BYJU'S Classes

CHEMISTRY

MOLE CONCEPT

INTERCONVERSION FINALE

NOTES

What you already know

- Relative atomic mass
- Relative molecular mass
- Dalton's atomic theory
- Law of conservation of mass
- Law of definite proportions
- Law of multiple proportions

What you will learn

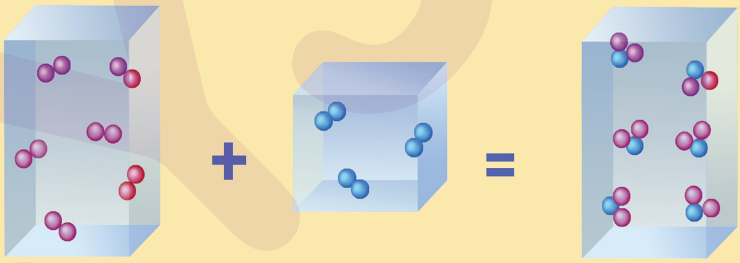
- Gay-Lussac's law
- Avogadro's law
- Relative density, Specific gravity and Vapour density
- Molar volumes at STP (NTP)

BOARDS MAIN

Gay-Lussac's Law

Statement

When **gases are combined or produced** in a chemical reaction, they do so in a **simple ratio by volume**, provided all gases are at the same **temperature and pressure**.



$$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$$

Two volumes of hydrogen combine with **one volume** of oxygen to give **two volumes** of water under the same **temperature and pressure**.

We already know, the mole ratio of the reactants and the products in a chemical reaction is in the whole number ratio.

According to **Gay-Lussac's law**, the volume ratio of the reactants and the products is also in the whole number ratio.

$$3H_{2(g)} + N_{2(g)} \rightarrow 2NH_{3(g)}$$

Here, **three volumes of hydrogen** combine with one volume of nitrogen to give two volumes of ammonia under the same temperature and pressure.

To calculate the volume of gases using Gay-Lussac's law

What will be the respective **volumes of hydrogen** and **oxygen** consumed (**in litres**), if **20 litres** of **H_2O(g)** is produced in the following reaction? (All gases are at the **same temperature and pressure**)

$2H_2(g) + O_2(g) \rightarrow H_2O(g)$

a) **10, 20** b) **20, 10** c) **40, 20** d) **20, 40**

Solution

Given, Volume of H_2O = 20 L

Reaction conditions → Same temperature and pressure

According to Gay-Lussac's law, at same temperature and pressure, the volume ratio of the reactants and the products is in the whole number ratio.

From the reaction, **$2H_2(g) + O_2(g) \rightarrow H_2O(g)$,**

Two volumes of hydrogen combine with one volume of oxygen to give two volumes of water.

For the production of 20 L of H_2O, 20 L of H_2 combines with 10 L of O_2.

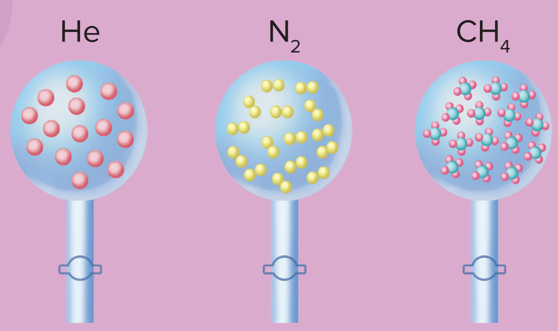
The correct option is **b**.

BOARDS MAIN

Avogadro's Law

Statement

Equal volumes of gases at the **same temperature and pressure** should contain **equal** numbers of **molecules/ particles**.



The **number of particles** in all the bulbs is **15** and the **volumes are identical**. This can also be stated as the **volume of gas is directly proportional to the number of particles at the same temperature and pressure**.

$$V \propto \text{Number of particles } \frac{V_1}{n_1} = \frac{V_2}{n_2}$$

Relative Density (R.D.)

It is the density of a substance **relative** to the density of another substance at the **same T and P**. It is a dimensionless quantity.

$$\text{R.D.} = \frac{\rho_{\text{substance}}}{\rho_{\text{reference}}}$$

R.D. is relative density and **ρ** is **density.**

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Specific Gravity (S.G.)

Specific gravity for **liquids** is measured with respect to **water** at 4°C.

$$\text{S.G. (For liquids)} = \frac{\rho_{substance}}{\rho_{water\ 4^\circ C}}$$

S.G. is **specific gravity** and ρ is **density.**

For **gases**, it is measured with respect to **air at STP**.

$$\text{S.G. (For Gas)} = \frac{\rho_{\text{gas at STP}}}{\rho_{\text{air at STP}}}$$

It is a **dimensionless** quantity.

Vapour Density (V.D.)

Density of the gas with respect to **hydrogen** gas at the **same temperature and pressure**. It indicates **how heavy a gas** is with respect to the **lightest gas**. It is also a **dimensionless** quantity.

$$\text{V.D.} = \frac{\text{Density of gas A at a given Temperature and Pressure}}{\text{Density of } H_2 \text{ gas at the same Temperature and Pressure}}$$ (**V.D.** is **vapour density**)

$$\text{V.D.} = \frac{\text{Molar mass}}{2}$$

BOARDS MAIN

Molar Volume at STP

It is the volume occupied by **1 mole** of a gas.

Molar volume at STP (Standard Temperature and Pressure)

At STP condition: Temperature = **0°C** or **273 *K***; Pressure = **1 *bar***; Molar volume at STP = **22.7 *L***

1 *atm* = 1.01325 *bar*

Calculation of molar volume at STP

$\rho(H_2 \text{ at STP}) = 0.089\ g/L$

Also, density $= \dfrac{M}{V_m}$

$0.089\ g/L = \dfrac{2}{V_m}\ g/mol$

Hence, molar volume, V_m (in *L/mol*) $= \dfrac{2}{0.089}$

$\mathbf{V_m}$ = **22.7 *L*** at **STP**; Temperature = **0°C** or **273 *K***; Pressure = **1 *bar*** according to the new standard.

$\mathbf{V_m}$ = **22.4 *L*** at STP; Temperature = **0°C** or **273 *K***; Pressure = **1 *atm*** according to the old standard.

Molar volume at NTP (Normal Temperature and Pressure)

At NTP condition: Temperature = **20°C** or **293 *K***; Pressure = **1 *atm***; Molar volume at NTP = **24 *L***

Finding the vapour density of a gas

Calculate the **vapour density of 20 g of methane gas.**

Solution

Vapour density = $\frac{\text{Molar mass}}{2}$

Molar mass of methane (**CH_4**) = 12 + (1 × 4) = 16 g

Hence, vapour density of methane = $\frac{16}{2}$ = 8

Vapour density **does not depend** upon the **mass of a gas**.

Finding the vapour density of a gas

The **relative density** of **gas A** with respect to another **gas B** is **2**. If the **vapour density** of **gas B** is **20**, find the **vapour density of gas A**.

Solution

Step 1:

Finding the molar mass of gas B (M_B)

Given,

Vapour density of gas B = 20

V.D. = $\frac{M_B}{2}$ = 20

M_B = 40 *g*

Step 3:

Finding the vapour density of gas A

Vapour density = $\frac{\text{Molar mass}}{2}$

∴ Vapour density of gas A = $\frac{80}{2}$ = 40

Step 2:

Finding the molar mass of gas A (M_A)

Relative density of gas A = $\frac{\text{Density of gas A at a T and P}}{\text{Density of gas B at the same T and P}}$

$= \frac{\text{Mass of 1 mole of gas A at a T and P}}{\text{Mass of 1 mole of gas B at the same T and P}}$

$\Rightarrow 2 = \frac{\text{Molar mass of A}}{\text{Molar mass of B}} = \frac{M_A}{M_B} = \frac{M_A}{40}$

M_A = 80 *g*

Finding the vapour density of a gaseous mixture

Calculate the **vapour density** of a mixture containing **44 *g* of CO_2** and **30 *g* of ethane**.

Solution

Step 1:

Finding the moles of the components

Given,

Mass of CO_2 = 44 *g*

Mass of ethane = 30 *g*

Molar mass of ethane(C_2H_6) = 30 *g*

Moles of CO_2 $= \frac{\text{Given mass}}{\text{Molar mass}}$

$= \frac{44\ g}{44\ g} = 1\ mol$

Moles of C_2H_6 $= \frac{\text{Given mass}}{\text{Molar mass}}$

$= \frac{30\ g}{30\ g} = 1\ mol$

Step 2:

Finding the average molar mass

Total mass = (44 + 30) g = 74 g

Total moles = $n_{CO_2} + n_{C_2H_6} = 1 + 1 = 2$

Average Molar mass

$$= \frac{\text{Total mass}}{\text{Total moles}} = \frac{74\,g}{2} = 37\,g$$

Step 3:

Finding vapour density

∴ Vapur density of mixture

$$\frac{\text{Molar mass}}{2} = \frac{37}{2} = 18.5$$

Finding the ratio of molar mass from the ratio of vapour density

Vapour density of two gases is in the ratio of **1 : 3**. What will be the **ratio of their molar masses**?

Solution

Let the two gases be A and B.

$$\frac{\text{Vapour density of gas A}}{\text{Vapour density of gas B}} = \frac{1}{3}$$

$$\text{Vapour density} = \frac{\text{Molar mass}}{2}$$

$$\frac{(\text{Molar mass of gas A})/2}{(\text{Molar mass of gas B})/2} = \frac{1}{3}$$

$$\frac{\text{Molar mass of gas A}}{\text{Molar mass of gas B}} = \frac{1}{3}$$

Hence, the ratio of the molar masses of gas A and gas B respectively is 1 : 3.

Finding the number of molecules from the number of moles

Gas A has a vapour density of 8.55. Find the **number of molecules** in **0.5 *mol*** of the gas.

Solution

Given: Number of moles of gas A = 0.5 mol

$$\text{No. of moles} = \frac{\text{Number of Particles (given)}}{N_A}$$

$$0.5 = \frac{\text{Number of molecules}}{N_A}$$

Hence, number of molecules = 0.5 N_A

Finding the vapour density from mass

A gas cylinder holds **85 *g* of gas X**. The **same** cylinder, when filled with **hydrogen**, holds **8.5 *g*** of **H_2** at the same temperature. Find its **vapour density**.

Solution

Let the volume of the cylinder be ‘V’ mL.

Given,
Mass of gas X in 'V' mL = 85 g
Mass of gas H_2 in 'V' mL = 8.5 g (at the same temperature)

$$\text{Vapour density} = \frac{\text{Mass of gas X / V mL at some T and P}}{\text{Mass of } H_2 \text{ gas / V mL at some T and P}} = \frac{85}{8.5} = 10$$

(Volume **V *mL*** is the same for both the gases as they are present in the same cylinder.)

Finding the vapour density of a mixture

A gaseous mixture of $\mathbf{H_2}$ and $\mathbf{CO_2}$ gas contains **66% by mass of $\mathbf{CO_2}$**. What is the **vapour density** of the mixture?

Solution

Step 1:

Finding the moles of all components

Let the mass of the mixture = 100 g

Given,

Mass of CO_2 in the mixture = 66% of 100 g

= 66 g

Mass of H_2 = (100 - 66) g = 34 g

$$\text{Moles of } CO_2 = \frac{\text{Given mass}}{\text{Molar mass}}$$

$$= \frac{66\ g}{44\ g} = 1.5\ mol$$

$$\text{Moles of } H_2 = \frac{\text{Given mass}}{\text{Molar mass}}$$

$$= \frac{34\ g}{2\ g} = 17\ mol$$

Step 2:

Finding the average molar mass

Total mass = 100 g

Total moles = 1.5 + 17 = 18.5 mol

Average Molar mass

$$= \frac{\text{Total mass}}{\text{Total moles}} = \frac{100}{18.5} = 5.41\ g$$

Step 3:

Finding the vapour density

$$\text{Vapur density} = \frac{\text{Molar mass}}{2}$$

$$= \frac{5.41}{2} = 2.7$$

Vapour density calculation

0.24 *g* of a volatile liquid on vaporisation gives **45 *mL* of vapours at STP**. What will be the **vapour density** of the substance? **(Density of $\mathbf{H_2}$ = 0.089 $\mathbf{gL^{-1}}$)**

a) 95.39 **b) 39.95** **c) 99.53** **d) 59.73**

Solution

$$\text{V.D.} = \frac{\text{Density of substance at a given temperature \& pressure}}{\text{Density of } H_2 \text{ gas at the same temperature \& pressure}}$$

Given,
Density of hydrogen = 0.089 $g\ L^{-1}$

Density of volatile liquid = $\dfrac{\text{Mass in } g}{\text{Volume in } L} = \dfrac{0.24\ g}{45 \times 10^{-3}\ L}$

V.D. = $\dfrac{0.24\ g / 45 \times 10^{-3}\ L}{0.089\ g\ L^{-1}} = 59.73$

Option d is correct.

Calculating the molar composition from vapour density

A **gaseous mixture of D_2 and CO_2** gas has a **vapour density of 12**. Calculate the **molar composition** of the mixture.

Solution

Step 1:

Finding the average molar mass

Given,

V.D. = 12

We know V.D. = $\dfrac{\text{Molar mass}}{2}$

So, $M_{avg} = 24\ g$

where **V.D.** is vapour density and $\mathbf{M_{avg}}$ is average molar mass.

Step 2:

Finding the molar composition of mixture

Let us consider 1 mol mixture of D_2 and CO_2, x moles of D_2 and (1 - x) moles of CO_2.

$m(D_2) + m(CO_2) = 24\ g$

Molar mass of $D_2 \times x$ + Molar mass of $CO_2 \times (1 - x) = 24$

$4x + 44 \times (1 - x) = 24$

$x = 0.5$

Number of moles of D_2 = x *mol* = 0.5 *mol*

Number of moles of CO_2 = (1 - x) *mol* = 0.5 *mol*

BOARDS MAIN

Interconversion of Mole-Volume

Volume at old STP $\xleftarrow{\times 22.4\ L}$ Mole

Volume at old STP $\xrightarrow[\div 22.4\ L]{}$ Mole

- **22.4 *L*** of any gas at **STP (1 *atm*, 0°C)** is the molar volume ($\mathbf{V_m}$, volume of one mole of gas).
- **11.2 *L*** of a gas at STP has 0.5 moles.
- **2 moles** of a gas at STP contains **44.8 *L*** volume.

$$\text{Number of moles} = \frac{\textit{Volume of gas (L, STP)}}{\textit{Molar volume (22.4 L)}} = \frac{\textit{Volume of gas (mL, STP)}}{\textit{22400 mL}}$$

Mole-Volume interconversion

What **volume** would **0.735 moles of O_2** gas occupy at **1 *atm* and 0°C**?

Solution

In the question STP condition is given.

So, **using the interconversion of mole-volume relationship**, we have, V (STP) = n × 22.4 *L*

So, V = 22.4 × 0.735 = 16.46 *L*

Mole-Volume interconversion

How many moles are there in **11.2 *L* of CO_2** gas at STP?

a) 0.5 *mol* of C atoms

b) 1 *mol* of O atoms

c) 0.5 *mol* of CO_2 molecules

d) 4 *mol* of total atoms

Solution

Using the interconversion of mole-volume relationship,

$$\text{The number of moles, } n = \frac{\text{Volume gas (at STP)}}{22.4\ L}$$

$$n = \frac{11.2}{22.4} = 0.5\ mol$$

a) 1 mole of CO_2 contains 1 mole of carbon atoms. So, 0.5 moles of CO_2 contain 0.5 moles of carbon atoms.

b) 1 mole of CO_2 contains 2 moles of oxygen atoms. So, 0.5 moles of CO_2 contain 1 mole of oxygen atoms.

c) Number of moles of CO_2 molecules = 0.5 *mol*

d) Total number of atoms in a CO_2 molecule is 3. So, 0.5 moles of CO_2 molecules contain 1.5 *mol* of total atoms.

Options **a, b, and c** are correct.

Mole-Volume interconversion

How many moles are there in **29.4 *L*** of **liquid ethanol at STP**?

a) 1.31 *mol* **b) 1.6 *mol*** **c) 1.1 *mol*** **d) Cannot be determined**

Solution

Volume of gas occupied at STP = 22.4 *L*

Using the **interconversion of mole-volume relationship**,

In the formula of mole-volume interconversion, we deal the volume of the gas.

$$\text{The number of moles, } n = \frac{\text{Volume of the gas}}{22.4\ L}$$

However, in the given question, since the volume of liquid is given, the number of moles cannot be determined.

Correct option is d.

BOARDS MAIN

Interconversion of Mole-Volume

- If the mass of a gas is given,

$$\text{Moles} = \frac{\textit{Given Mass}}{\textit{Molar Mass}}$$

Volume of gas (L) = Moles × Molar volume

= Moles × 22.4

- If the volume of gas is given,

$$\text{Moles} = \frac{\textit{Volume of gas (L)}}{22.4\ L}$$

Mass = Moles × Molar mass

Mass-Volume interconversion

What **volume (in *L*)** is occupied by **60 *g* of ethane at STP**?

Solution

Step 1:

Finding the number of moles of ethane using the formula,

$$n = \frac{\text{Given mass}}{\text{Molar Mass}} = 60/30 = 2\ mol$$

Step 2:

Using the interconversion of mole-volume relationship,

V (STP, L) = n × 22.4

V = 22.4 L × 2 = 44.8 L

Mass-Mole-Volume interconversion and molecular formula determination

16 *g* of an ideal gas **SO_x** occupies **5.6 *L* at STP**. Find the value of **x**.

Solution

Step 1:
Finding the number of moles of SO_x gas
Using the interconversion of mole-volume relationship,
We have, the number of moles,

$$n = \frac{\text{Volume gas (at STP)}}{22.4\ L}$$

$$n = \frac{5.6}{22.4} = 0.25\ mol$$

Step 2:
Finding the value of x
0.25 mol of gas contains 16 g of an ideal gas, SO_x .

Then, 1 mol of gas will contain 64 g of SO_x.
Thus, 64 g is the molar mass of SO_x.
32 + 16x = 64
x = 2

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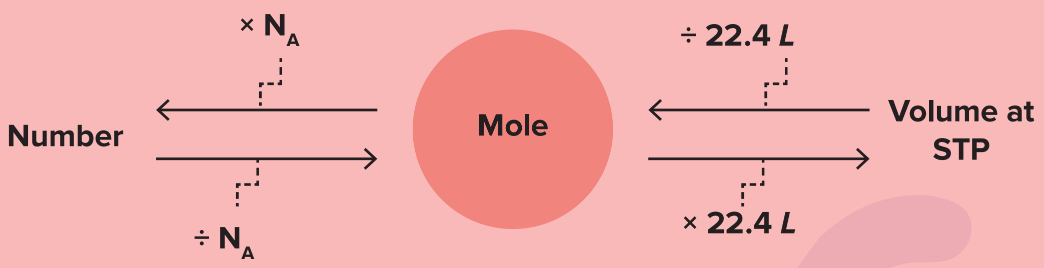
Interconversion of Mole-Volume



If the number of particles of a gas are given,

$$Moles = \frac{Number\ of\ particles}{N_A}$$

Number of particles = Moles × N_A

If volume of gas is given,

$$Moles = \frac{Volume\ of\ gas\ (L)}{22.4\ L}$$

Volume of gas (L) = Moles × 22.4 L

Finding the volume from the number of atoms

Calculate the **volume** occupied by **Cl_2 gas** at **STP** (atm) if the number of **Cl atom**s is the **same** as the number of **O atoms** present **in 4.8 *g* ozone**.

Solution

Step 1:

Finding the number of oxygen atoms in ozone

Number of moles (n) = $\frac{\text{Given mass (m)}}{\text{Molar Mass (M)}}$

Given mass of ozone = 4.8 *g*

Molar mass of ozone = 3 × 16 = 48 *g/mol*

n = $\frac{4.8}{48}$ = 0.1 *mol* of ozone molecules

1 mol of ozone molecule contains 3 atoms of oxygen.

So, by unitary method, 0.1 *mol* of ozone molecules will contain 0.1 × $\frac{3}{1}$, i.e., 0.3 moles of oxygen atoms.

Step 2:

Finding the number of molecules of Cl_2 gas

Given that the number of Cl atoms is the same as the number of O atoms , i.e., 0.3 *mol*.

1 molecule of chlorine contains 2 atoms.

So, by unitary method, the number of Cl_2 molecules present in 0.3 *mol* of Cl atoms is $\frac{0.3}{2}$, i.e., 0.15 *mol*

Step 3:

Finding the volume occupied by Cl_2 gas

V (STP, L) = n × 22.4

V = 22.4 L × 0.15 = 3.36 L

Particles-Volume interconversion

4.4 *g* of CO_2 and **2.24 *L* of H_2** at **STP** are mixed in a container. Find the **total number of molecules** present in the container.

a) 6.02 × 10^{23} **b) 12.04 × 10^{22}** **c) 2 moles** **d) 6.02 × 10^{24}**

Solution

Step 1:

Finding the number of moles of CO_2

Using the interconversion of mole-mass relationship,

We have, the number of moles,

$$n = \frac{\text{Given mass}}{\text{Molar mass}}$$

$$n = \frac{4.4}{44} = 0.1\ mol$$

Step 2:

Finding the number of moles of H_2

Using the interconversion of mole-volume relationship,

We have, the number of moles,

$$n = \frac{\text{Volume of gas (at STP, } L\text{)}}{22.4\ L}$$

$$n = \frac{2.24}{22.4} = 0.1\ mol$$

Step 3:

Total number of molecules

Total number of moles carbon dioxide and hydrogen gas = 0.2 mol

The total number of atoms = $0.2 \times N_A = 12.046 \times 10^{22}$

Particles-Volume interconversion

From **160 g of a $SO_2(g)$** sample, **1.2046×10^{24} molecules of SO_2** are removed. Find the **volume** of the left over **$SO_2(g)$ at STP**.

Solution

Step 1:

Finding the number of moles of SO_2

Using the interconversion of mole-mass relationship,

The number of moles

$$n = \frac{\text{Given mass}}{\text{Molar mass}}$$

$$n = \frac{160}{64} = 2.5\ mol$$

Step 2:

Finding moles of SO_2 removed

Now, the number of moles of SO_2 removed

$$= \frac{1.2046 \times 10^{24}}{N_A}$$

$$= \frac{1.2046 \times 10^{24}}{6.023 \times 10^{23}} = 2\ mol$$

Step 3:

Number of moles remaining

The number moles remaining

= 2.5 - 2 = 0.5

Step 4:

Volume of left over SO_2

Volume of left over $SO_2 = n \times 22.4\ L$

$V = 0.5 \times 22.4 = 11.2\ L$

Finding the volume from the number of electrons present in the sample

A pure sample of CO_2 contains a total of **2.2×10^{10} electrons**. Find the **volume occupied by CO_2 at STP (*atm*)**.

Solution

Step 1:

Finding the number of molecules of CO_2

Number of electrons present in a CO_2 molecule = 6 + (8 × 2) = 22 electrons

By unitary method, 2.2×10^{10} electrons will be present in $2.2 \times 10^{10} \times \frac{1}{22}$, i.e., 10^9 molecules.

Step 2:

Finding the moles of CO_2

$$\text{Number of moles (n)} = \frac{\text{Number of molecules}}{N_A \text{ (Avogadro's number)}}$$

$$= \frac{10^9}{6.023 \times 10^{23}} = 1.66 \times 10^{-15}\ mol$$

Step 3:

Finding the volume occupied by CO_2

Volume of gas occupied at STP = 22.4 L

Volume of gas, V = moles × 22.4 L

V (STP, L) = n × 22.4

V = 22.4 × 1.66 × 10^{-15} = 3.71 × 10^{-14} L

BOARDS MAIN

Interconversion of Mole-Volume, Mass, and Number of Particles