LECTURE №1

Basic concepts and laws of chemistry

18.01.2016

QUIZ ME

1. What is Chemistry?

- is studies the physical properties and chemical change of matter
- is studies the composition, structure, properties and change of matter and energy
- is studies the physical properties and chemical change of compounds

NEXT

WHAT IS CHEMISTRY?

Chemistry **is the study of matter, including its composition, properties, and structure, how it changes, and how it interacts with energy.**

Matter is pretty important because it's anything that has mass and takes up space - basically, all of the 'stuff' that makes up our world! Chemists study **atoms**, which are the basic building blocks of matter, as well interactions between atoms.

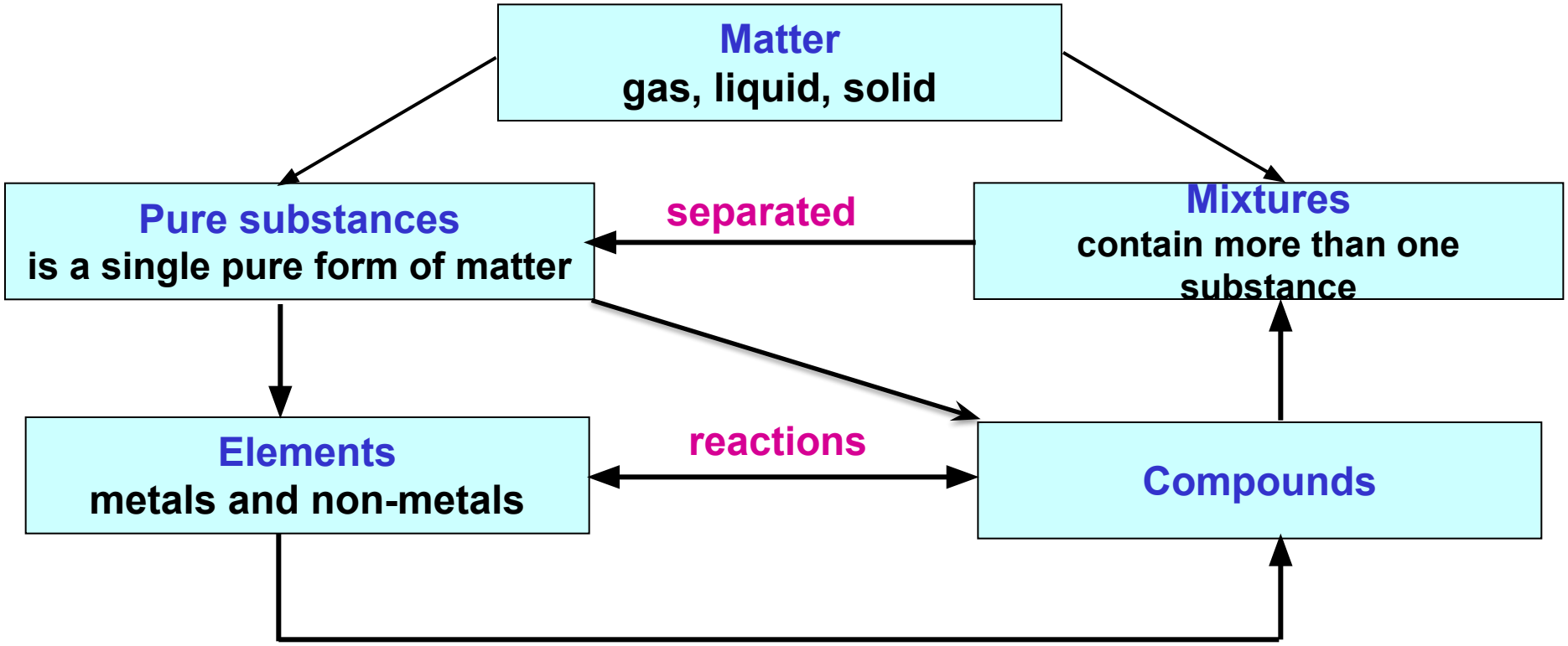
We also study **subatomic particles**, which are smaller than atoms, and these include things like protons, neutrons, and electrons. Since everything on Earth is made of matter, and matter is made of atoms, you can see how this creates the overlap between chemistry and other sciences.

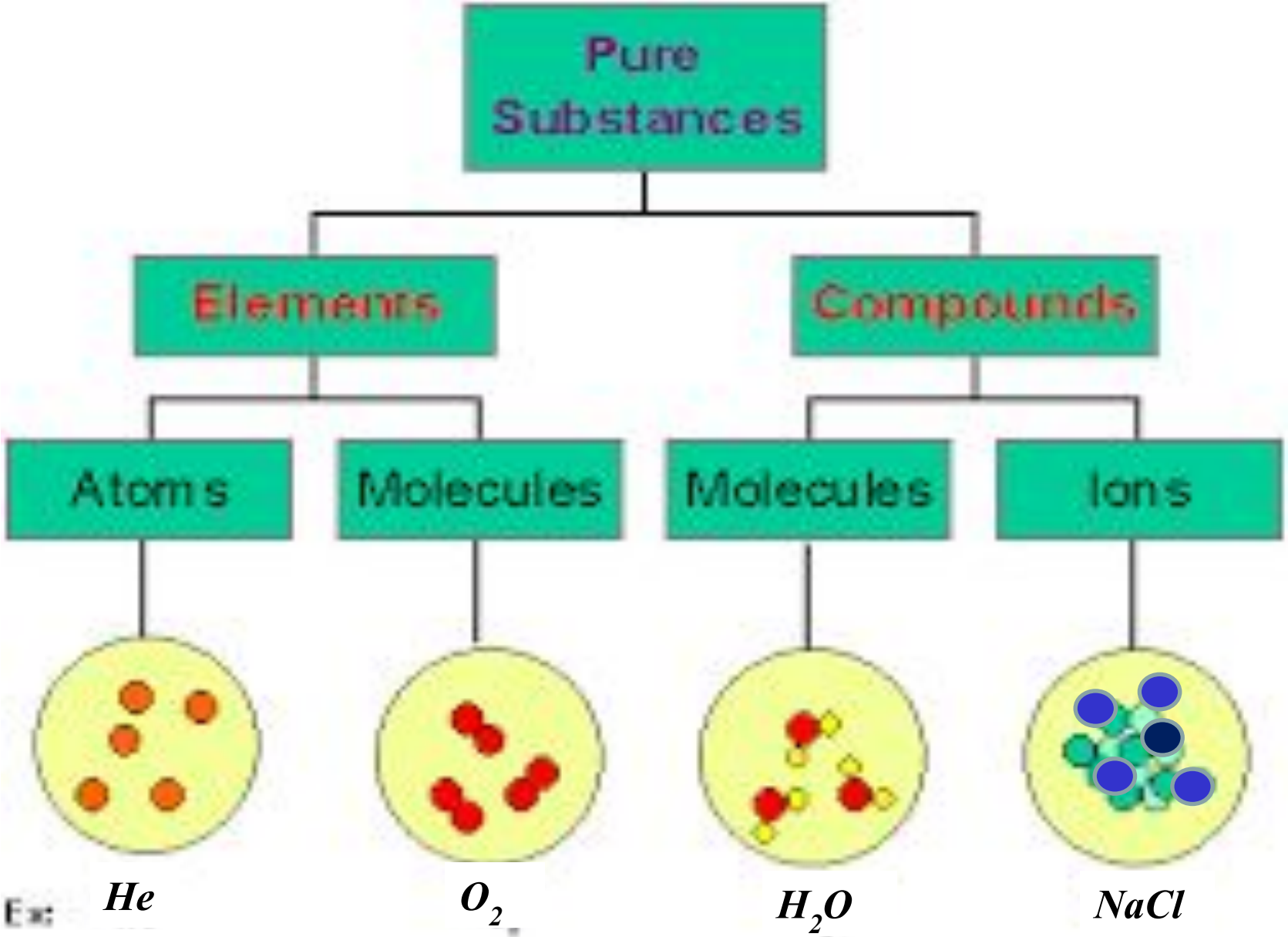
The universe is composed of matter and energy.

Matter **is anything that occupies space and has rest mass and volume** – rocks, oceans, the air that we breather and we, ourselves, are all composed of matter.

Energy **has no shape or form – it is defined as ability to do work.**

Matter is generally observed in three physical states:




Pure Substances
Elements
Compounds
Atoms
Molecules
Molecules
Ions
Ex: He
O_2
H_2O
NaCl

QUIZ ME

2. A pure substance can only be:

- a heterogeneous mixture
- an element or a compound
- an element
- compound

A MIXTURE

is any physical material that is made up of various constituent substances, which haven't chemically interacted with each other.

A HETEROGENEOUS MIXTURE

is a mixture that composes of components that aren't uniform or they have localized regions that all have different properties.

- Emulsion
- Suspension
- Aerosol
- Smoke

A HOMOGENEOUS MIXTURE

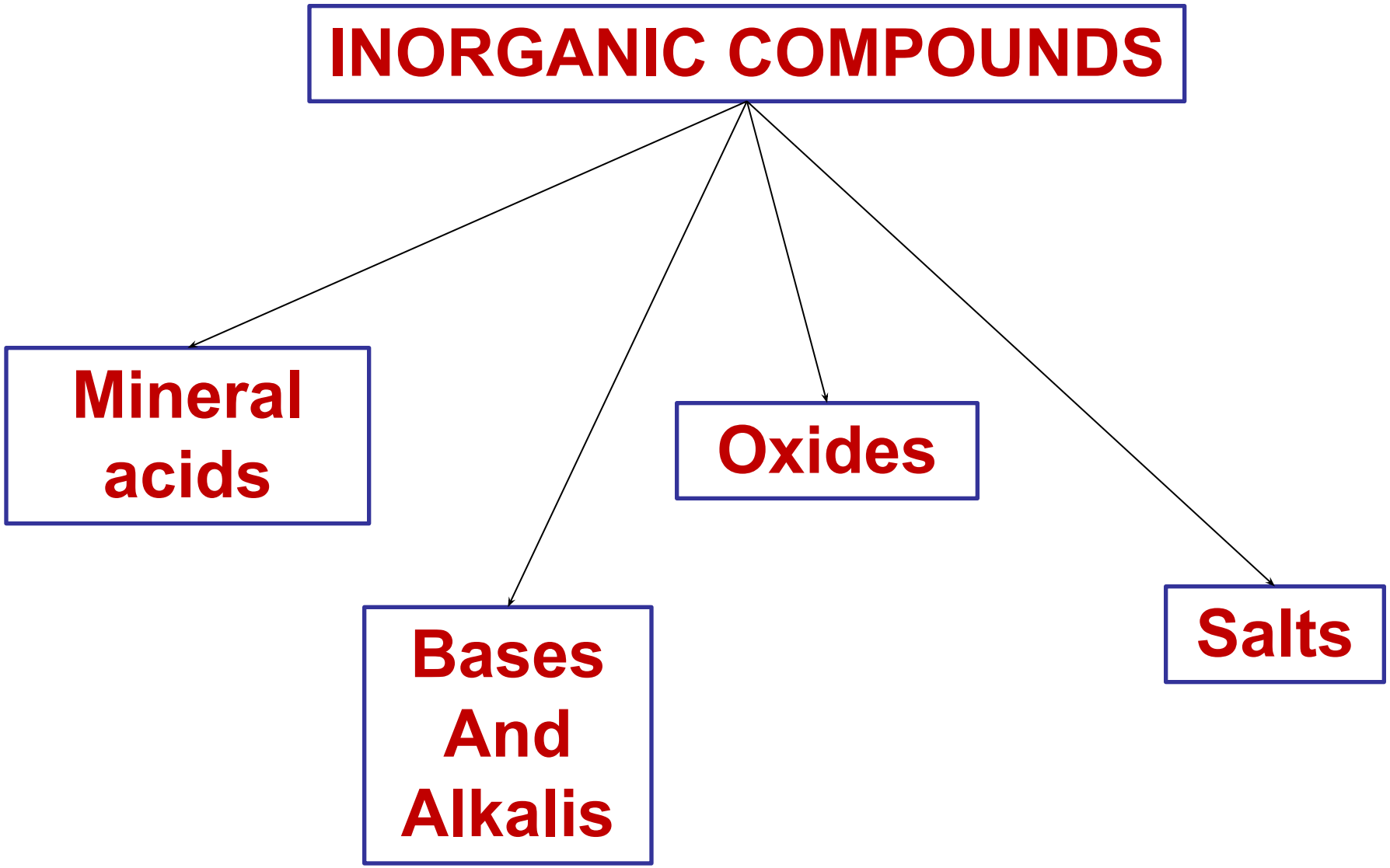
is simply any mixture that is uniform in composition throughout.

- Precious stones
- Alloys
- Air
- Solution

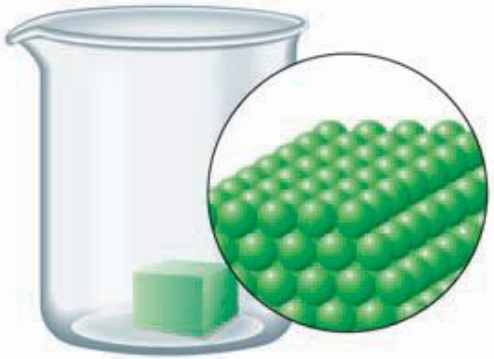
QUIZ ME

3. Which one of the following mixture is homogeneous?

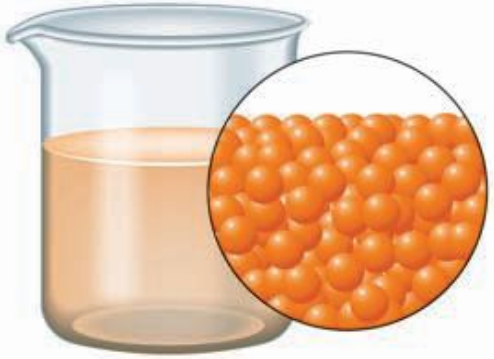
- starch and sugar
- graphite and charcoal
- calcium carbonate and calcium bicarbonate
- ethanol and water


INORGANIC COMPOUNDS
Mineral acids
Bases And Alkalis
Oxides
Salts

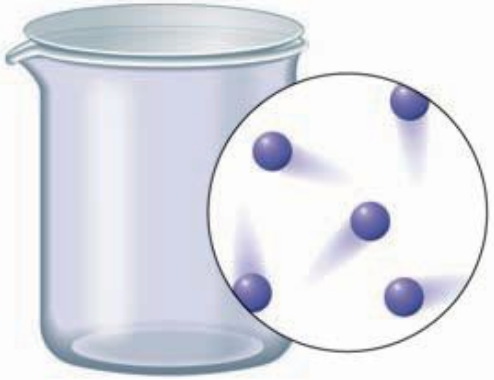
PHYSICAL STATE OF MATTER



Solid ***the form of matter characterized by rigidity; a solid is relatively*** **incompressible** and has fixed shape and volume.

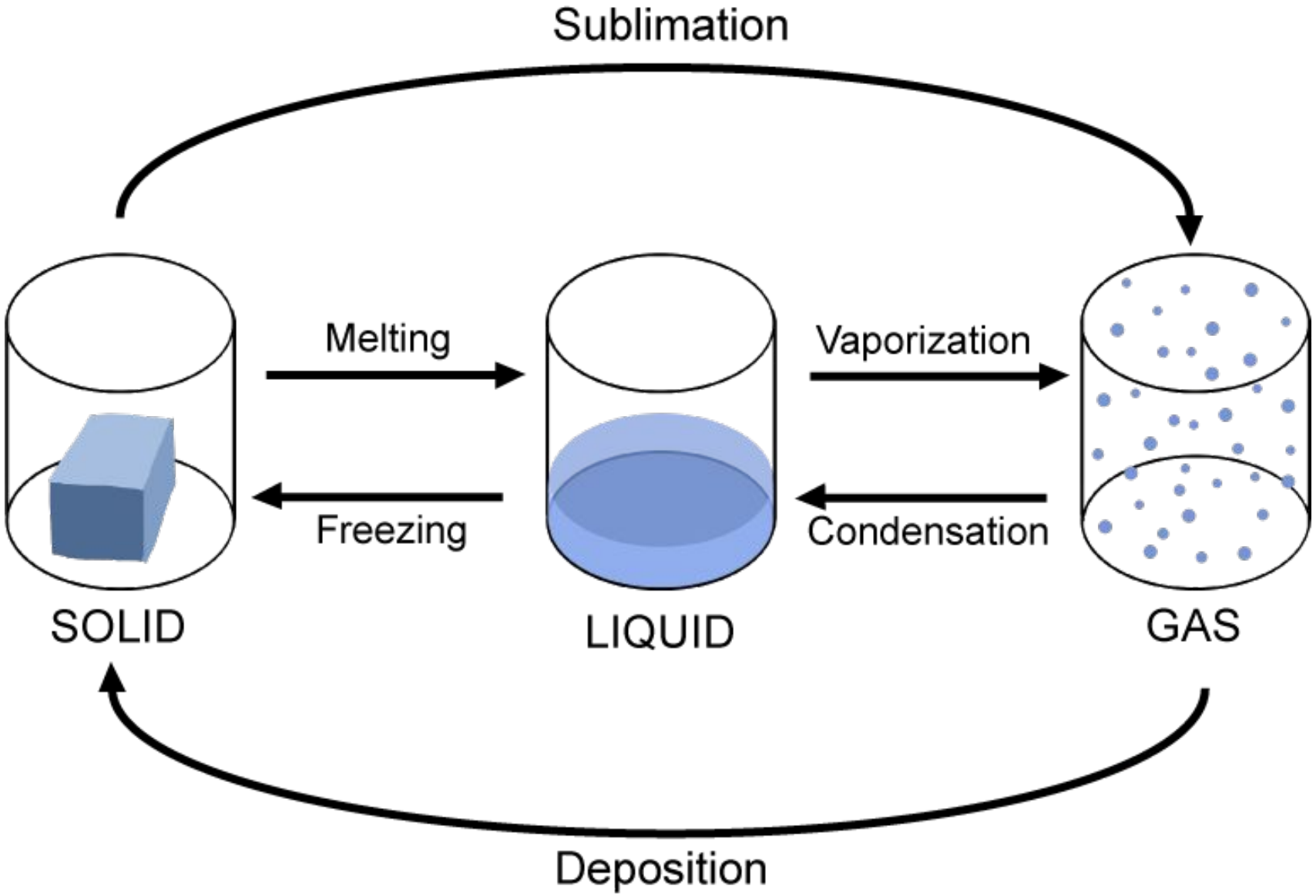


Liquid ***the form of matter that is a relatively incompressible fluid; a liquid*** has a fixed volume but no fixed shape.



Gas ***the form of matter that is an easily compressible fluid; a given quantity*** of gas will fit into a container of almost any size and shape.

EXAMPLE OF PHASE CHANGES



Properties of Matter

- **Physical properties** are the characteristics of matter that can be changed without changing its composition.
  - ✓characteristics that are directly observable

- **Chemical properties** are the characteristics that determine how the composition of matter changes as a result of contact with other matter or the influence of energy.
  - ✓characteristics that describe the behavior of matter

An atom is the basic unit of a chemical element. Everything in the world is made out of atoms.

An element is a pure substance that cannot be broken down by chemical methods into simpler components.

Combinations of atoms are called molecules. A molecule is a part of matter that is made up of more than one atom. Molecules may contain one kind of atom or more than one kind of atom.

A compound is a pure substance that consists of two or more elements chemically combined in a fixed proportion. *All compounds are molecules, but not all molecules are compounds.*

An ion is an atom or group of atoms in which the number of electron s is different from the number of protons. Atoms may lose electrons to form *cations*, or gain electrons to form *anions*.

A chemical reaction is the change that occurs when atoms rearrange themselves and form new compounds.

- **Combination reaction** is a reaction in which two or more reactant combine to form a single product is known as combination reaction.
- **Decomposition reaction** is a reaction in which a single compound breaks into two or more simpler compounds is known as decomposition reaction.
- **Displacement reaction** is a chemical reaction in which a more reactive element displaces a less reactive element from its aqueous salt solution.
- **Double Displacement reaction** is a chemical reaction in which ions gets exchanged between two reactants which forms a new compound is called as double displacement reaction.
- **Precipitation Reaction** is a chemical reaction that involves the formation of an insoluble product (precipitate; solid)

TYPES OF CHEMICAL REACTIONS

Reaction type	Explanation	General formula
Combination	Two or more compounds combine to form one compound.	$A + B \rightarrow AB$
Decomposition	The opposite of a combination reaction – a complex molecule breaks down to make simpler ones.	$AB \rightarrow A + B$
Precipitation	Two solutions of soluble salts are mixed, resulting in an insoluble solid (precipitate) forming.	A + soluble salt B → precipitate + soluble salt C
Neutralisation	An acid and a base reaction with each other. Generally, the product of this reaction is a salt and water.	acid + salt → salt + water
Combustion	Oxygen combines with a compound to form carbon dioxide and water. These reactions are exothermic, meaning they give off heat.	$A + O_2 \rightarrow H_2O + CO_2$
Displacement	One element trades places with another element in the compound.	$A + BC \rightarrow AC + B$

What are some clues that a chemical reaction has occurred?

- A color change
- A solid forms
- Bubbles form
- A heat change
- A flame is produced

QUIZ ME

4. The father of modern chemistry is:

- Dalton
- Lavoisier
- Mendeleeff
- Proust

NEXT

Chemical reactions are governed by certain laws, which have become fundamental concepts in chemistry. Some of them are:

- ***Law of conservation of energy*** leads to the important concepts of equilibrium, thermodynamics and kinetics.
- **Law of conservation of mass** continues to be conserved in isolated systems, even in modern physics.
- ***Law of multiple proportions***
- ***Law of definite composition***, although in many systems (notably biomacromolecules and minerals) the ratios tend to require large numbers, and are frequently represented as a fraction.
- ***Fick's laws of diffusion***
- ***Le Chatelier's principle***

Gas Laws:

- ***Avogadro's law***
- ***Boyle's law (1662, relating pressure and volume)***
- ***Charles's law (1787, relating volume and temperature)***
- ***Gay-Lussac's law (1809, relating pressure and temperature)***
- ***Henry's law***

Antoine Lavoisier (1743–1794), a French chemist, was one of the first to insist on the use of the balance in chemical research. By weighing substances before and after chemical change, he demonstrated the ***law of conservation of mass***, **which states that the total mass remains constant during a chemical change (chemical reaction)**:

Matter can be neither created nor destroyed, though it can be rearranged. Mass remains constant in an ordinary chemical change.

$$2Hg + O_2 \rightarrow 2HgO\downarrow$$

2*200	+	32	=	2*(200+16)
		432	=	432

The Proust's law of definite proportions states that ***a chemical compound always contains exactly the same proportion of elements by mass*** and forms the basis of stoichiometry.

An equivalent statement is the law of constant composition, which states that all samples of a given chemical compound have the same elemental composition.

Thus in the formation of compound, elements are connected with each other in certain weight ratios:

m(Cu) : m(S) = Ar(Cu) : Ar(S) = 64 : 32 = 2 : 1

In order to obtain **copper sulphide** (**CuS**) must be mixed copper and sulfur powders in a weight ratio of **2 : 1**

John Dalton (1766 - 1844)

DALTON'S ATOMIC THEORY

John Dalton (1808) used the Greek concept of an atom and the laws of definite proportions, conservation of mass and multiple proportions to give the atomic theory on scientific basis.

Dalton proposed that the properties of elements differ from one another because their atoms differ. He also recognized that even though they may share the same atoms, compounds have properties that bear no relationship to those elements of which they are composed. **Dalton's atomic theory stated that**:

1) All matter is made of atoms. Atoms are indivisible and indestructible.

2) All atoms of a given element are identical in mass and properties

3) Compounds are formed by a combination of two or more different kinds of atoms.

4) A chemical reaction is a rearrangement of atoms.

An **atom** is the smallest unit of matter that defines the chemical elements. Every solid, liquid, gas, and plasma is made up of neutral or ionized atoms. ***Atoms are very small***: the size of atoms is measured in picometers - trillionths (10^{-12}) of a meter.

The atomic mass (ma) is the mass of an atomic particle, sub-atomic particle, or molecule. The protons and neutrons account for almost all of the mass of an atom. By international agreement, **1 unified atomic mass unit is defined as 1/12 of the mass of a single carbon-12 atom (at rest):**

$$1\ a.m.u. = \frac{1}{12} \cdot m_C = 1{,}66057 \cdot 10^{-27}\ kg$$

The mass number should also not be confused with the **relative atomic mass** (also **called atomic weight**) of an element, which is the ratio of the average atomic mass of the different isotopes of that element (weighted by abundance) to the unified atomic mass unit. This weighted average can be quite different from the near-integer values for individual isotopic masses.

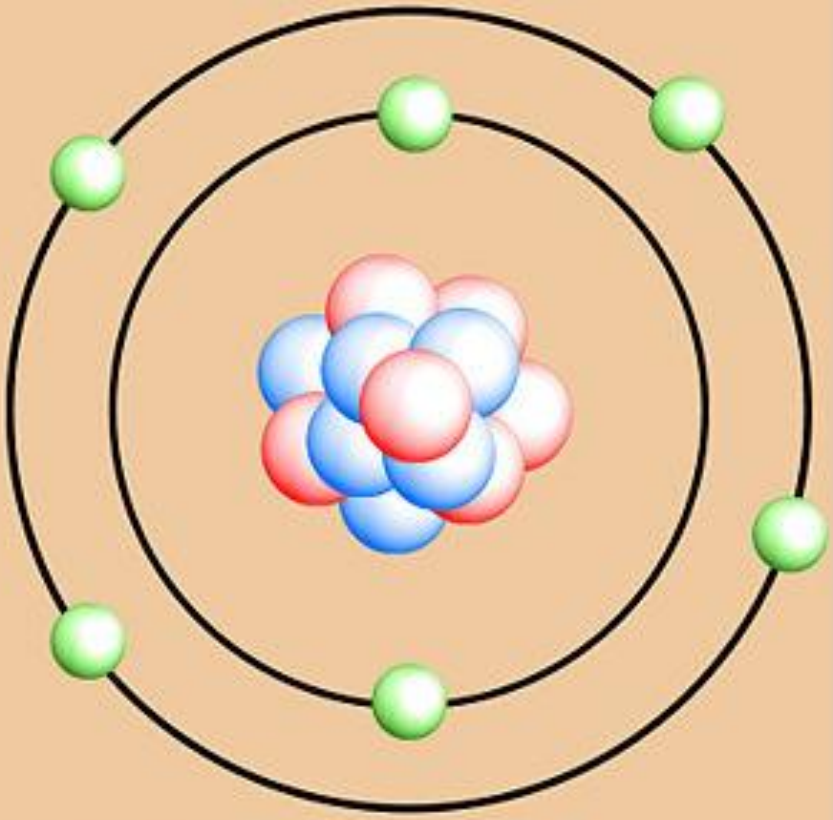
RELATIVE ATOMIC MASS OF AN ELEMENT

For example, there are two main isotopes of chlorine:

	$^{35}_{17}Cl$	$^{37}_{17}Cl$
Number of electrons (**Z**)	**17**	**17**
Number of protons (**Z**)	**17**	**17**
Number of neutrons (**A – Z**)	**18**	**20**

In any given sample of chlorine that has not been subjected to mass separation there will be roughly 75% of chlorine atoms which are chlorine-35 and only 25% of chlorine atoms which are chlorine-37. **This gives chlorine a relative atomic mass of 35.5 (actually 35.4527 g/mol).**

Carbon Atom



- neutron
- proton
- electron

protons = 6

neutrons = 6

6 + 6 = 12

Atomic Mass = 12

STRUCTURE OF CARBON ATOMS

Mass number = 6 protons + 6 neutrons

Ar=12

It is the total number of protons and neutrons present in the nucleus of an atom.

Atomic number = 6 protons / 6 electrons

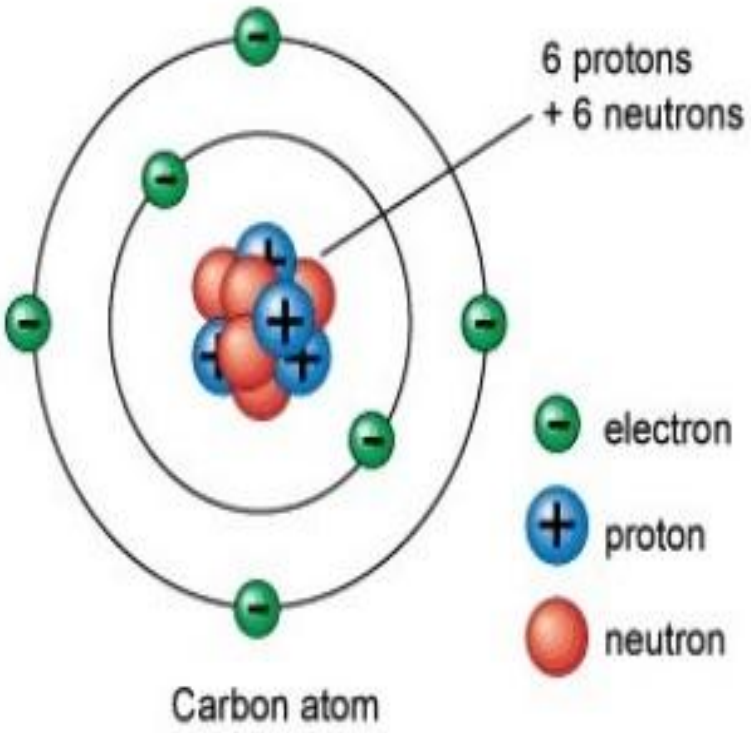
Z=6

The number of protons present in the nucleus of an atom is called the atomic number.

12,011

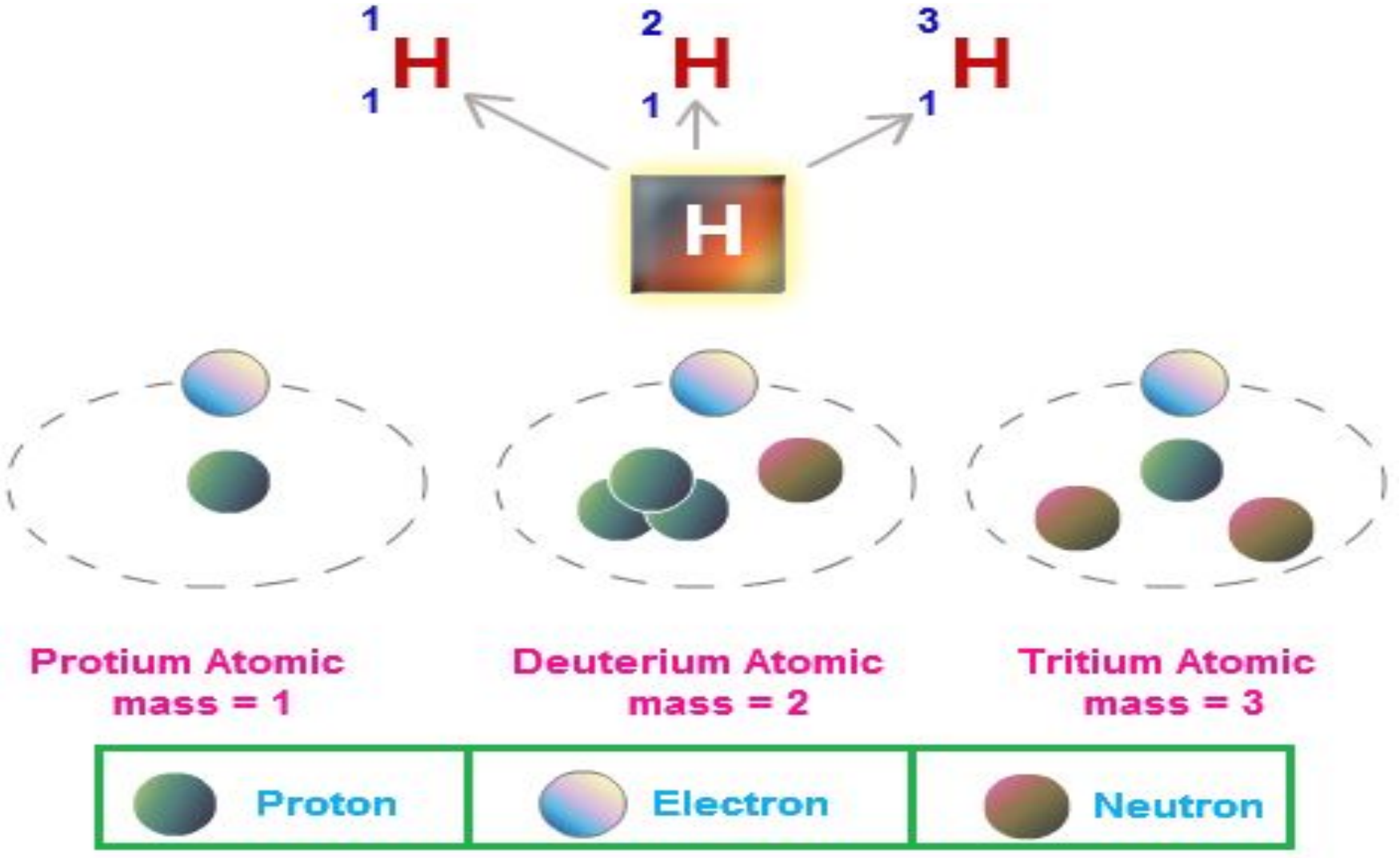
ATOMIC WEIGHT

What are isotopes?



Isotopes are variations of chemical elements that have the same number of protons but different numbers of neutrons.

Hydrogen has three isotopes:



1 proton	1 proton	1 proton
0 neutrons	1 neutron	2 neutrons

An Introduction To Atomic Number, Isotopes And Isobars

ISOTOPES

- Atoms having same atomic number but different mass numbers .
- ^{123}I, ^{125}I, ^{127}I, ^{131}I

ISOBARS

- Atoms having same number of nucleons but differ in number of protons i.e. have same mass number and different atomic number.
- ^{40}Cl, ^{40}Ar, ^{40}K, ^{40}Ca

CHEMICAL BOND

The sharing or transfer of electrons creates some attraction force between elements that is called as chemical bond.

Types of Chemical Bonding:

As a matter of convenience we usually divide chemical bonds into different types. There are two major classes of bonding:

Ionic bonding which results from electrostatic interaction among ions; and can be formed by the transfer of one or more electrons from one atom or group of atoms to another.

Covalent bonding which results from sharing one or more electron pairs between two atoms.

These represent two extremes and all bonds have at least some degree of both ionic and covalent character. Compounds in which the bonding is predominantly ionic are called ionic compounds, and those in which the bonding is predominantly covalent are called covalent compounds.

Bonding between metal ions is known as **metallic bonding**.

A hydrogen bond is an interaction that directs the association of the covalently bounded hydrogen atom with one or more other atoms, group of atoms or molecules into an aggregate structure that is sufficiently stable to make it convenient for the chemist to consider it as an independent chemical species.

The amount of a substance is the mole (symbol: **mol**) is defined arbitrarily as the amount of a substance which has as many atoms or molecules as there are atoms in 12 grams of the carbon isotope C-12.

The number of atoms in a mole is called *Avogadro's number*, the value of which is approximately 6.022×10^{23}.

One mole of a substance always contains almost exactly the relative atomic mass or molar mass of that substance.

$$for\ \ atom:\ \ \nu = \frac{m_A}{Ar}$$

$$for\ \ compound:\ \ \nu = \frac{m_M}{Mr}$$

$$\nu = \frac{N}{N_A} = \frac{N}{6{,}02 \cdot 10^{23}}$$

Relative molecular mass (Mr) or ***molecular weight*** refers to the mass of a molecule is calculated as the sum of the mass of each constituent atom multiplied by the number of atoms of that element in the molecular formula:

$$Mr(Na_2SO_4) = 23 \cdot 2 + 32 \cdot 1 + 16 \cdot 4 = 142 \ \ m.m.u$$

In chemistry, the ***molar mass M*** **is a physical property. It is defined as the mass of a given substance (chemical element or chemical compound) divided by it's a amount of substance**. The base SI unit for molar mass is kg/mol. However, **molar masses are almost always expressed in g/mol.** As an example, the molar mass of sodium sulfate is approximately:

$$M(Na_2SO_4) = 142 \ \ g/mol$$

Even before the creation of the doctrine of atom and molecula it was found that simple and complex chemical substances react in the reaction mass in strictly defined ratios.

Law of equivalents: All substances react and form in equivalent proportions.

The equivalent ratio is the same number of moles of equivalents. ***Thus the law of equivalents can be formulated differently***: **the number of mole equivalents for all substances involved in the reaction is the same.**

The **equivalent** (symbol: **Eq**), sometimes termed the **molar equivalent**, is a unit of electrical charge used in chemistry.

The equivalent of substance A **is the amount of substance A multiplied by its valence.**

$$Eq_{Element} = \frac{Ar}{Val}$$

$$for\ \ metal\ \ Eq(Al) = \frac{Ar(Al)}{Val(Al)} = \frac{27}{3} = 9\ \ g-eq/mole$$

$$for\ \ non-metal\ \ Eq(O) = \frac{Ar(O)}{Val(O)} = \frac{16}{2} = 8\ \ g-eq/mole$$

The equivalent could be also formally defined through the amount of substance which will either: ***react with or supply one mole of hydrogen ions (H+) in an acid-base reaction; or react with or supply one mole of electrons in a redox reactiom*****.**

The mass of one equivalent of a substance is called its equivalent weight.

$$Eq(H_2S) = \frac{1}{2}$$

$$Eq(NH_3) = \frac{1}{3}$$

$$Eq(CH_4) = \frac{1}{4}$$

$$K\overset{+7}{M}nO_4 + H_2SO_4 \xrightarrow{+5\bar{e}} \overset{+2}{M}nSO_4 + H_2O$$

$$Eq_{OX}(KMnO_4) = \frac{1}{+\bar{e}} = \frac{1}{5\bar{e}}$$

$$Na_2\overset{+4}{S}O_3 \xrightarrow{-2\bar{e}} Na_2\overset{+6}{S}O_4$$

$$Eq_{RED}(Na_2SO_3) = \frac{1}{-\bar{e}} = \frac{1}{2\bar{e}}$$

$$Eq(acid\ H_X EO_Y) = \frac{M_{H_x EO_y}}{x(H^+)}$$

$$Eq(base\ Me(OH)_n) = \frac{M_{Me(OH)_n}}{n(OH^-)}$$

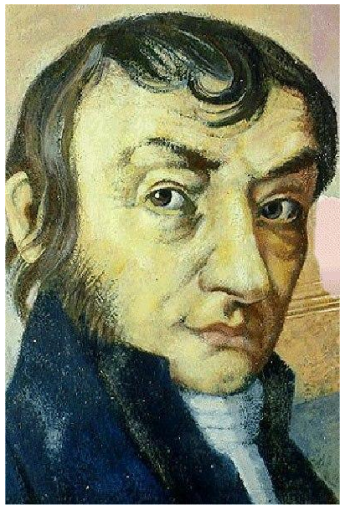
$$Eq(oxide\ E_X \overset{II}{O}_Y) = \frac{M_{E_X O_Y}}{2 \cdot Y(O)}$$

$$Eq(salt\ Me_X EO_Y) = \frac{M_{Me_X EO_Y}}{X_{Me} \cdot Val_{Me}}$$

Law of Equivalents: *the mass ratio of the reacting and produced substances in the reaction is directly proportional to the ratio of their equivalent weights*

$$\frac{m_A}{m_B} = \frac{Eq_A}{Eq_B}$$

$$or\ for\ gas: \quad \frac{m_A}{V_{gas}} = \frac{Eq_A}{E_{V(gas)}}$$



Avogadro's Law

Amedeo Avogadro introduced the term "molecule" and distinguished it from 'atom'. According to Avogadro, particles in the gaseous state do not exist as atoms but as molecules.

In 1811 he proposed his famous hypothesis, now known as 'Avogadro's Law'. **The Law states that "Equal volume of all the gases at same temperature and pressure, contains equal number of molecules."**

- Standard temperature and pressure is called as STP. For gases, the term STP is often used. STP means the temperature of the gas is 273K and the pressure of the gas is 1 atm. *Avogadro said that* **1 mole of any gas at STP occupies 22.4L of volume.**
- Avogadro also expressed the number of atoms present in the mole of a gas. *He stated that* **6.022×10^{23} particles are present in the 1 mole of a gas.**

BOYLE'S LAW

According to Boyle's Law **when the temperature is constant, the pressure and volume of a gas are inversely proportional** (PV = constant)

$$P_1V_1 = P_2V_2$$

Thus increasing the gas pressure, it's volume is reduced.

CHARLES' LAW

According to Charles' Law **the volume of a gas is proportional to the Kelvin temperature as long as the pressure is constant** (V = k*T)

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

Note: The temperature for gas laws must always be expressed in Kelvin where Kelvin = ºC +273.15

GAY-LUSSAC'S LAW

Gay Lussac's Law of pressure and temperature describes the direct relationship between pressure and temperature, if mass and volume of gas are fixed. **If the absolute temperature of a fixed gas volume is increased, then the pressure will be increases proportionally** (P=k*T):

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

Partial Pressure

Pressure each gas in a mixture would exert if it were the only gas in the container:

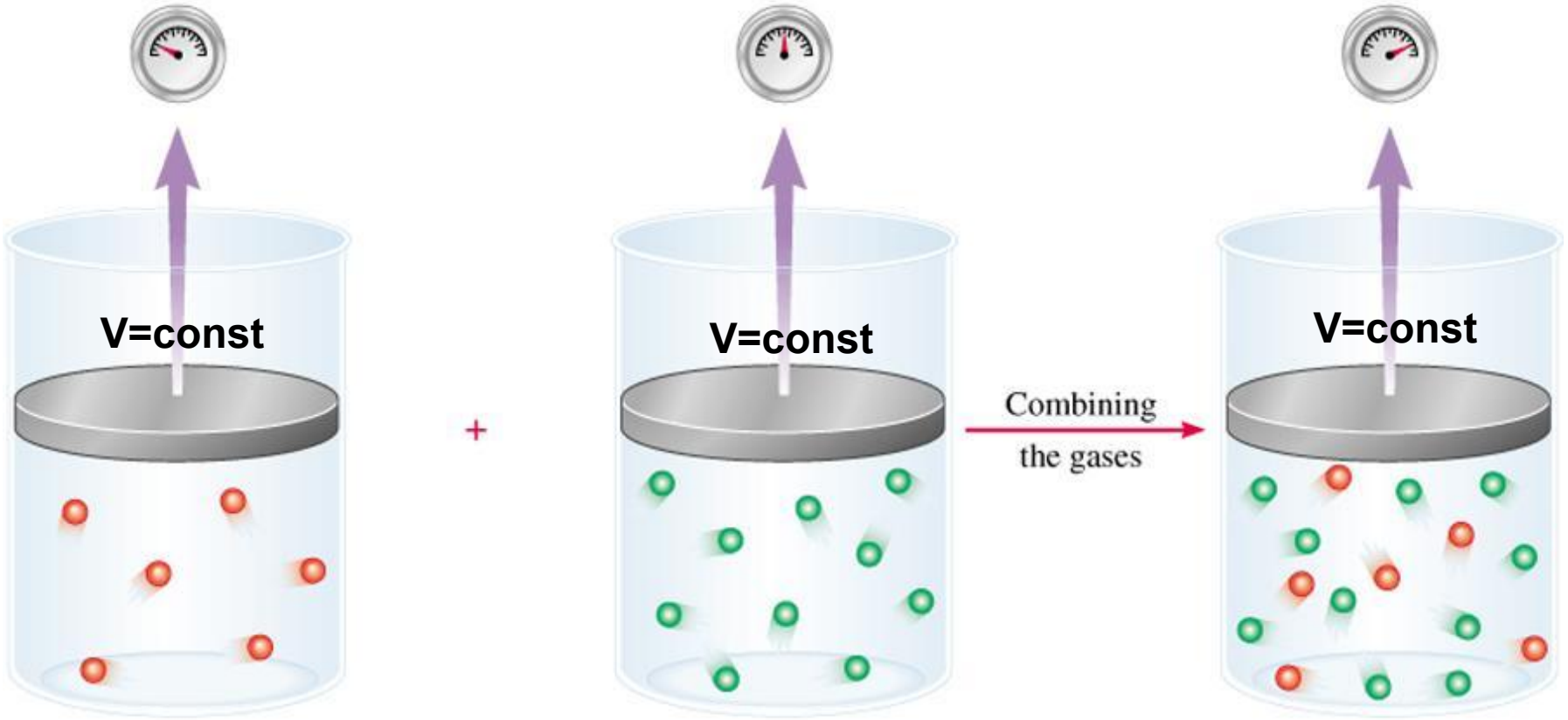
$$P_A \cdot V_A = P_A^{'} \cdot V_{gases\ mixture} \quad \Rightarrow P_A^{'} = \frac{P_A \cdot V_A}{V_{gases\ mixture}}$$

Dalton's Law of Partial Pressures (1801)

The total pressure exerted by a gas mixture is the sum of the partial pressures (P'_n) of the gases in that mixture:

$$P_{Total} = P'_1 + P'_2 + P'_3 + \ldots.$$

Dalton's Law of Partial Pressures



P'_A P'_B $P_{total} = P'_A + P'_B$

THE COMBINED GAS LAW

If the amount of the gas is constant, then Boyle's Charles' and Gay-Lussac's Laws can be combined into one relationship:

$$\frac{P_1 \cdot V_1}{T_1} = \frac{P_2 \cdot V_2}{T_2}$$