4 x $6.022x10^{23}$ atoms.
c. One mole of CO_2 = 1x12+2x16 =44 g One mole of H_2O= 2x1+16 =18 g
Therefore $6.022x10^{23}$ CO_2 molecules will be weighed more.
18.At a definite temperature and pressure,volume of one mole all gases are same. This volume is called ..
Answer: Molar volume.
19. At STP molar volume of a gase will be ….... litre. **Answer**: 22.4 litre.
20. Match the contents of the columns A & B. .

A	B
a. 88 g CO_2	Avogadro number
b. $6.022x10^{23}$	196 g
c. 2 mole of H_2SO_4.	64 g O_2.

Answer

A	B
a. 88 g CO_2	64 g O_2.
b. $6.022x10^{23}$	Avogadro number
2 mole of H_2SO_4.	196 g