# *BASIC LAW's of CHEMISTRY AND CHEMICAL CALCULATION (stoichiometric)*

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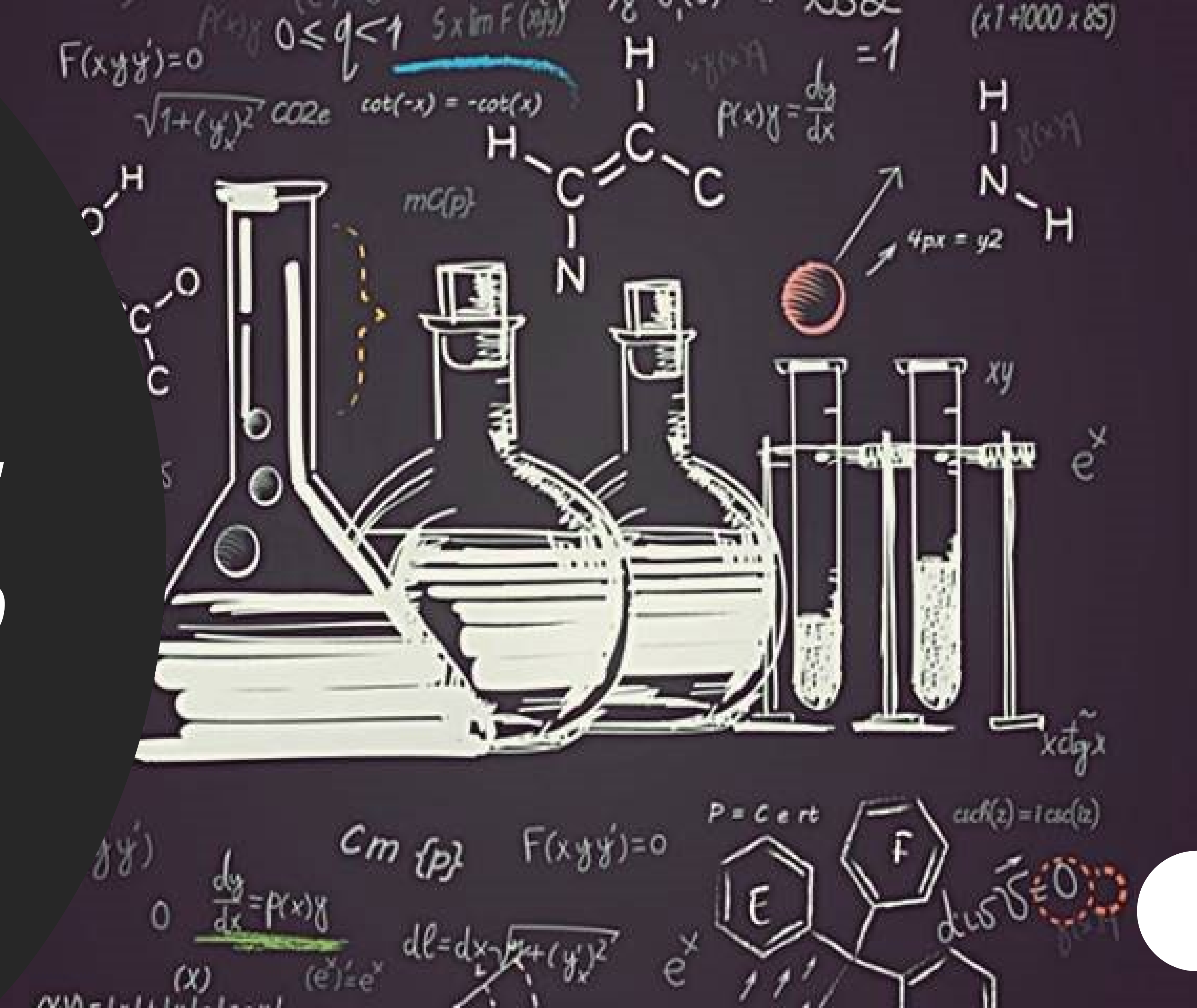
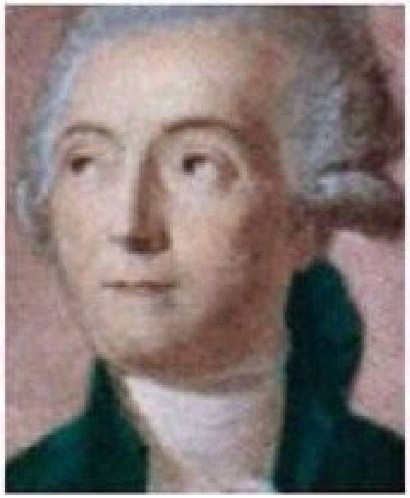
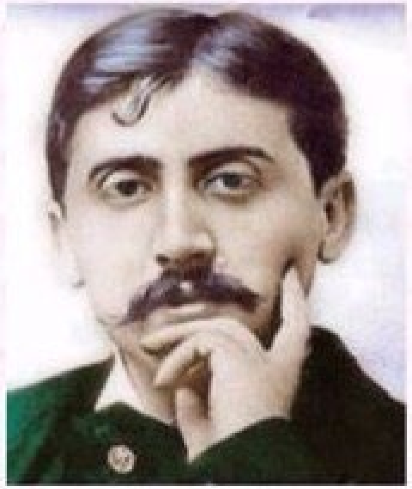




# *Scientist of the Basic Laws of Chemistry*

# *Intro*

The basic laws of chemistry are the laws used to underlie chemical calculations and quantitative relationships of reactants and products in chemical equations. Quantitative aspects can be obtained from the measurement of mass, volume, concentration related to the number of particles of atoms, ions, molecules or related chemical formulas in chemical reaction equations.

The stoichiometric chemical calculations require relevant basic laws. There are several important basic laws including:

1. Law of Conservation of Mass
2. Law of Fixed Comparison
3. Law of Multiple Comparison
4. Law of Comparative Volume
5. Avogadro's Hypothesis Law

# *Law of Conservation of Mass (Lavoisier's Law)*

- Lavoisier's law is also known as the law of conservation of mass. This theory was coined by a French scientist, Antoine Laurent Lavoisier. The law was discovered when Lavoisier burned white liquid mercury with oxygen until it turned into red mercury oxide. Then, Lavoisier also heated the red mercury oxide until it re-formed white mercury and oxygen.
- In that study Lavoisier then found that there was a role for oxygen gas in the combustion reaction. The mass of oxygen during the combustion process was the same as the mass of oxygen formed after mercury oxide was heated.
- Lavoisier's Law states: "**The total mass of the substance before the reaction is equal to the total mass after the substance has reacted.**"
- This is then referred to as the law of conservation of mass because in a chemical reaction mass does not change.

# *Law of Conservation of Mass (Lavoisier's Law)*

| If a reaction: | A + B → C + D | | | |
|---|---|---|---|---|
| Mass before: | a | b | - | - |
| Reaction : | x | y | c | d |
| Mass after : | (a-x) | (b-y) | c | d |

The mass before reaction is **a + b**

The mass after reaction is **(a-x) + (b-y) + c + d**

Then:

The mass of matter before reaction = the mass matter after reaction

$$\mathbf{a + b = (a-x) + (b-y) + c + d}$$

***Example Question***

5 grams of oxygen is reacted with 5 grams of magnesium metal to form a magnesium oxide compound. How many of mass of magnesium oxide is produced from this reaction?

***Solution:***

- $Mg + O_2 \rightarrow MgO_2$
- Mass of substance before reaction = mass of substance after reaction
- Mass Mg + Mass $O_2$ = Mass $MgO_2$
- 5 grams of Mg + 5 grams of $O_2$ = 10 grams of $MgO_2$
- So the mass of magnesium oxide produced is 10 grams

# *Law of Fixed Comparison (Proust's Law)*

- Proust's Law is also known as the "Law of Fixed Comparison". This is because in 1799 Joseph Louis Proust discovered that every compound is composed of elements with a definite and fixed composition. Therefore, the law reads: "**The ratio of the masses of the elements in each compound contains a certain and fixed composition**".
- One example of an experiment is the reaction of the element hydrogen with oxygen to form a water compound and then the results show the ratio of the mass of hydrogen to oxygen in constant action, which is 1:8.
- Comparison of Compounds Example

| | |
|---|---|
| *Carbon monoxide* | *C : O = 3 : 4* |
| *Carbon dioxide* | *C : O = 3 : 8* |
| *Calcium oxide* | *Ca : O = 5 : 2* |
| *Hydrogen peroxide* | *H : O = 1 : 16* |
| *Hydrogen monooxide (water)* | *H : O = 1 : 8* |
| *Sulphur dioxide* | *S : O = 3 : 2* |

# *Law of Fixed Comparison (Proust's Law)*

***Example Question***

The masses of carbon (C) and oxygen (O) have a ratio of 3:8. If the carbon that reacts is 1.5 grams, what is the mass of oxygen reacted and the mass of carbon dioxide formed?

***Solution:***

- Mass Comparison: 3 : 8

  *Carbon = 3 = 1.5 grams*

  *Oxygen = 8 = ? grams*

  *Carbon dioxide = 11 = ? grams*

- Mass of Oxygen = 8/3 × 1.5 grams = 4 grams
- Mass of Carbon dioxide = 11/3 × 1.5 = 5.5 grams.
- So the mass of oxygen reacted is 4 grams and the mass of Carbon dioxide formed is 5.5 grams.

# *Law of Multiple Comparison (Dalton's Law)*

- Dalton's law was first coined by an English scientist named John Dalton. In his research, John Dalton compared the elements contained in several compounds.
- As a result, the law of multiple proportions was found which reads: "**If any two elements can form more than one compound with one element's mass is fixed, then the ratio of the masses of the other in the compound is a simple whole number**". An example is sulfur and oxygen which can form two compounds.

# *Law of Multiple Comparison (Dalton's Law)*

***Example Question***

Phosphorus and oxygen are reacted to form two types of compounds. In 55 grams of the first compounds there are 31 grams of phosphorus and 71 grams of the second compound contains 40 grams of oxygen. Does this compound belong to Dalton's law?

***Solution:***

| | **Mass of phosphorus** | **Mass of oxygen** | **Mass of compound** |
|---|---|---|---|
| The first Compound | 31 grams | ? | 55 grams |
| The second Compound | ? | 40 grams | 71 grams |

- Mass of oxygen in the first compound = 55 - 31 = 24
- Mass of phosphorus in the second compound = 71 - 40 = 31
- The ratio of the mass of phosphorus in the first and the second compounds is

  = 31 : 31 → divided by 31 then the result is = 1 : 1
- The ratio of oxygen in the first and the second compounds is

  = 24 : 40 → divided by 8 then the result is = 3 : 5
- From these results, the ratio of oxygen and phosphorus in the first end the second compounds, namely 1:1 and 3:5, is an integer and simple.

# *Law of Comparative Volumes (Gay-Lussac's Law)*

- This law, also known as the Law of Comparative Volume, was discovered by a French scientist, Joseph Gay Lussac. In his research, he wanted to prove about the volume of gas in a chemical reaction. The results of the study concluded that temperature and pressure affect gas changes.
- A simple experiment that was carried out resulted in a ratio of the volume of hydrogen : oxygen : water vapor is 2: 1: 2. It appears that the ratio of the volume corresponds to the ratio of the coefficients of the element or compound in the balanced reaction equation, ie the reaction equation with the number of atoms on the left is the same as on the right.
- Water formation reaction: $2H_2\ (g) + O_2\ (g) \rightarrow 2H_2O\ (g)$
- Volume Comparison: 2: 1: 2, such as the comparison of the reaction coefficients
- The law of comparison reads as follows: "**When measured at the same temperature and pressure, the volumes of the reacting gas and the resulting gas are proportional as whole numbers and simple**"

# *Law of Comparative Volumes (Gay-Lussac's Law)*

***Example Question***

2 liters of hydrogen gases reacts with 2 liters of chlorine gases to produce 4 hydrogen chloride gases. If 10 liters of hydrogen gases are reacted, how much hydrogen chloride gases is produced?

***Solution:***

Volume Comparison

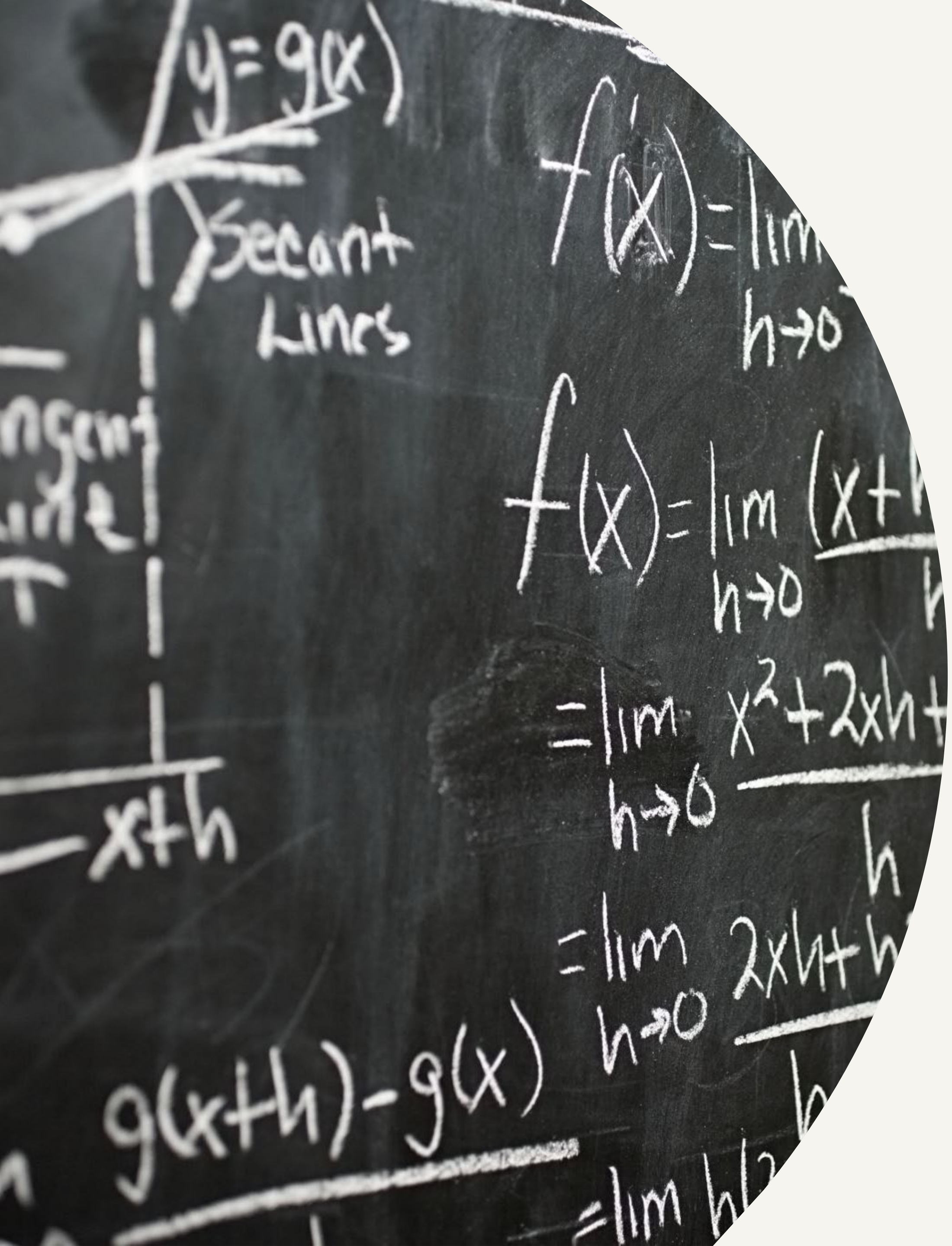
- Hydrogen 2 1
- Chlorine 2 1
- Hydrogen Chloride 4 2
- If the hydrogen gas that is reacted is 10 liters then the hydrogen chloride gas produced is: = 2 × 10 = 20 liters ( 2 = Hydrogen Chloride ratio value)
- So the hydrogen chloride produced from the reaction of 10 liters of hydrogen gas is 20 liters.

# *Avogadro's Hypothesis Law*

- Avogadro's hypothesis is a theory discovered by Amedeo Avogadro in 1811. In his research, Avogadro found that an elemental particle does not always have to be a single atom, it can also be an elemental molecule or two or more atoms.
- Avogadro's hypothesis then says: "**At the same temperature and pressure, the ratio of the same volume of gas has the same number of molecules**."
- The mathematical formula of Avogadro's law is as follows:

$$\frac{V_1}{N_1} = \frac{V_2}{N_2}$$

- Where: N = number of certain gas molecules, V = volume of gas space




# *Avogadro's Hypothesis Law*

***Example Question***

5 liters cylinder contains $2\times10^{22}$ molecules of carbon dioxide gases. At the same temperature and pressure, how many molecules of nitrogen gas are in a 4 liters cylinder?

***Solution:***

- Given: $N_1 = 2\times10^{22}$, $V_1$ = 5 liters, $V_2$ = 4 liters. $N_2$ = …?
- $\frac{V_1}{N_1} = \frac{V_2}{N_2}$
- $\frac{5}{2\times10^{22}} = \frac{4}{N_2}$
- $N_2 = \frac{(2\times10^{22})\times4}{5}$
- $N_2 = 1.6\times10_{22}$
- So the amount of nitrogen gas in a 4 liters cylinder is $1.6\times10^{22}$

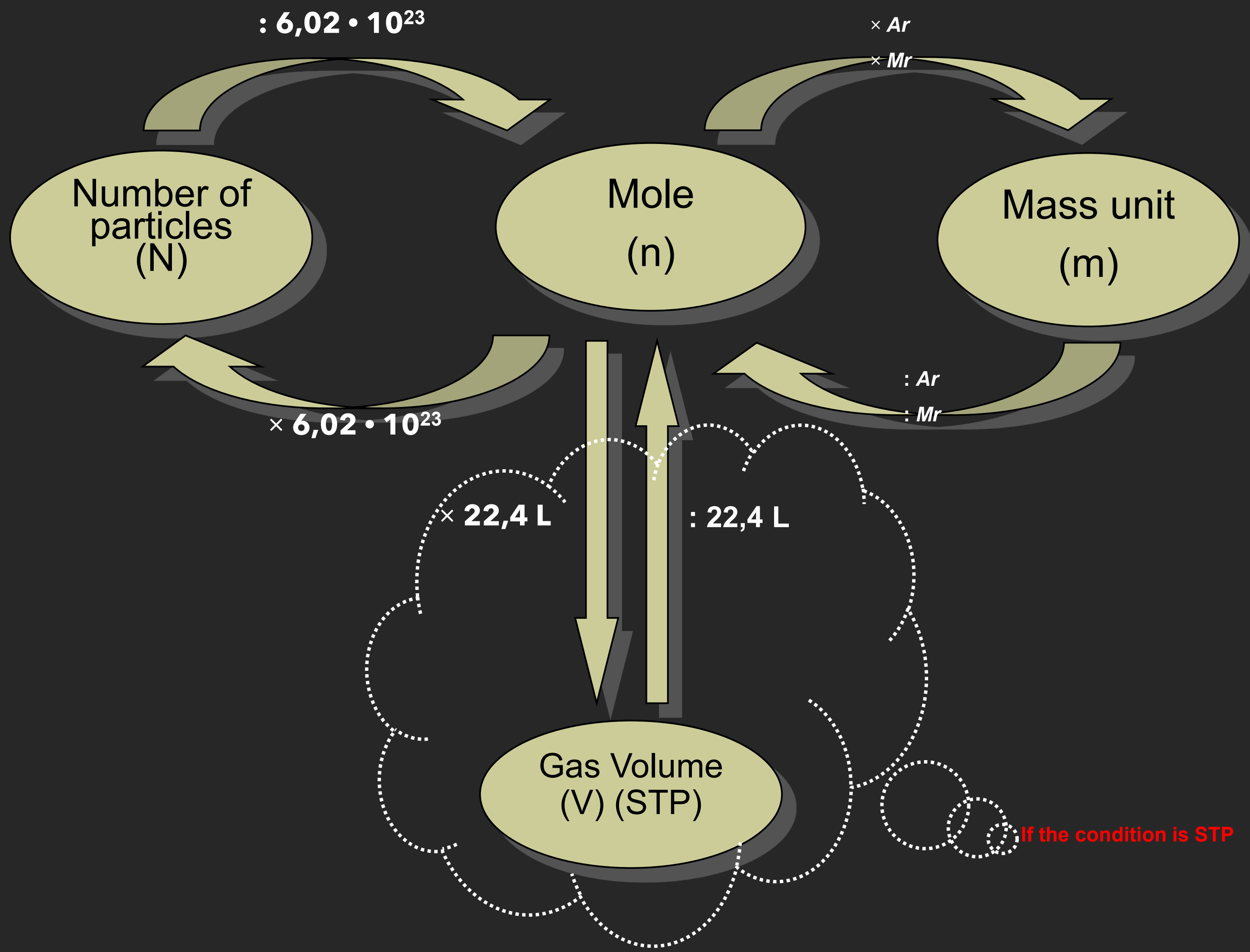
# *Stoichiometric*

- **The mole** is a unit of quantity of matter in chemistry. The mole symbol is n.
- The number of particles in 1 mole of an experiment is 6.02 × 1023 particles/mol. This number is Avogadro's constant with the symbol NA or L

$$L = NA = 6{,}02 \times 10^{23}$$

$$n = \frac{N}{NA}$$

- N is the number of particles in the material.




# *The mole concept can be illustrated by:*

- **Note:** STP is Standard for Temperature and Pressure, under conditions of 0 °C and 1 atm.

# *If the conditions are not 0 °C and 1 atm (not STP), the formula is:*

**$P \cdot V = n \cdot R \cdot T$**

Where:

- P = Pressure (atm)
- R = gas constant = 0.082 L atm $mol^{-1}$ $K^{-1}$
- V = Volume (L)
- n = moles (moles)
- T = temperature (K)

temperature can not with Celsius!!!

Now, prove it!

- If the condition is STP, the formula of volume is $V = n \cdot 22{,}4$ L

# *Molarity* (M) or Solution Concentration

$$M = \frac{n}{V} \quad or \quad M = \frac{mass}{Ar / Mr} \times \frac{1000}{v}$$

Where:

- M = Molarities or Solution Concentration (Molar)
- n = mole (mol)
- V = volume in Litre (L)
- Mass = the mass of matter (gram)
- Ar/Mr = the mass relative of atom or molecule (gram $mol^{-1}$)
- $v$ = volume in millilitre (mL)

while for dilution, the formula is

$$M_1 . V_1 = M_2 . V_2$$

# *Next meeting*

practice and try some chemistry calculations