CHAPTER 2

MAIN CONSTITUENTS OF MATTER

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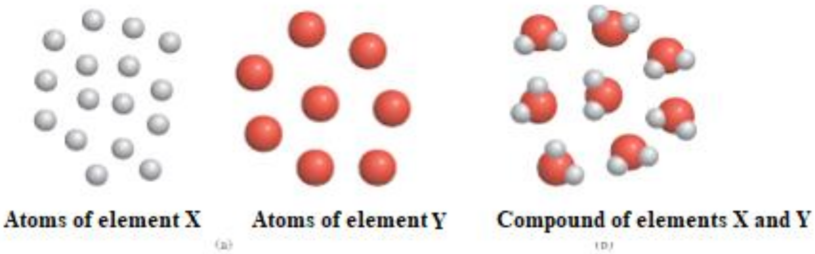
CHAPTER 2

MAIN CONSTITUENTS OF MATTER

I- Introduction

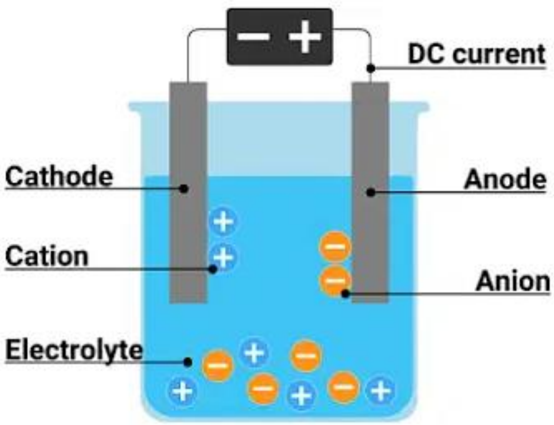
The modern version of atomic theory was laid out by John Dalton in 1803, who postulated that elements are composed of extremely small particles, called atoms, and that all atoms of a given element are identical, but they are different from atoms of all other elements.



II- Faraday's experiment: relationship between matter and electricity

Some of the earliest evidence about atomic structure was supplied in the early 1800s by the English chemist **Humphry Davy** (**1778–1829**). He found that when he passed electric current through some substances, the substances decomposed. He therefore suggested that the elements of a chemical compound are held together by electrical forces.

In **1832– 1833**, **Michael Faraday**, Davy’s student, discovered that the amount of substance produced at an electrode by electrolysis depends on the quantity of charge passed through the cell.



To find out how many moles of electrons pass through a cell in a particular experiment, we need to measure the electric current and the time that the current flows.

The number of coulombs of charge passed through the cell equals the product of the current in amperes (coulombs per second) and the time in seconds:

Charge (C) = Current (A)× Time (s) ⇒ **q = A .t**

The electric charge on 1 mol of electrons is 96,485 C/mol e^-, so the number of moles of electrons passed through the cell is:

$$\text{Moles of e- = Charge (C)} \times \frac{1\ \text{mol}\ e^-}{96{,}500\ \text{C}}$$

Studies of Faraday's work by **George Stoney** (1826–1911) led him to suggest in **1874** that units of electric charge are associated with atoms. In 1891, he suggested that they be named **electrons**.

Table 1. Derived units (where E and B are the electric and magnetic fields, L is the length, t is the time, q is the charge, x is the distance, U is the potential)

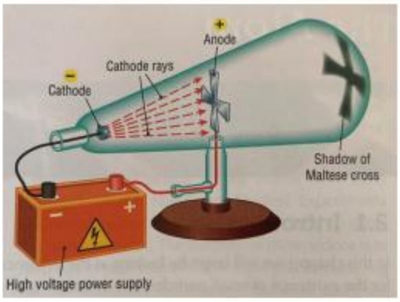
Quantity	Definition of quantity	IS Unit	Equation
Area	Length squared	m^2	A= L .L
Volume	Length cubed	m^3	V= A . L
Density	Mass per unit volume	kg/m^3	d = m/V
Speed	Distance traveled per unit time	m/s	ν = x/t
Acceleration	Speed changed per unit time	m/s^2	γ = ν/t
Magnetic field	force per (speed times charge)	N.s/m.C = kg/s.C = Tesla	B = F.t/x.q
Electric field	volt per metre	(V/m)	E = U/d
Force **Electric force** **Magnetic force**	- Mass times acceleration of object - Charge times electric field - charge times speed times magnetic field	$kg.m/s^2$(= newton, N) (Coulomb × Volt)/m C.(m/s).T	F = m .γ Fe = q E F_m = q.ν. B
Pressure	Force per unit area	$kg/(m.s^2)$ (=pascal,Pa)	P = F/A
Energy	Force times distance traveled Charge times volt	$kg.m^2/s^2$(=joule, J) C. Volt	E = F. x E = q.U

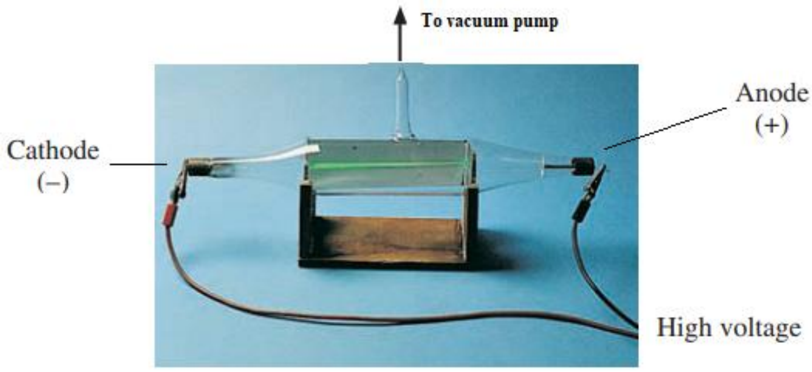
III- Highlighting the constituents of matter and atom

1- Discovery of Subatomic Particles

➢ Discovery of the Electron

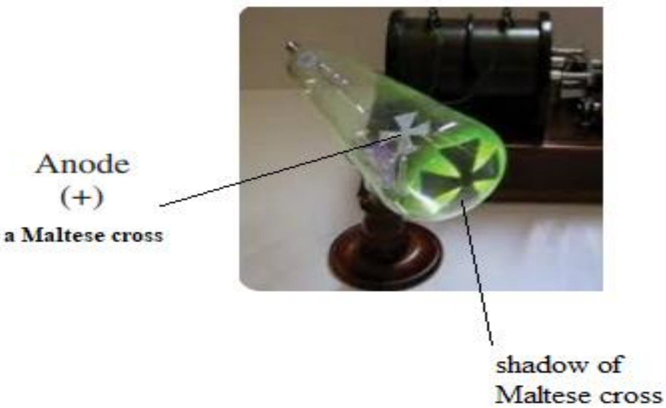
In 1875, **William Crookes** (English chemist) used a vacuum tube called a **cathode ray tube**; along glass tube with an electrode at each end, inside the tube there was gas at low pressure (**0.01 mmHg)** and at high voltage (**50000 V**).



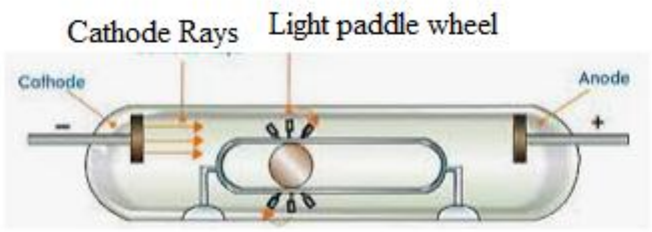


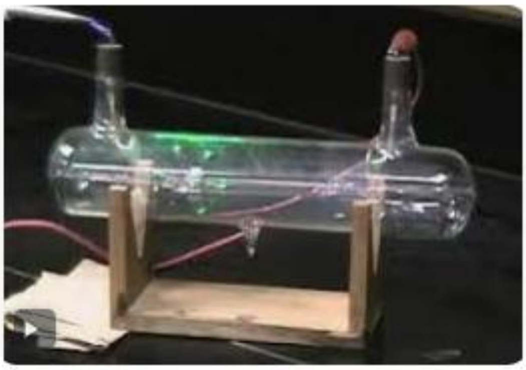
When the high-voltage current is turned on, the glass tube emits a greenish light. Experiments showed that this greenish light is caused by the interaction of the glass with cathode rays, which are rays that originate from the cathode (negative electrode).

- These Rays travelled from **the cathode (negative electrode) to the anode (positive electrode),** they are called **cathode rays.**
- They travelled in straight lines – to show the presence of radiation he placed a Maltese cross inside the tube – a sharp shadow in glow formed at end of tube.

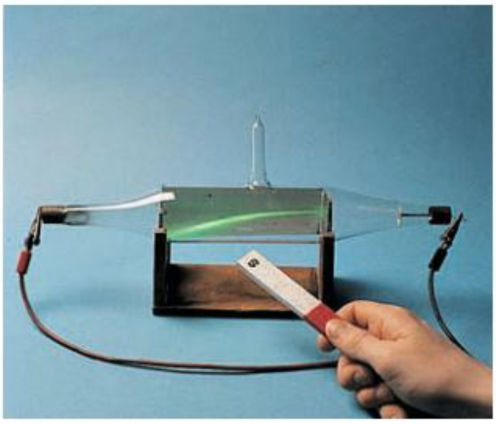


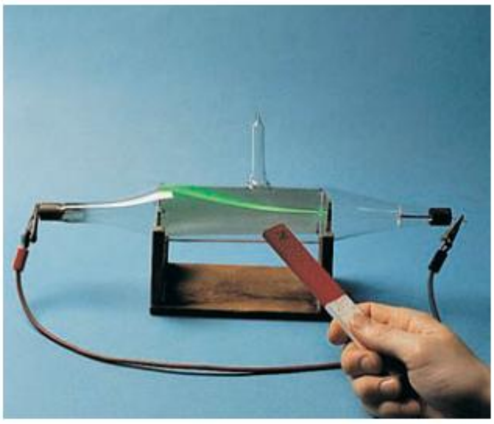
Crookes carried out a second experiment to investigate the properties of cathode rays. It consisted of a light paddle wheel mounted on rails in front of the cathode.

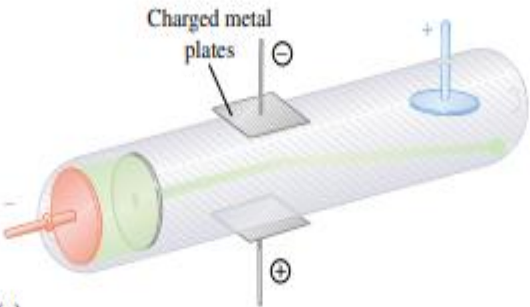




- When current on – paddle wheel rotated and travelled down the tube. Vanes always turned away from the cathode**: they were struck by particles from the cathode.**
- The beam of the ray bends away from the negatively charged plate and toward the positively charged plate in an electric field. Interaction of cathode rays with a magnetic field is also consistent with negative charge.







(c)

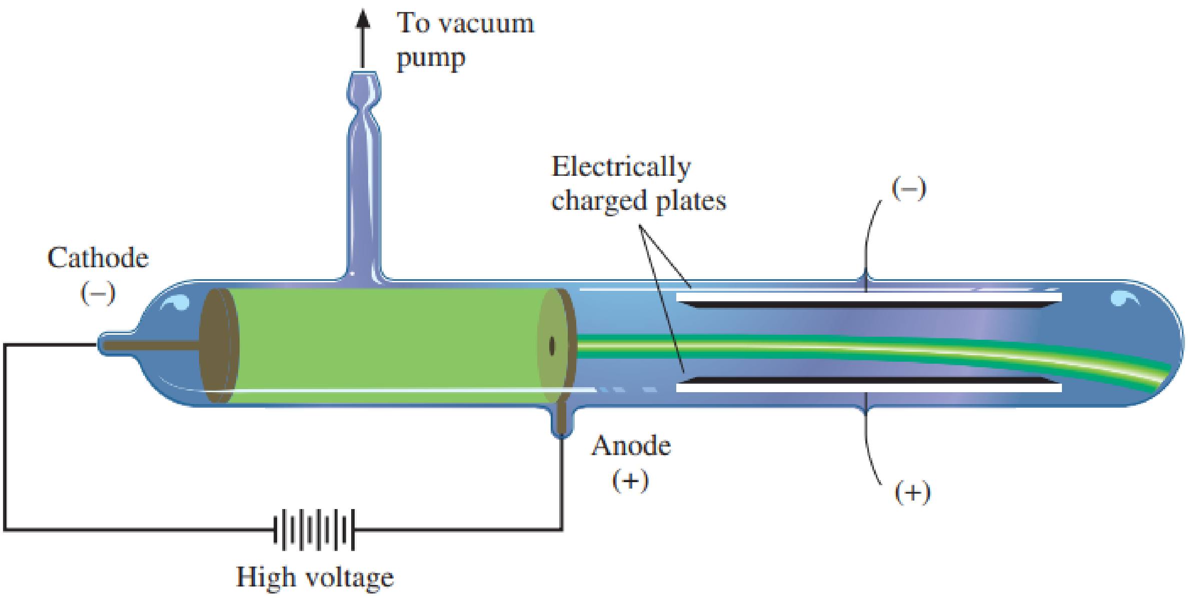
Crookes deducted properties of the cathode:

- **Cathode rays travel in straight lines (**an object placed in a beam of ray casts a shadow)**.**
- **Cathode rays cause glass to fluorescence when they stroke it.**
- **Cathode rays possess enough energy to move a paddle wheel that means, Cathode rays (electrons) have mass.**
- **The cathode ray (electrons) consists of a beam of negatively charged particles (**as demonstrated by their deflection in an electric field**) and they are constituents of all matter.**

➢ Physical properties of electron

a. Joseph John Thomson (calculation of e/m_e ratio) (Nobel 1906)

In **1897**, an English physicist, J. J. Thomson, used a cathode ray tube and his knowledge of electromagnetic theory to determine the ratio of electric charge to the mass of an individual electron **e/m_e**.



When in an electric field, charged particles experience a force which can accelerate them to high velocities. If q is the charge of the particle and E is the magnitude of the electric field, then force F is given as:

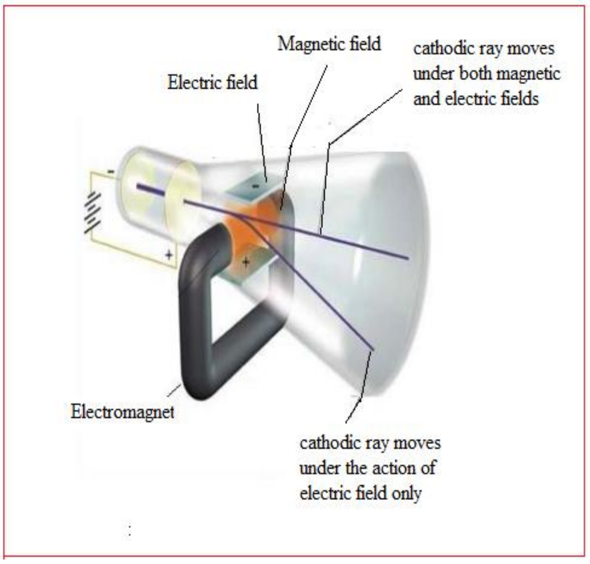
$$F_e = q \cdot E$$

A potential difference U exists across the two ends of the field, and the work (W) done on the particle when accelerated across the field would be:

$$W = q \cdot U$$

A charged particle of charge q moving with a velocity v in a magnetic field of strength B also experiences a force. This force, F_m is given by:

$$F_m = q\,(v \times B)$$



- It is important to understand that the magnetic field can never change the magnitude of the velocity of a substance. It can only change the direction.

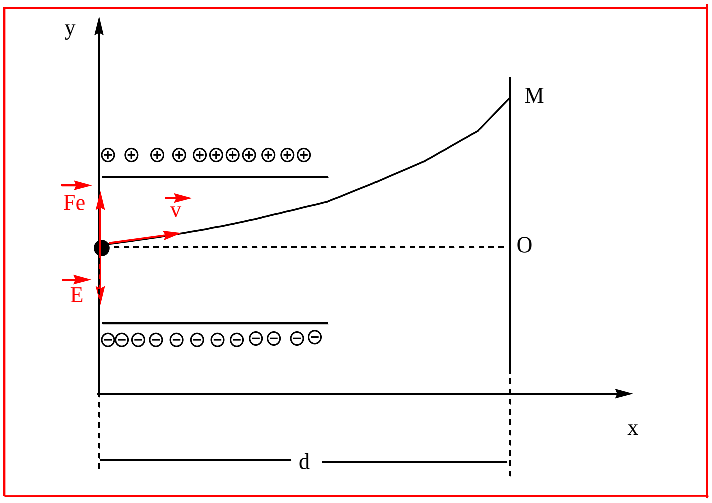
Electric (E) and magnetic fields (B) are adjusted such that the beam of electrons is not deflected and travel in straight lines. This means that the sum of all the forces acting on it is equal to zero.

$$\|\overrightarrow{Fe}\| + \|\overrightarrow{Fm}\| = 0 \quad \Rightarrow \quad q.B.v = q.E \quad \Rightarrow \quad \boxed{v = \frac{E}{B}}$$

By turning off the magnetic field, Thomson could measure the deflection of the cathode rays in the electric field alone. In this case, Electrons (mass m_e) gain acceleration (γ), which can be calculated as follows:

$$\sum F_{ex} = m_e.\gamma = F_e \qquad \Rightarrow q.E = m_e\gamma \quad \Rightarrow \quad \boxed{\gamma = \frac{q.E}{m_e}}$$

Suppose that an electron with charge"-e" and mass m is moving to the right, as shown in Figure at the right. It passes through a region of length d in which there is an electric field E pointing up. If the electron is deflected upward by a distance OM as it passes through the field.



- The velocity v_x of the particles perpendicular to the field remains constant (abscise axis).

$$v_x = x/t \quad \Rightarrow t = x/v_x$$

- The velocity v_y of the particles parallel to the field remains accelerate (ordinate axis).

$$y = oM = \frac{1}{2}\gamma.t^2 \Rightarrow \qquad y = \frac{1}{2}.\frac{q.E}{m_e}.\frac{X^2}{V^2}$$

noted that: q = e (electron charge) ; x = d (distance travelled on abscise axis) ; y=OM (distance travelled on ordinate axis). The charge to mass ratio of the electron is given by:

$$\boxed{\frac{e}{m_e} = \frac{2.OM.v^2}{E.d^2}}$$

The unknown quantity e/m is expressed in terms of the known quantities d, E, v, and l. Notice that the deflection of the electron in this example and in Thomson's tube determines neither the value of **e** nor the value of **m**, but only their ratio.

$$\boxed{e/m_e = 1.7589 \times 10^{11} \text{ coulomb/kg}}$$

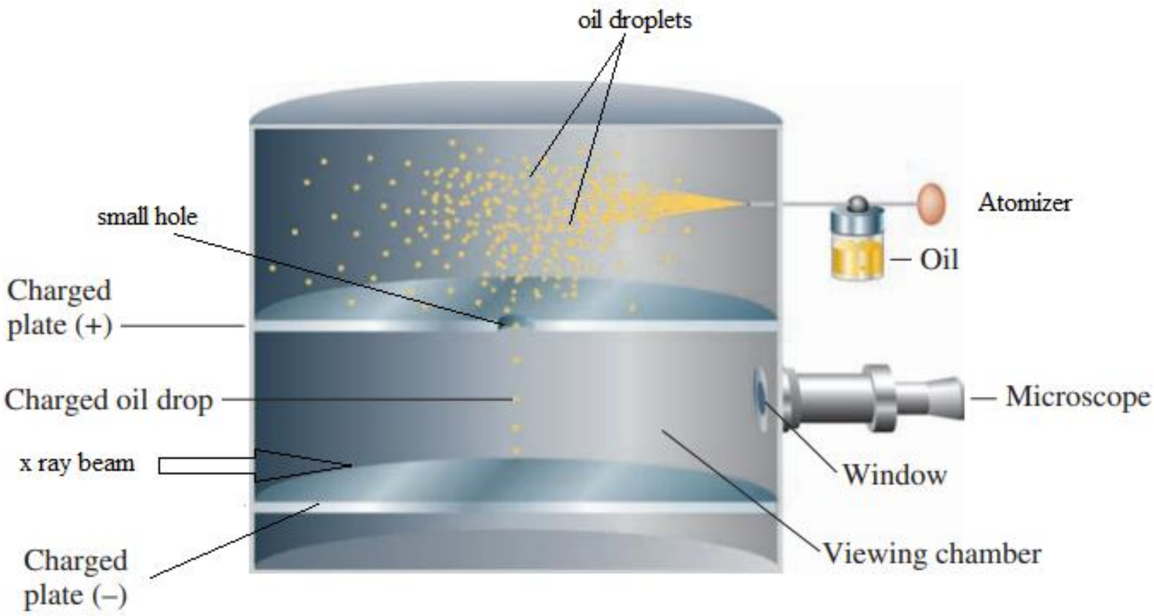
Exercise 1.

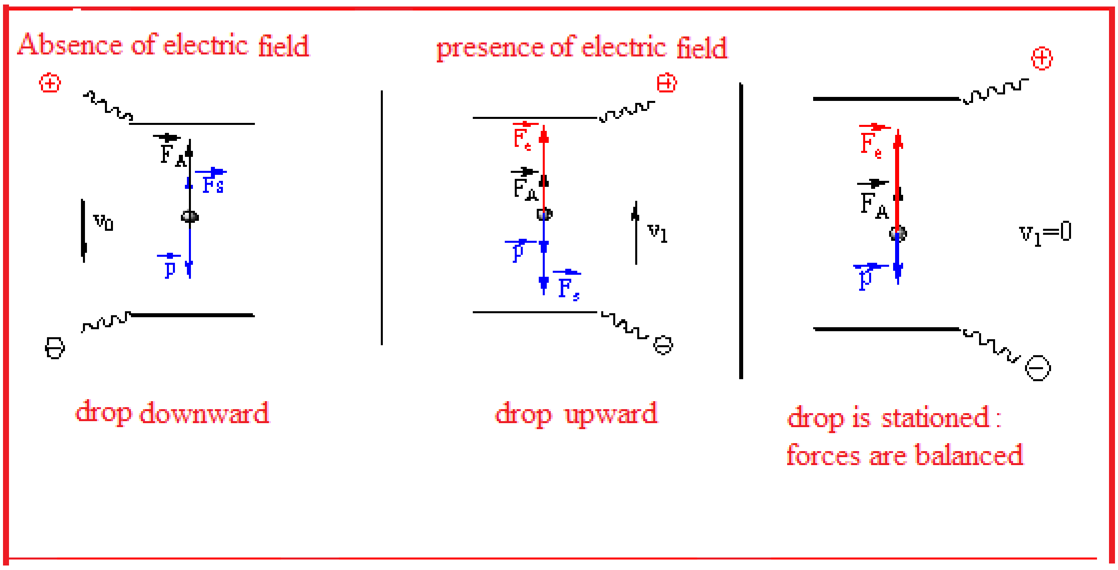
A beam of electrons having a velocity of 4.00×10^7 m/s enters a 5×10^{-3} T magnetic field in an electric field of intensity 2×10^4 volt/m situated between two plats separated of a distance d = 10 cm. This beam of electrons is deflected once the magnetic field is removed by an amount of 4.4 cm. Determine e/m_e from these observations, and compares the result with the known value. (1.76×10^{11} C/kg).

b. Millikan's oil-drop experiment

In **1909** the U.S. physicist **Robert Millikan** performed a series of ingenious experiments in which he obtained the charge on the electron by observing how a charged drop of oil falls in the presence and in the absence of an electric field.

Millikan created microscopic oil droplets, which could be electrically charged by friction as they formed or by using X-rays. These droplets initially fell due to gravity, but their downward progress could be slowed or even reversed by an electric field ($E = U / d$) lower in the apparatus. By adjusting the electric field strength and making careful measurements and appropriate calculations, Millikan was able to determine the charge on individual drops.





❖ When the oil drop is stationed within the volume, once a voltage is applied across the plates, there is an electric force, *F* , acting upwards. This is given by:

$F_e = E \cdot q$; where **q** is the charge on the oil drop and **E** is the field strength.

The electric field can be expressed as a function of the voltage U across the plates and the spacing d between them:

E = U/ d where **U** is the voltage on the plates and **d** is their separation.

The downward force acting on the oil drop is due to the gravitational pull on the drop:

The drop is being pulled down by its weight **p = m. g** (the gravitational pull)

Where $m = \rho.V = \rho.\frac{4}{3}\pi r^3 \Rightarrow p = (4/3)\pi r^3.\rho.g$

Where ρ **in** kg/m^3 is the density of the oil and **g** = Acceleration of gravity in m/s^2.

Assuming that the oil drop is approximately spherical, its volume is given by the following formula:

$$V = (4/3)\pi r^3$$

Where r is the radius of the oil drop.

There is a third force acting on the oil drops. The buoyancy due to the surrounding air between the plates introduces an upward thrust: the plate introduces an upward thrust:

$$F_A = g' m \qquad \Rightarrow F_A = (4/3)\pi r^3.\rho_o.g$$

Where ρ_0 is the density of the air (1.2929 kg/m^3).

In the correct conditions, the electrostatic force and the force of gravity can be balanced, such that the oil drop is brought to rest. In this case, we can express the charge on the oil drop as follows:

$$F_e = P \quad \Rightarrow \quad \mathbf{q = \frac{mgd}{U}}$$

Therefore, the equation for the charge of the oil drop can be expressed as:

$$\mathbf{q = \frac{d}{U} \cdot \frac{4}{3} \pi r^3 (\rho_{oil} - \rho_{air})}$$

❖ When switching off the voltage and letting the drop fall. As the drop falls down through the viscous air, it experiences an upward drag force given by Stokes's law as follows:

When the oil drop is in the electric field, there is an electric force, F , the gravitational pull P, the buoyancy force and Stokes's force acting upwards. This is given by:

$$F_{s\uparrow} = 6\pi\eta r v_o$$

In this equation, η is the viscosity of air (1.81×10^{-5} kg/m.s) and v is the speed of the oil drop.

Using this expression and applying Newton's 2nd Law to a falling oil drop under the influence of the viscous and buoyant force, one can show that the radius of the oil drop is:

$$\boxed{\mathbf{r = 3\sqrt{\frac{\eta v_0}{2(\rho - \rho_0)g}}}}$$

And the charge on the droplet is given by:

$$\boxed{\mathbf{q = \frac{6\pi\eta r}{E}(v_1 + v_0)}}$$

Looking at the charge data that Millikan gathered, you may have recognized that the charge of an oil droplet is always a multiple of a specific charge, 1.6×10^{-19} C.

Oil drop	Charge in coulombs (C)
A	4.8×10^{-19} C
B	3.2×10^{-19} C
C	6.4×10^{-19} C
D	1.6×10^{-19} C
E	4.8×10^{-19} C

Millikan concluded that this value must therefore be a fundamental charge, the charge of a single electron, with his measured charges due to an excess of one electron (1 times 1.6×10^{-19} C), two electrons (2 times 1.6×10^{-19} C), three electrons (3 times 1.6×10^{-19} C), and so on, on a given oil droplet.

Since the charge of an electron was now known due to Millikan's research, and the charge-to-mass ratio was already known due to Thomson's research (1.759×10^{11} C/kg), it only required a simple calculation to determine the mass of the electron as well.

$$\text{cause} \quad \frac{e}{m} = 1.758\,820 \times 10^{8}\ \text{C/g}$$

$$\text{then} \quad m = \frac{e}{1.758\,820} = \frac{1.602\,176 \times 10^{-19}}{1.758\,820 \times 10^{8}}$$

$$= 9.109\,382 \times 10^{-28}\ \text{g}$$

$$\boxed{e = 1.6 \times 10^{-19}\text{coulomb}}$$

$$\boxed{m_e = 9{,}108 \times 10^{-31}\text{Kg}}$$

Exercise 2

An oil drop has a mass of 8.22×10^{-11} kg and is balanced in an electric of 4.36×10^{7} N/C.

a) Calculate the charge on the oil drop. ($q = +1.85 \times 10^{-17}$ C).

b) How many electrons would need to have been lost or gained? (≈ 116 e^- lost) ?

c) Supposed that the oil drop is now experiencing a downward acceleration of 6.1 m/s^2. Calculate the electric force. (3.05×10^{-10} N).

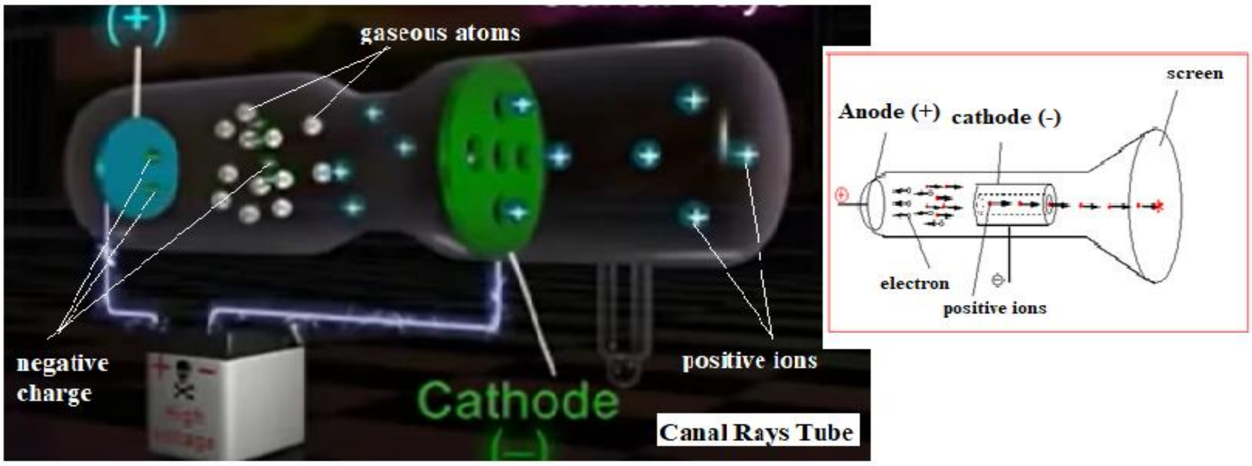
d) Supposed that the oil drop is now experiencing a upward acceleration of 17.4 m/s^2 . Calculate the electric force. (6.2×10^{-10} N).

Data : $\rho_{\text{الزيت}} = 1.26 \times 10^{3}$ Kg/m^3 ; g = 9.81m/s ; $\eta = 18 \times 10^{-6}$ Kg/ m.s

➢ Discovery of the Electron

In **1886**, **Eugen Goldstein** (1850–1930) first observed that a cathode-ray tube also generates a stream of positively charged particles that moves toward the cathode. This faint luminous ray was seen extending from the holes in the back of the cathode.

These were called **canal rays** because they were observed occasionally to pass through a channel, or "canal," drilled in the negative electrode.



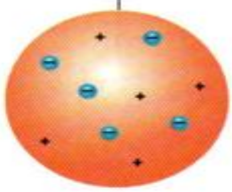
https://www.youtube.com/watch?v=1JX7iTm3Uw8

These *positive rays*, or *positive ions*, are created when the gaseous atoms in the tube lose electrons. Positive ions are formed by the process

$$\textbf{Gas atom} \rightarrow \textbf{cation}^{+} + \textbf{e}^{-}$$

Different elements give positive ions with different *e/m* ratios. The regularity of the *e/m* values for different ions led to the idea that there is a unit of positive charge and that it resides in the **proton.** The proton is a fundamental particle with a charge equal in magnitude but opposite in sign to the charge on the electron. Its mass is almost 1836 times that of the electron.

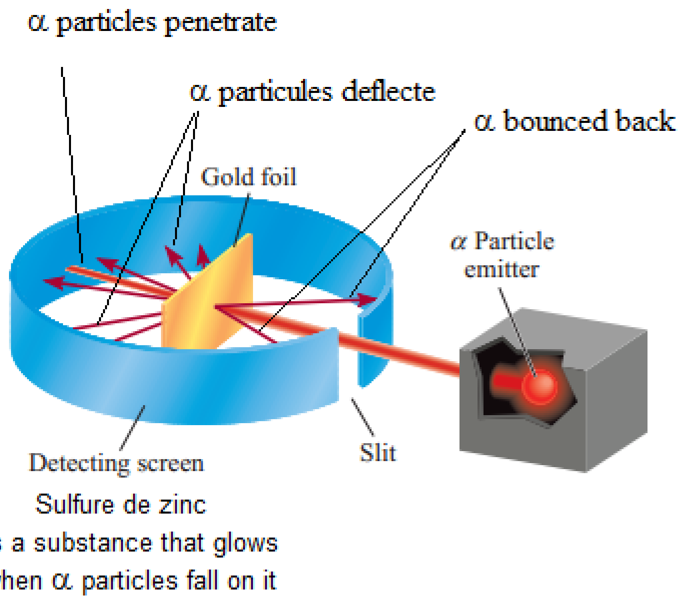
By the early 1900s, two features of atoms had become clear: They contain electrons, and they are electrically neutral. To maintain electrical neutrality, an atom must contain an equal number of positive and negative charges. On the basis of this information, Thomson proposed that an atom could be thought of as a uniform, positive sphere of matter in which electrons are embedded. Thomson's so-called "plum pudding" model was the accepted theory for a number of years.



IV- Rutherford planetary model

In **1910, the New Zealand physicist Ernest Rutherford and his collaborators** decided to use α particles (positive particles provided from radioactive polonium) to probe the structure of atoms. They carried out a series of experiments using very thin foils of gold and other metals as targets for particles from a radioactive source.

- They observed that the majority of particles penetrated the foil either undeflected or with only a slight deflection.
- They also noticed that every now and then an α particle was scattered (or deflected) at a large angle.
- In some instances, an α particle actually bounced back in the direction from which it had come!
- This was a most surprising finding, for in Thomson's model, the positive charge of the atom was so diffuse (spread out) that the positive α particles were expected to pass through with very little deflection.



To explain the results of the α-scattering experiment, Rutherford devised a new model of atomic structure, suggesting **that most of the atom must be empty space**.

- This structure would allow most of the α particles to pass through the gold foil with little or no deflection.
- The atom's positive charges are all concentrated in the ***nucleus**, a dense central core within the atom.*
- Whenever an α particle came close to a nucleus in the scattering experiment, it experienced a large **repulsive force** and therefore a large deflection.
- Moreover, an α particle traveling directly toward a nucleus would experience an **enormous repulsion** that could completely reverse the direction of the moving particle.

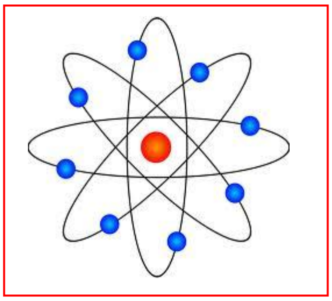
The positively charged particles in the nucleus are called ***protons*.** In separate experiments, it was found that the charge of each proton has the same *magnitude* as that of an electron.

Modern measurements show that an atom has a diameter of roughly 10^{-10} m and that a nucleus has a diameter of about 10^{-15} m.

$$\boxed{q_P = +1.6\times10^{-19} c}$$

$$\boxed{m_P = 1.6726\times10^{-27} Kg}$$

Rutherford was able to determine the magnitudes of the protons on the atomic nuclei. The picture of atomic structure that he developed is called the **Rutherford model of the atom**.



The Neutron

Rutherford's model of atomic structure left one major problem unsolved. It was known that hydrogen, the simplest atom, contains only one proton and that the helium atom contains two protons. Therefore, the ratio of the mass of a helium atom to that of a hydrogen atom should be 2:1. (Because electrons are much lighter than protons, their contribution can be ignored.) In reality, however, the ratio is 4:1. Rutherford and others postulated that there must be another type of subatomic particle in the atomic nucleus; the proof was provided by another English physicist, **James Chadwick,** in **1932**.

When Chadwick bombarded a thin sheet of beryllium with α particles, a very high-energy radiation similar to γ rays was emitted by the metal. Later experiments showed that the rays actually consisted of **electrically neutral particles having a mass slightly greater than that of protons.** Chadwick named these particles **neutrons.**

The mystery of the mass ratio could now be explained. In the helium nucleus, there are two protons and two neutrons, but in the hydrogen nucleus, there is only one proton and no neutrons; therefore, the ratio is 4:1.

There are other subatomic particles, but the electron, the proton, and the neutron are the three fundamental components of the atom that are important in chemistry.

TABLE 2.1 A Comparison of Subatomic Particles

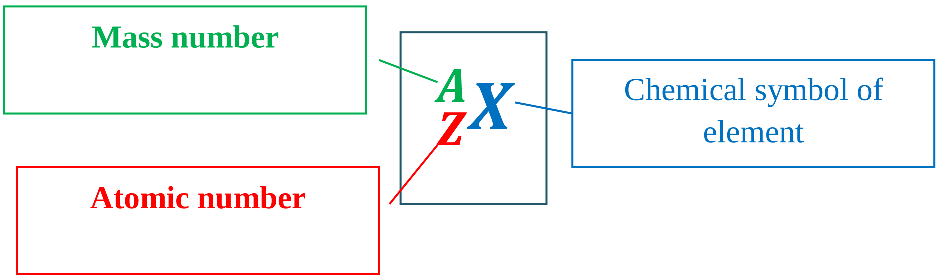
	Mass		Charge	
Particle	**grams**	**amu***	**coulombs**	***e***
Electron	9.109382×10^{-28}	5.485799×10^{-4}	$-1.602176 \times 10^{-19}$	-1
Proton	1.672622×10^{-24}	1.007 276	$+1.602176 \times 10^{-19}$	$+1$
Neutron	1.674927×10^{-24}	1.008 665	0	0

V- Presentation and characteristics of the atom

1. Symbol

Chemical elements are represented by a chemical symbol, with the atomic number and mass number sometimes affixed as indicated below.

A **nuclide** is an atom characterized by a definite atomic number and mass number. The shorthand notation for any nuclide consists of the symbol of the element with the atomic number written as a subscript on the left and the mass number as a superscript on the left.



2. Atomic number Z

All atoms can be identified by the number of protons and neutrons they contain. The number of protons in the nucleus of each atom of an element is called the **atomic number (Z).**

In a neutral atom the number of protons is equal to the number of electrons, so the atomic number also indicates the number of electrons present in the atom. The chemical identity of an atom can be determined solely by its atomic number.

3. Mass number A

The **mass number (A)** is the total number of neutrons and protons present in the nucleus of an atom of an element. Except for the most common form of hydrogen, which has one proton and no neutrons, all atomic nuclei contain both protons and neutrons. In general, the mass number is given by

mass number = number of protons + number of neutrons

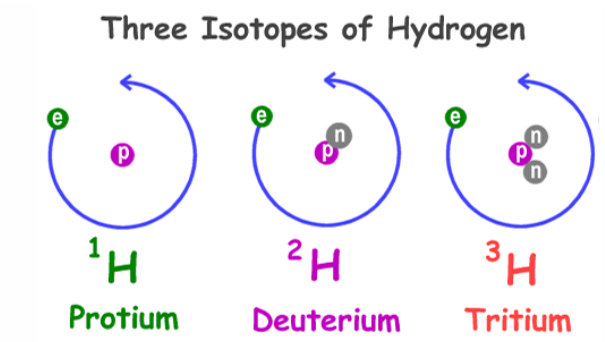
= atomic number + number of neutrons

The number of neutrons in an atom is equal to the difference between the mass number and the atomic number, or **(A - Z).**

VI-Isotopic and relative abundance of different isotopes

The term `isotope´ is derived from the Greek (meaning equal place): the various isotopes of an element occupy the same position in the periodic table. Isotopes of an element can either be stable or unstable (radiogenic).

Isotopes are atoms whose nuclei contain the same number of protons but a different number of neutrons.



The percentage of a given isotope in the naturally occurring sample of an element is called **isotopic abundance (e%)**.

You calculate the **atomic mass** of an element by multiplying each isotopic mass $\mathbf{M_e}$ by its fractional abundance **e%** and summing the values.

$$\textbf{atomic mass} = \textbf{average mass} = \frac{\sum \mathbf{M_e} \times \mathbf{e\%}}{\mathbf{100}}$$

Exercise 3.

Chlorine has two naturally occurring isotopes: $^{35}_{17}Cl$ with a natural abundance of 75.77% and an isotopic mass of 34.969 amu, and $^{37}_{17}Cl$ with a natural abundance of 24.23% and an isotopic mass of 36.966 amu. What is the atomic mass of chlorine?

Isobars: are the atoms of different elements with the same mass number but different atomic numbers. In other words, isobars have different number of protons, neutrons and electrons but the sum of protons and neutrons (i.e., number of nucleons) is same.

Example: $^{40}_{18}Ar$, $^{40}_{19}K$ and $^{40}_{20}Ca$

Isotones: Isotones are the atoms of different elements with the same number of neutrons but different mass numbers.

Example: $^{30}_{14}Si$, $^{31}_{15}P$ and $^{32}_{16}S$

Exercise 3.

The atomic mass of Ga is 69.72 amu. There are only two naturally occurring isotopes of gallium: ^{69}Ga, with a mass of 69.0 amu, and ^{71}Ga, with a mass of 71.0 amu. The natural abundance of the ^{69}Ga isotope is approximately: **a**. 15%; b. 30% ;**c**. 50% ;**d**. 65% or **e**. 80%.

VII- Mass spectrometry: Bainbridge spectrograph

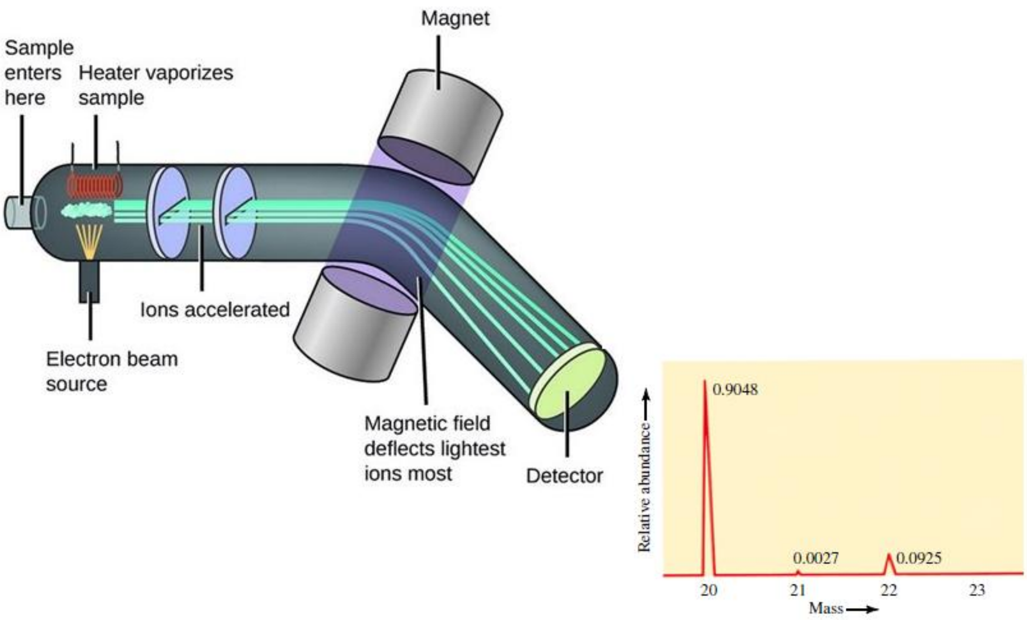
(Separation of isotopes and determination of the atomic mass and the average mass of an atom)

The most direct and accurate method for determining atomic and molecular masses is mass spectrometry.

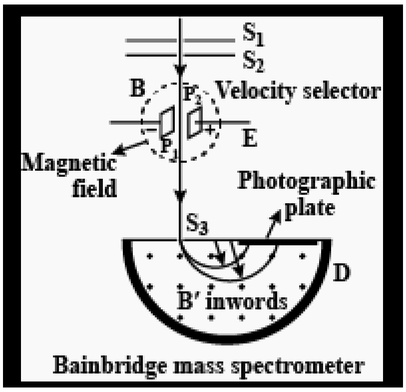
In a mass spectrometer, a gaseous sample is bombarded by a stream of high-energy electrons. Collisions between the electrons and the gaseous atoms (or molecules) produce positive ions by dislodging an electron from each atom or molecule.

$$M + e^- \rightarrow M^{\bullet+} + 2e^-$$

1. **Ion Source**: All mass spectrograph starts with an ion source to be detected. The ions are produced either by electron-bombardment of gases or by heating the suitable coated filaments.



2. **Energy, Momentum, and Velocity Filter**: The velocity selector allows the ions of a particular velocity to come out of it, by the combined action of an electric and a magnetic field. The velocity selector consists of two plane parallel plates, **P1 and P2, which produce a uniform electric field E and an electromagnet, to produce a** uniform magnetic field **B** (represented by the dotted circle). These two fields are so adjusted that the deflection produced by one field is nullified by the other, so that the ions do not suffer any deflection within the velocity selector.



Bainbridge mass spectrometer

The force exerted by the electric field is equal to **q . E** and the force exerted by the magnetic field is equal to **B . q . v** where v is the velocity of the positive ion.

$$F_e = F_m \Rightarrow qE = qvB \Rightarrow \mathbf{v = \frac{E}{B}}$$

Where **E** and **B** are the electric field intensity and magnetic induction respectively and **q** is the charge of the positive ion.

3. **Evacuated Chamber**: These positive ions having the same velocity are subjected to another strong uniform magnetic field of induction **B′** at right angles to the plane of the paper acting inwards. These ions are deflected along circular path of radius **R** and strike the photographic plate. The force due to magnetic field **B′. q . v** provides the centripetal force.

$$qvB' = \frac{mv^2}{R} \Rightarrow \frac{q}{m} = \frac{v}{RB'} \Rightarrow \boxed{\frac{q}{m} = \frac{E}{BB'R}}$$

4. **Detector:** It may be a photographic plate or an electrometer. The distance between the opening of the chamber and the position of the dark line gives the diameter 2R from which radius R can be calculated.

Ions of smaller e/m ratio trace a wider curve than those having a larger e/m ratio, so that ions with equal charges but different masses are separated from one another.

Exercise 4

Bainbridge mass spectrometer was used to separate two ions, one of which was oxygen ^{16}O and the other was unknown. The velocity of the ions was 200 km/s and they are deflected by a magnetic fiel of 0.3 Tesla. The unknown ion is deflected along circular path of radius R equals twice the ^{16}O radius. The distance between the two contact spots of ions on the screen is 1.38 cm. what is the mass of unknown ion?

VIII- Energy of connection and cohesion of the nuclei

In nuclear reactions, matter is transformed into energy. The relationship between matter and energy is given by **Albert Einstein's** (theory of relativity) now famous equation:

$$\boxed{\Delta E = \Delta m \times C^2}$$

ΔE stands for energy, **Δm** stands for mass defect, and **$c = 3 \times 10^8$ m/s**, the constant that relates the two, is the speed of light.

This equation tells us that the amount of energy released when matter is transformed into energy is the product of the mass of matter transformed and the speed of light squared. And the **Mass Defect** is given by:

mass number

Mass of neutron

Theoretical Mass of nuclei

$$\Delta m = [{}_{P}\, mZ + (A - Z)m_N] - M({}^{A}_{Z}X)$$

Mass of proton

proton number

atomic number

The nuclei

IX- Stability of atomic nuclei

The energy required to break down a nucleus into its component nucleons is called the ***nuclear binding energy***.

Example: what is the nuclear binding energy of iron ${}^{56}_{26}Fe$ when m_p = 1.0072 uma ; m_N = 1.0086uma ; M(Fe) = 55.9375uma.

- Nuclear binding energies are usually expressed in terms of **kJ/mole of nuclei** or **MeV's/nucleon**

- **Mega electronvolt (MeV)**

An electronvolt (symbol eV) is the measure of an amount of kinetic energy gained by a single electron accelerating from rest through an electric potential difference of one volt in vacuum.

$$E = q \times U$$

$$1ev = 1{,}6\times10^{-19}\ c \times 1\ volt \Rightarrow 1ev = 1{,}6\times10^{-91}\ c\times volt$$

$$\boxed{1\ ev = 1{,}6\times10^{-19}\ joule}$$

$$\boxed{1\ Mev = 10^{6}\ ev}$$

The stability of the nucleus of an atom can be determined by calculating the **average binding energy a**, defined as follows:

$$a = \frac{\Delta E}{A}$$

The greater the average binding energy, the more stable the element

- **The energy equivalent of 1 amu**

$$\Delta E = \Delta m \times C^2$$

$$\Delta E = 1 \times 1.66 \times 10^{-27} \times (3 \times 10^8)^2$$

$$\Delta E = 14.94 \times 10^{-11} J$$

$J = (Kg.m^2)/s^2$

$$\Delta E = \frac{14{,}94 \times 10^{-11}}{1{,}6 \times 10^{-19}} = 9{,}31 \times 10^8 \text{ ev}$$

$$\boxed{\Delta E = 931 \text{ Mev}}$$

$$\boxed{1uma \longrightarrow 931Mev}$$

Example: Find the mass defect of a copper-63 nucleus if the actual mass of a copper-63 nucleus is 62.91367 amu.

- Find the composition of the copper-63 nucleus and determine the combined mass of its components.
- Copper has 29 protons and copper-63 also has (63 - 29) 34 neutrons. The mass of a proton is 1.00728 amu and a neutron is 1.00867 amu.
  - what is the combined mass ?
- Calculate the mass defect.
- Determine the binding energy of the copper-63 atom.
- Compare the stability of the copper-63 nucleus with the iron-56 nucleus.