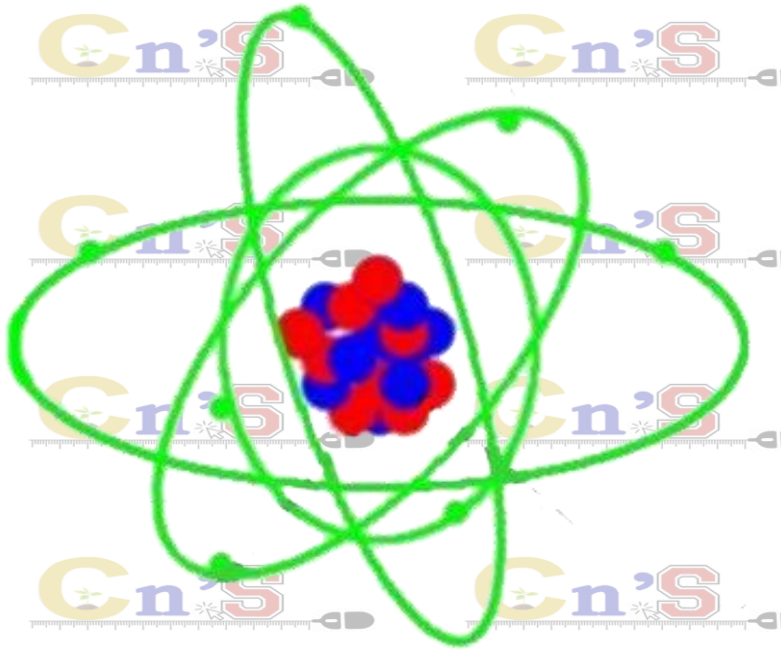
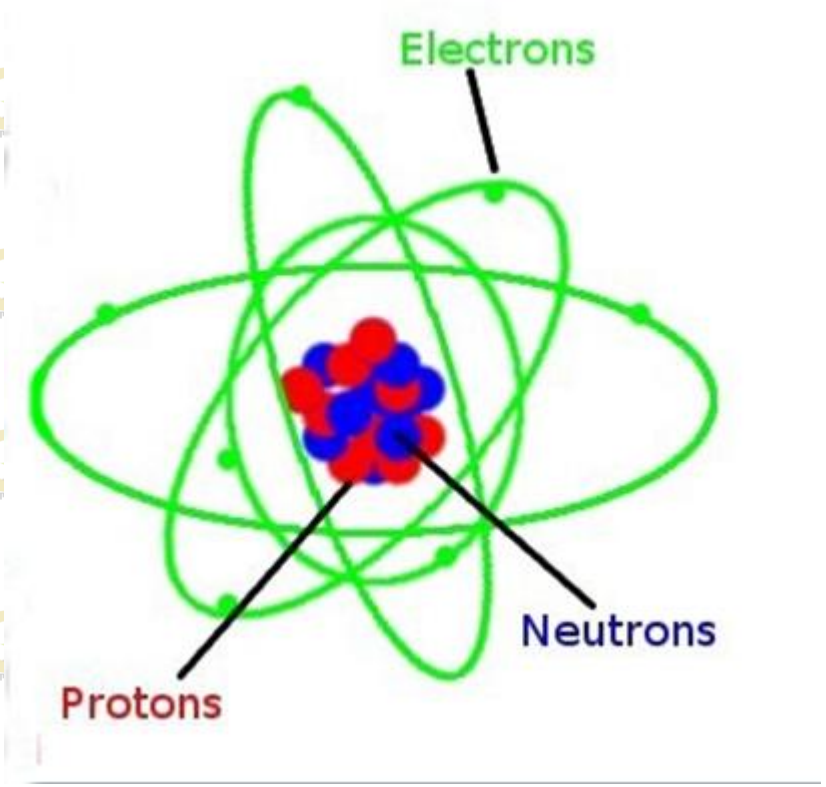
ATOMIC STRUCTURE



Sub Atomic Particles

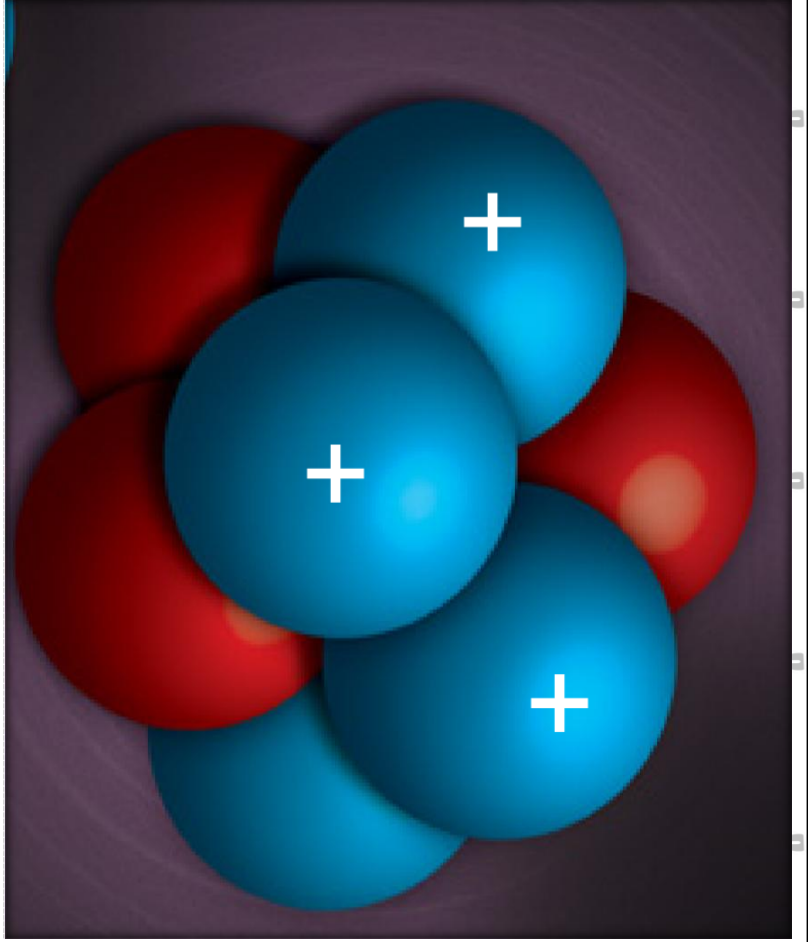


Protons

Neutrons

Electrons

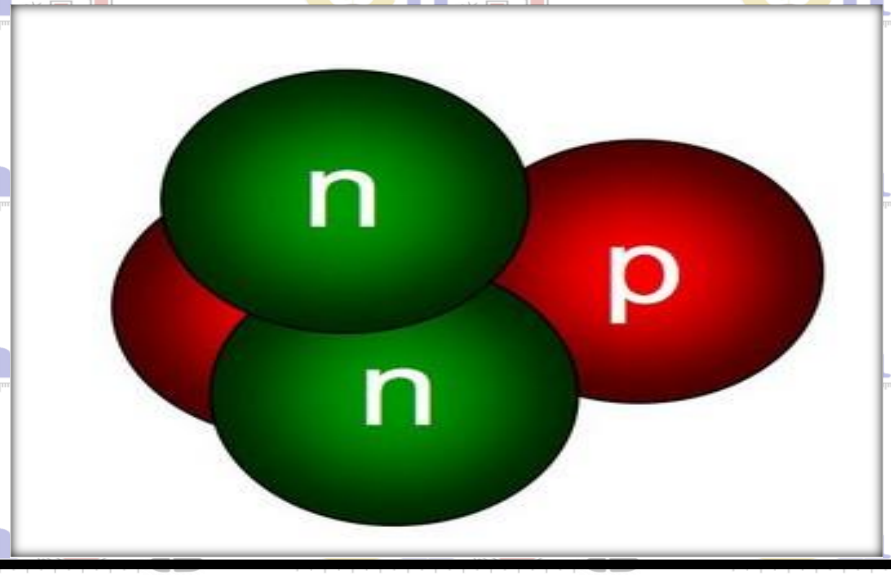
Protons

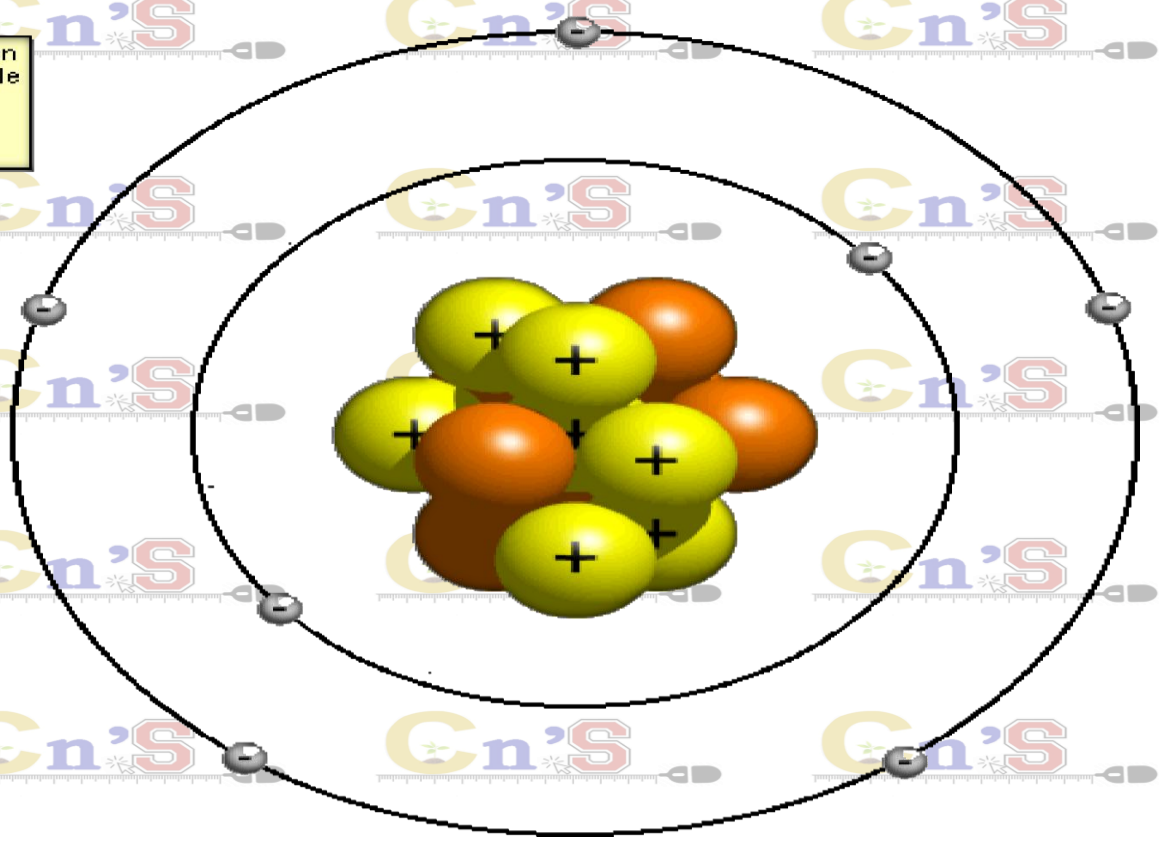


- Located in nucleus of atom
- Has a positive charge
- Number of Protons = Atomic Number
- Has 1 AMU in mass (Atomic Mass Unit)

Neutrons

- Located in nucleus of atom
- Has NO electrical charge
- Has mass of 1 amu
- Number of neutrons usually is equal to number of protons





Electrons

- Located outside the nucleus of the atom
- Housed in Electrical Clouds, Shells, Orbits
- Has a negative charge
- Does not have an amu because of tiny size

Hydrogen Atom Electron Cloud

THE STRUCTURE OF ATOMS

Atoms consist of a number of fundamental particles, the most important are ...

	Mass / kg	Charge / C	Relative mass	Relative charge
PROTON				
NEUTRON				
ELECTRON				

THE STRUCTURE OF ATOMS

Atoms consist of a number of fundamental particles, the most important are ...

	Mass / kg	Charge / C	Relative mass	Relative charge
PROTON	1.672×10^{-27}	1.602×10^{-19}	**1**	**+1**
NEUTRON	1.675×10^{-27}	**0**	**1**	**0**
ELECTRON	9.109×10^{-31}	1.602×10^{-19}	$\frac{1}{1836}$	**-1**

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Calculate the mass of a carbon-12 atom; it has 6 protons, 6 neutrons and 6 electrons

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$$6 \times 1.672 \times 10^{-27} + 6 \times 1.675 \times 10^{-27} + 6 \times 9.109 \times 10^{-31} = 2.0089 \times 10^{-26} \text{ kg}$$

MASS NUMBER AND ATOMIC NUMBER

Atomic Number (Z)Number of protons in the nucleus of an atom

Mass Number (A) Sum of the protons and neutrons in the nucleus

MASS NUMBER AND ATOMIC NUMBER

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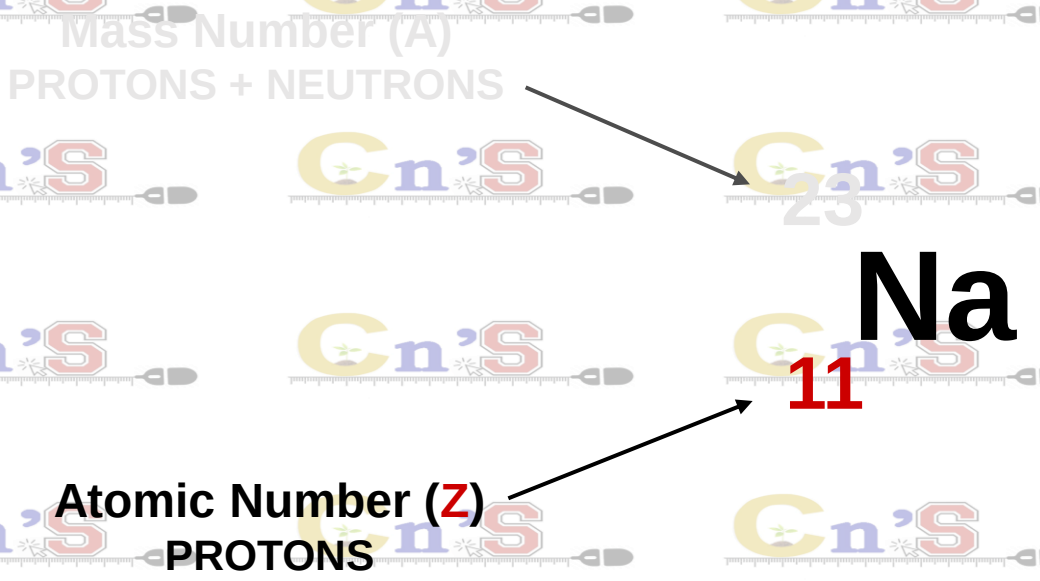


MASS NUMBER AND ATOMIC NUMBER

Atomic Number (Z) — **Number of protons in the nucleus of an atom**

Mass Number (A) — **Sum of the protons and neutrons in the nucleus**

Mass Number (A)
PROTONS + NEUTRONS

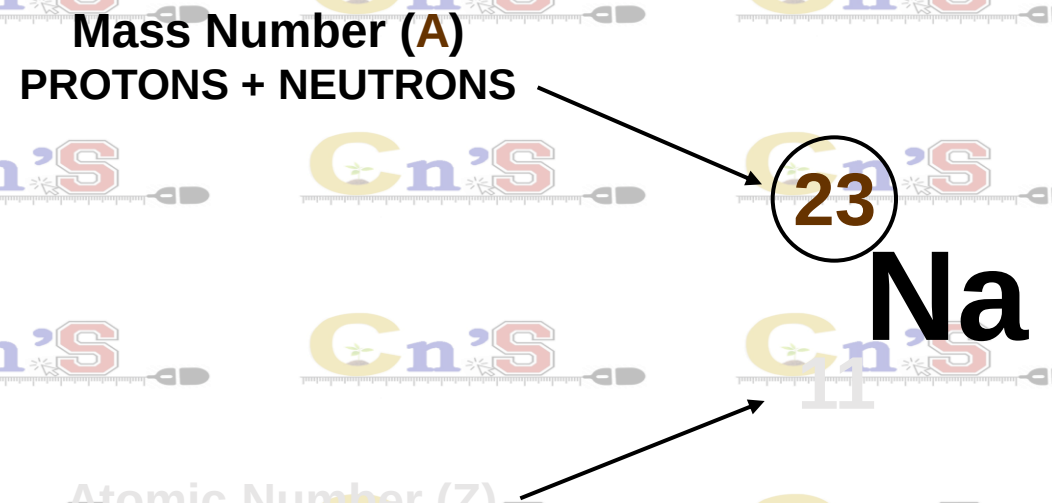
Atomic Number (Z)
PROTONS

THESE ALWAYS GO TOGETHER – ANYTHING WITH 11 PROTONS MUST BE SODIUM

MASS NUMBER AND ATOMIC NUMBER

Atomic Number (Z) — Number of protons in the nucleus of an atom

Mass Number (A) — **Sum of the protons and neutrons in the nucleus**



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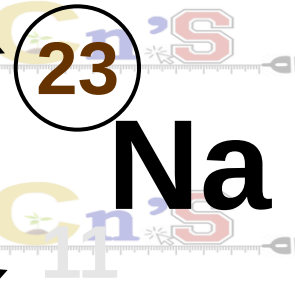
PROTONS + NEUTRONS



THERE WILL BE 12 NEUTRONS IN THE NUCLEUS

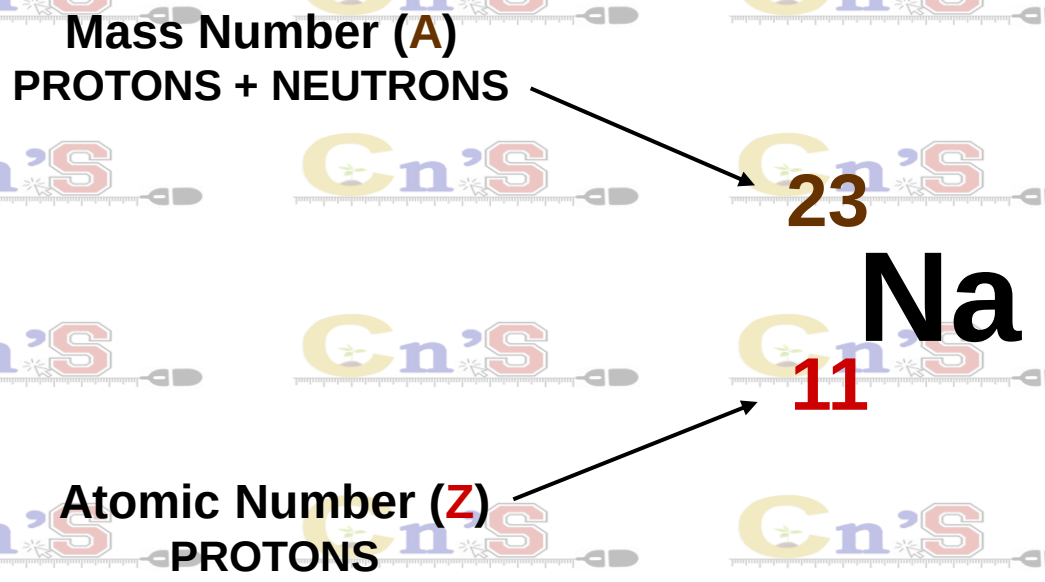
23 – 11 = 12

Atomic Number (Z)
PROTONS

MASS NUMBER AND ATOMIC NUMBER

Atomic Number (Z) — Number of protons in the nucleus of an atom

Mass Number (A) — Sum of the protons and neutrons in the nucleus



MASS NUMBER AND ATOMIC NUMBER

	Protons	Neutrons	Electrons	Charge	Atomic Number	Mass Number	Symbol
A	19	21	19				
B	20			0		40	
C				+	11	23	
D	6	6		0			
E	92			0		235	
F	6					13	
G		16		2-	16		
H							$^{27}Al^{3+}$

MASS NUMBER AND ATOMIC NUMBER

	Protons	Neutrons	Electrons	Charge	Atomic Number	Mass Number	Symbol
A	19	21	19	0	19	40	^{40}K
B	20	20	20	0	20	40	^{40}Ca
C	11	12	10	+	11	23	$^{23}Na^{+}$
D	6	6	6	0	6	12	^{12}C
E	92	143	92	0	92	235	^{235}U
F	6	7	6	0	6	13	^{13}C
G	16	16	18	2-	16	32	$^{32}S^{2-}$
H	13	14	10	3+	13	27	$^{27}Al^{3+}$

RELATIVE MASSES

Relative Atomic Mass (A_r)

The mass of an atom relative to the ^{12}C isotope having a value of 12.000

$$A_r = \frac{\text{average mass per atom of an element}}{\text{mass of one atom of carbon-12}} \times 12$$

Relative Isotopic Mass

Similar, but uses the mass of an isotope ^{238}U

Relative Molecular Mass (M_r)

Similar, but uses the mass of a molecule CO_2, N_2

Relative Formula Mass

Used for any formula of a species or ion NaCl, OH^-

ISOTOPES

Definition
Atoms with…

the same atomic number but different mass number or

the same number of protons but different numbers of neutrons.

The first isotopes discovered were those of neon by Thomson and Aston in 1912-1913. The mass spectrograph is a precise instrument used to determine the atomic masses

ISOTOPES

Definition Atoms with…

the same atomic number but different mass number or

the same number of protons but different numbers of neutrons.

Properties

Chemical properties of isotopes are identical

Physical properties (such as density) can differ

ISOTOPES OF HYDROGEN

Definition — Atoms with...

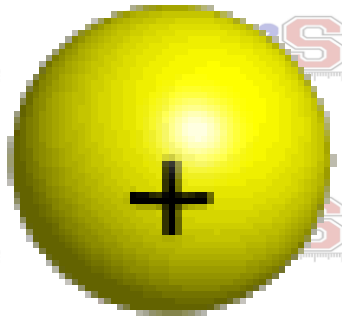
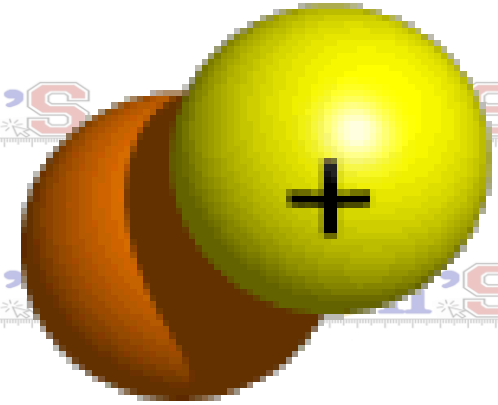
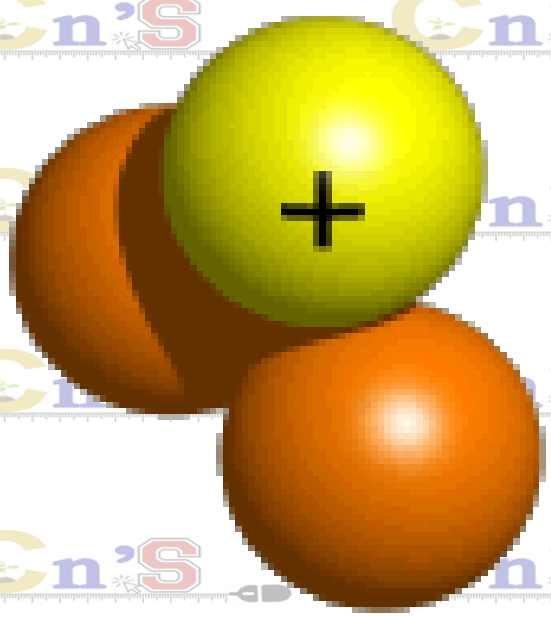
the same atomic number but different mass number or
the same number of protons but different numbers of neutrons.

Properties — Chemical properties of isotopes are identical
Physical properties (such as density) can differ

	Protons	Neutrons
$^{1}_{1}H$	1	0
$^{2}_{1}H$	1	1
$^{3}_{1}H$	1	2

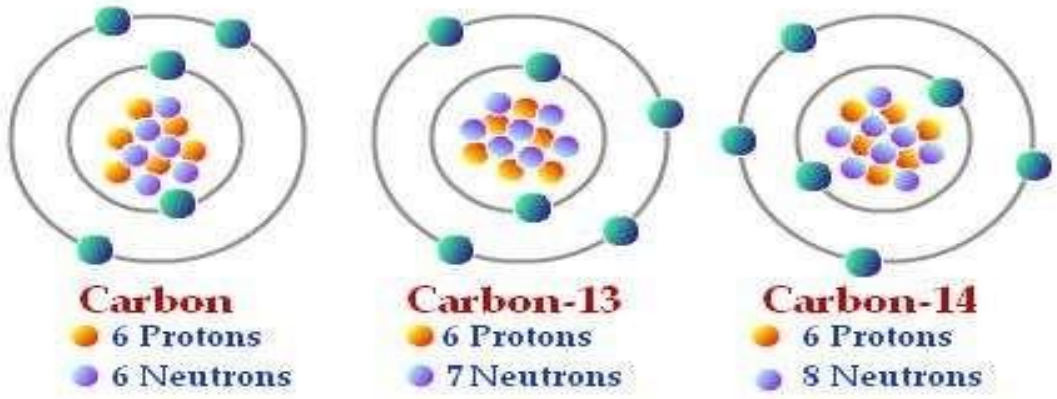
Relative atomic masses measured by chemical methods rarely produce whole numbers. This was explained when the mass spectrograph revealed that atoms of the same element could have different masses due to the variation in the number of neutrons in the nucleus. The observed mass was a consequence of the abundance of each type of isotope.

The Nuclei of the Three Isotopes of Hydrogen

Protium	Deuterium	Tritium
		
1 proton	1 proton 1 neutron	1 proton 2 neutrons

Classification of atoms:

- **Isotopes** - Elements having same atomic number (protons) , but different mass numbers (nucleons). **eg: ^{12}C, ^{13}C and ^{14}C**



are three isotopes of the element carbon with mass numbers 12, 13 and 14 respectively. The atomic number of all carbon isotopes is 6.

There are two common isotopes of chlorine. Calculate the average relative atomic mass of chlorine atoms

	Protons	Neutrons	%
$^{35}_{17}Cl$	17	18	75
$^{37}_{17}Cl$	17	20	25

ISOTOPES - CALCULATIONS

There are two common isotopes of chlorine. Calculate the average relative atomic mass of chlorine atoms

	Protons	Neutrons	%
$^{35}_{17}Cl$	17	18	75
$^{37}_{17}Cl$	17	20	25

Method 1 **Three out of every four atoms will be chlorine-35**

$$\text{Average} = \frac{35 + 35 + 35 + 37}{4} = 35.5$$

ISOTOPES - CALCULATIONS

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Method 1 Three out of every four atoms will be chlorine-35

Average = 35 + 35 + 35 + 37 = 35.5
4

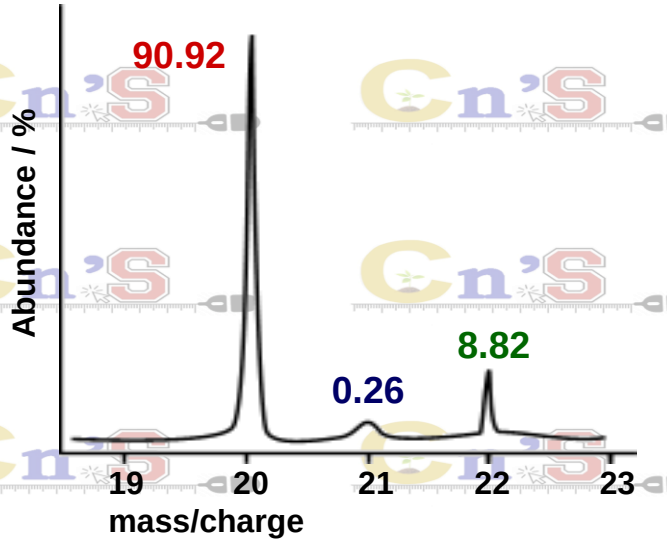
Method 2 Out of every 100 atoms 75 are ^{35}Cl and 25 are ^{37}Cl

$$\text{Average} = \frac{(75 \times 35) + (25 \times 37)}{100} = 35.5$$

MASS SPECTRA

An early application was the demonstration by Aston, (Nobel Prize, 1922), that naturally occurring neon consisted of 3 isotopes... ^{20}Ne ^{21}Ne ^{22}Ne.

- **positions of peaks gives atomic mass**
- **peak intensity gives relative abundance**
- **highest abundance is scaled up to 100%**
  - other values are adjusted accordingly.



Calculate the average relative atomic mass of neon using the above information.

Out of every 100 atoms 90.92 are ^{20}Ne, 0.26 are ^{21}Ne and 8.82 are ^{22}Ne

$$\text{Average} = \frac{(90.92 \times 20) + (0.26 \times 21) + (8.82 \times 22)}{100} = 20.179$$

Relative atomic mass = **20.18**

Naturally occurring potassium consists of potassium-39 and potassium-41. Calculate the percentage of each isotope present if the average is 39.1.

Assume there are x nuclei of ^{39}K in every 100; so there will be (100-x) of ^{41}K

so $$\frac{39x + 41(100-x)}{100} = 39.1$$

therefore $39x + 4100 - 41x = 3910$

thus $-2x = -190$

and $x = 95$

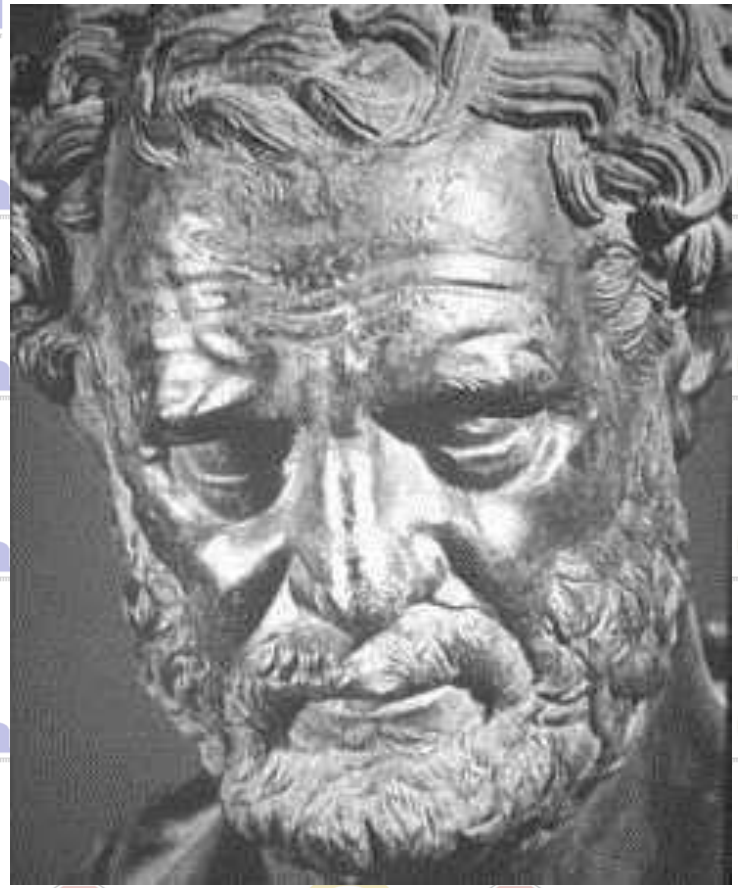
ANSWER There will be **95%** ^{39}K and **5%** ^{41}K

ATOM:

Every matter consists of basic entities called elements.

- Each element is composed of smallest particles called '**ATOM**'.
- Atom- the name is derived from Greek language **Atomos** means '**Not to be cut'.**

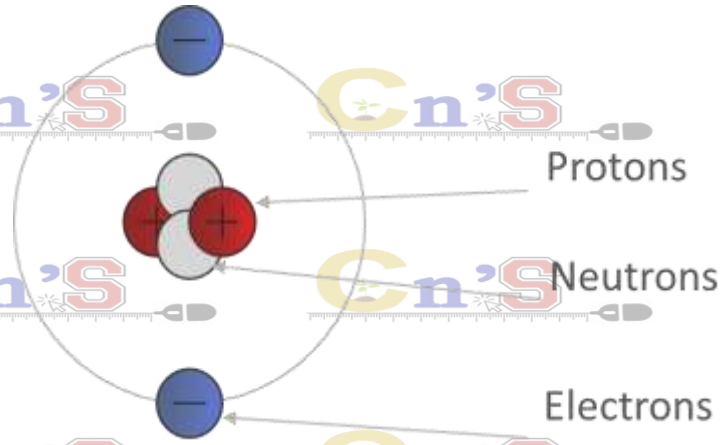
Atom and ‘DEMOCRITUS’



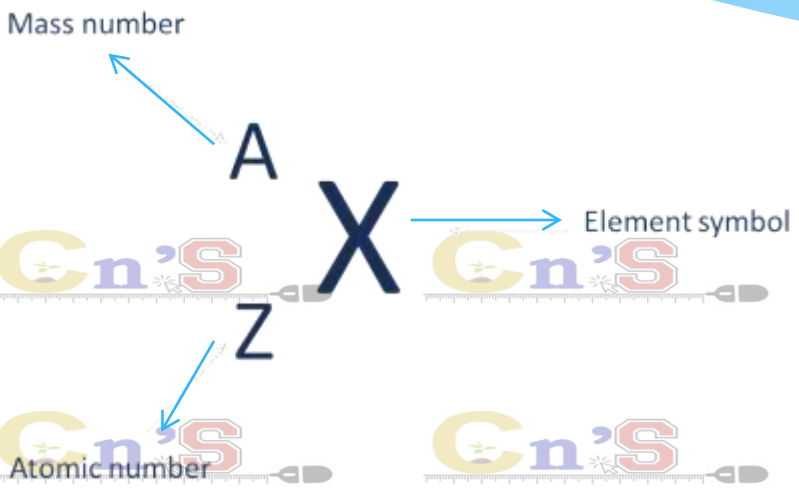
- **DEMOCRITUS** was a Greek preSocratic philosopher who began search for description of matter more than 2400 years ago (4th century B.C.)
- **Democritus** was the person who first suggested the existence of ATOM & coined the name **ÁTOMOS**’ means **Not to be cut or Indivisible.**

Atomic structure

- Atom consists of positively charged **NUCLEUS** at the centre and negatively charged **Electrons** revolving around it.
- Radius of an atom -- 10^{-10} m.
- Radius of the nucleus -- 10^{-15} m.
- Nucleus consists of Protons and Neutrons together called Nucleons.
- Most of the mass of an Atom is possessed by Nucleus.



Representation of an Atom:



Example:

$^{235}U_{92}$ X-Uranium

A-235 Z-92

John Dalton : (6 September 1766 – 27 July 1844) an English chemist, meteorologist and physicist

- Matter is made of indivisible atoms, they are indestructible.
- All atoms of a given (same) element are identical in their physical and chemical properties. • Atoms of different elements differ in their physical and chemical properties. • Atoms of different elements combine in simple whole-numbers ratios to form Molecules • Chemical reactions consist of the combination separation or rearrangement of atoms

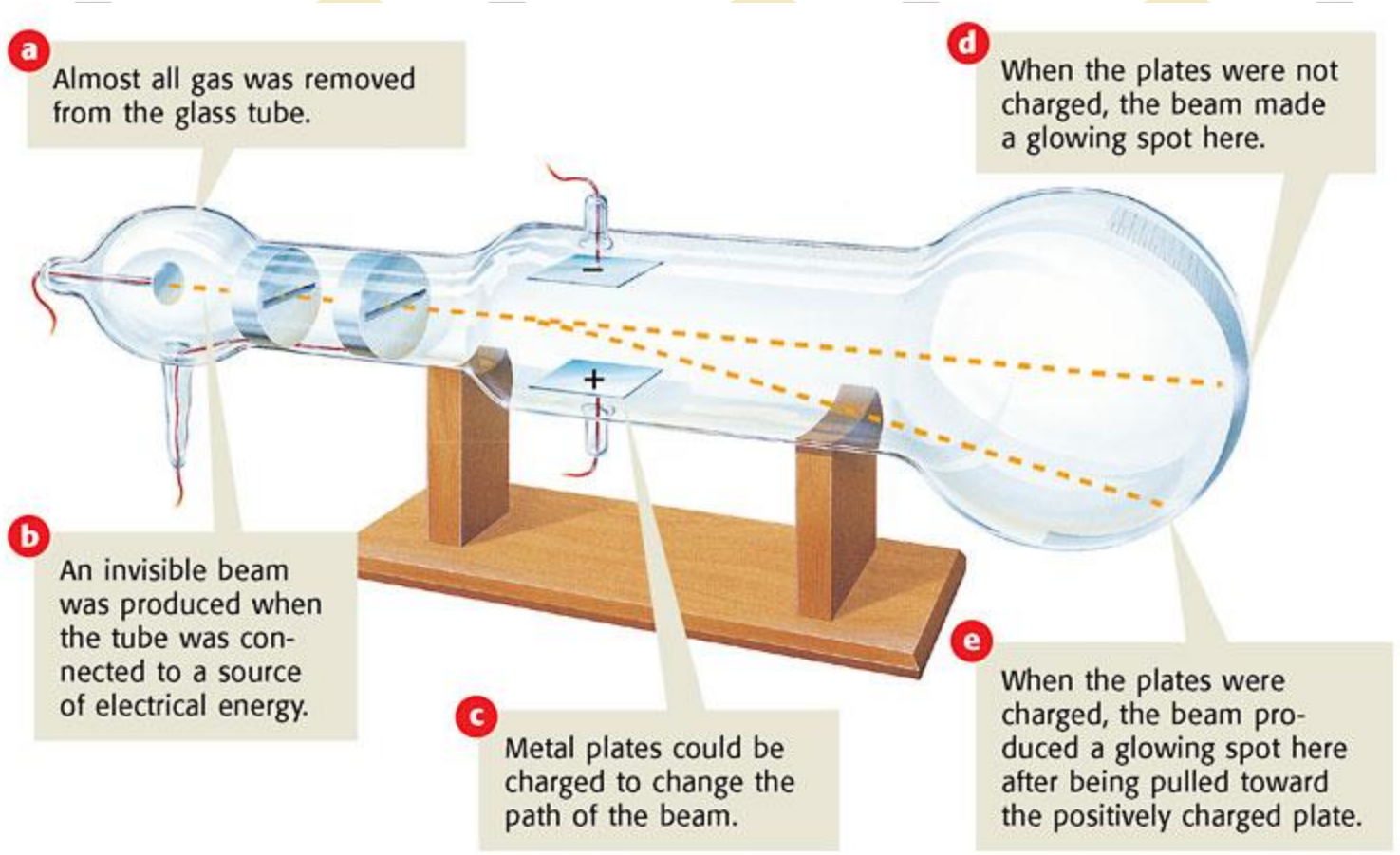
Limitations:

- It could not explain why and how do atoms combine together to form compound atoms (molecules)
- The nature of forces which hold atoms together in compound atoms
- Why atoms cannot exist in free state and why compound atoms can exist freely.

Thomson's Discovery of Electrons

In 1897, a British scientist named **J. J. Thomson** showed that there was a mistake in Dalton's theory. Thomson discovered that there are small particles *inside* the atom. This means that atoms can be divided into even smaller parts.

Thomson experimented with a cathode ray tube .



Thomson discovered that a positively charged plate (marked with a +in the drawing) attracted the beam. Thomson concluded that the beam was made of particles that have negative electric charges. He also concluded that these negatively charged particles are present in every kind of atom. The negatively charged particles that Thomson discovered are now called ***electrons***.

Fluorescent screen

- The role of this part is to display where the electrons are hitting the CRT.
- It is a screen coated with a material that emits light when struck by electrons.
- Zinc sulfide or Phosphorus are two commonly used materials.

The e/m value of cathode rays shows that they are simply electrons

JJ.Thomson concluded from his experiments that cathode rays consist of streams of negatively charged particles. Stoney named this particles as electrons. He found that e/m value remained the same no matter which gas was used in discharge tube. He concluded that all atoms contained electrons.

Discovery of Electrons (Cathode Rays)

A gas discharge tube is fitted with two metallic electrodes acting as cathode and anode. The tube is filled with a gas ,air or vapours of substance at any desired pressure. The electrodes are connected to source of high voltage. The exact voltage required depends upon length of tube and pressure inside tube. The tube is attached to vacuum pump by means of small side tube so that conduction of electricity may be studied at any value of low pressure It is observed that current does not flow through gas at ordinary pressure even at high voltage of 5000 volts. When pressure inside tube is reduced to 0.0001 atm and high voltage of 5000-15000 volts is applied, then an electric discharge takes place through the gas producing a uniform bright green glow inside tube.

These rays created fluorescence on glass wall opposite to cathode . These rays are called cathode rays. The colour of glow or fluorescence produced on walls of glass tube, depends upon composition of glass.

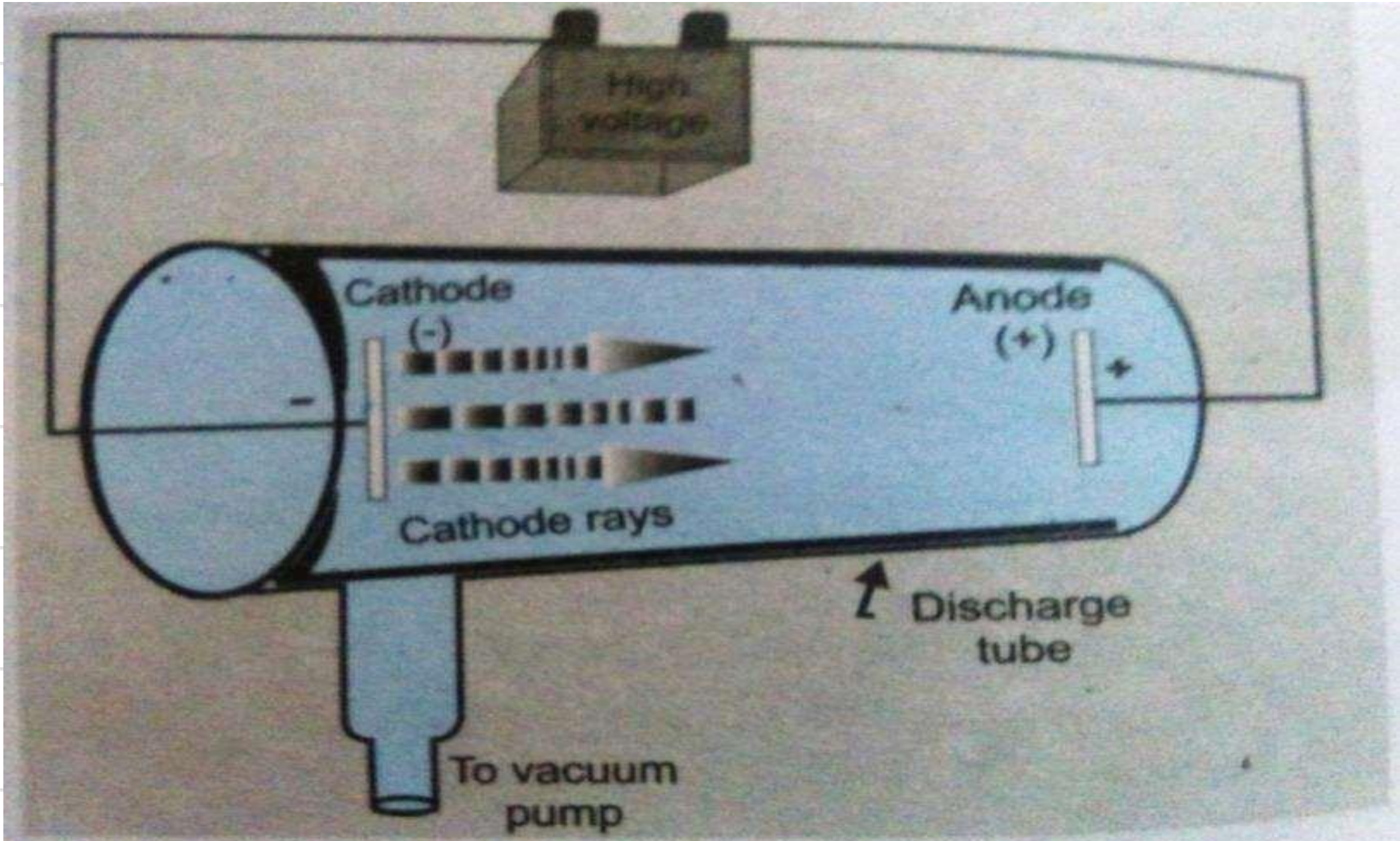


Fig (5.1) Production of the cathode rays

Properties of cathode rays

Travel in straight lines
or travel linearly

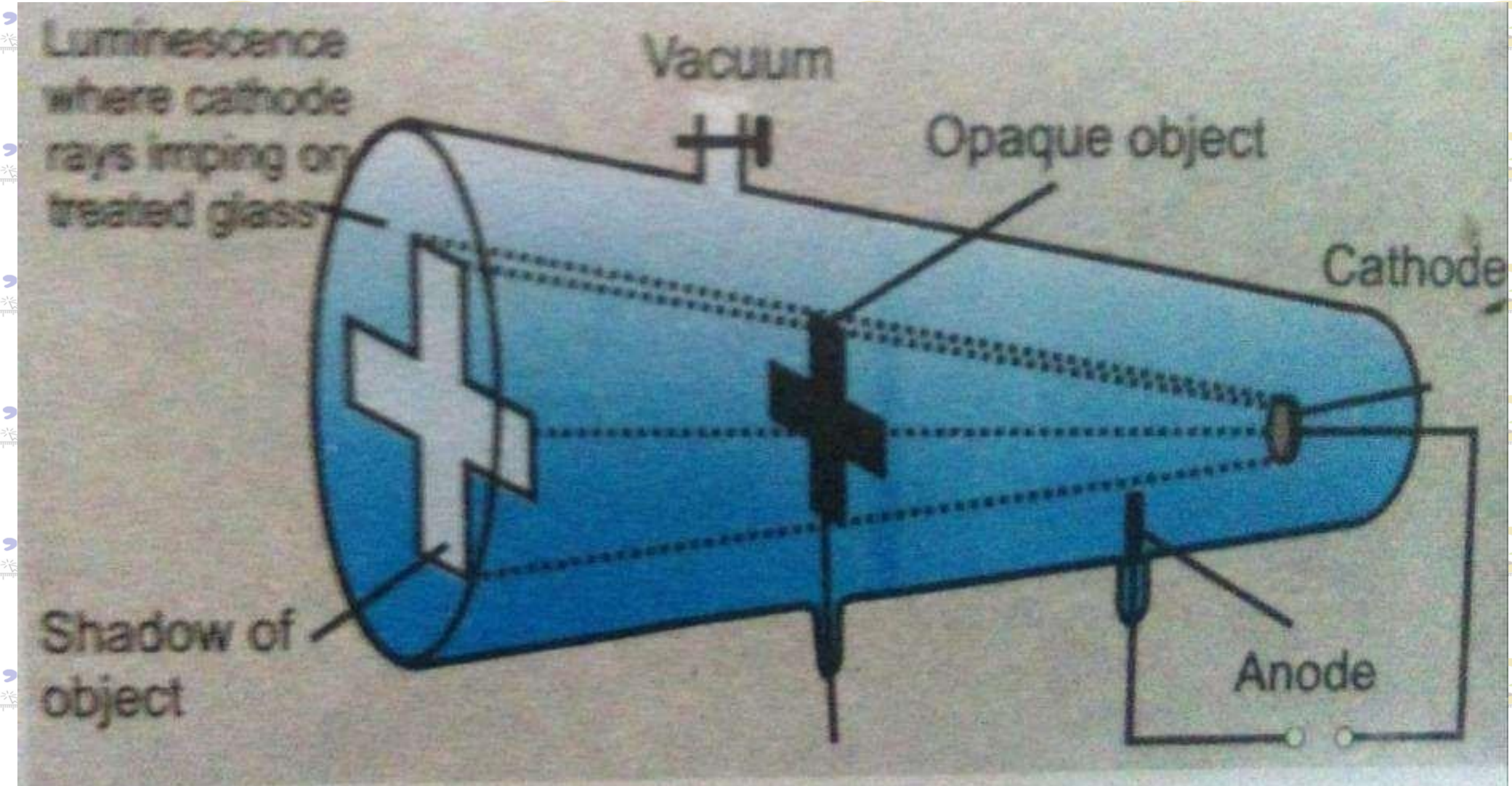
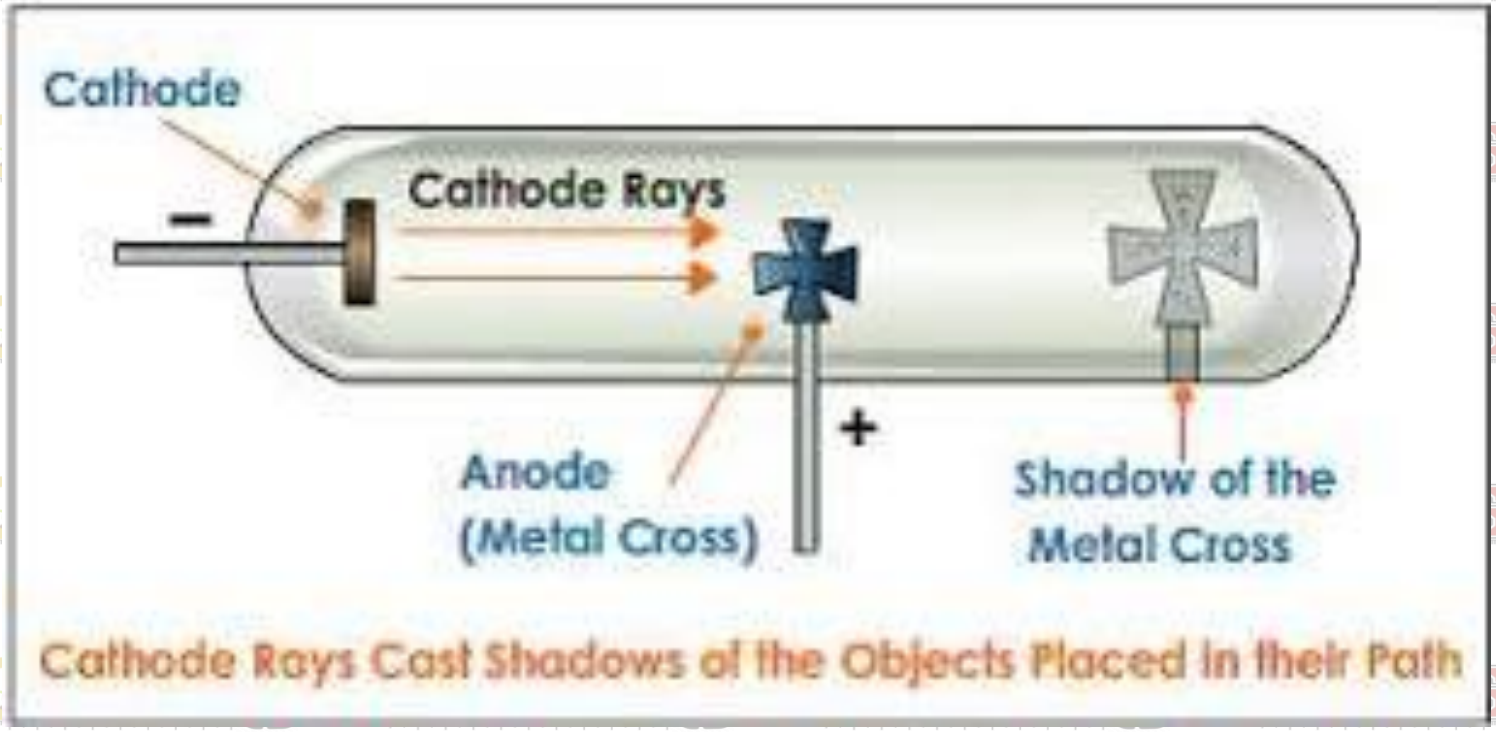
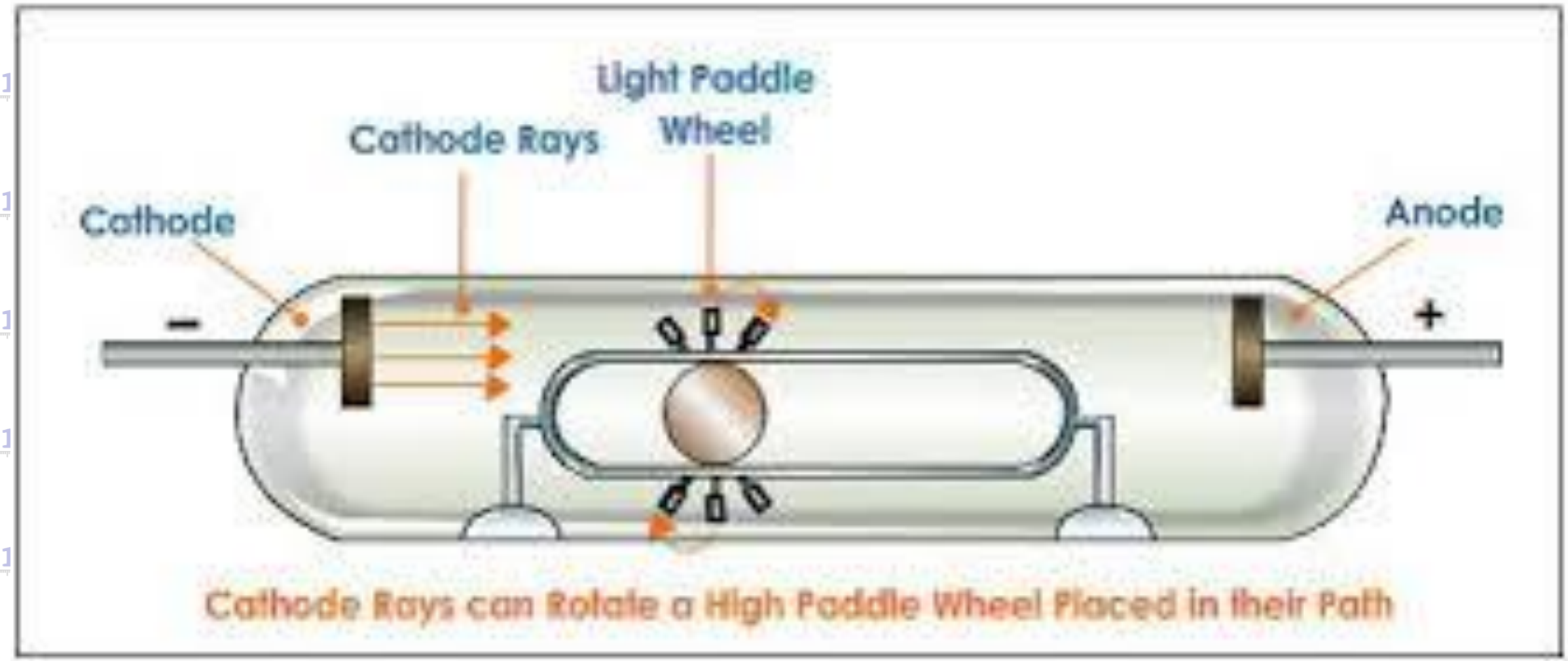


Fig (5.3) Cathode rays cast a shadow of an opaque object


Cathode
Cathode Rays
−
+
Anode
(Metal Cross)
Shadow of the
Metal Cross
Cathode Rays Cast Shadows of the Objects Placed in their Path

Cathode rays can create momentum

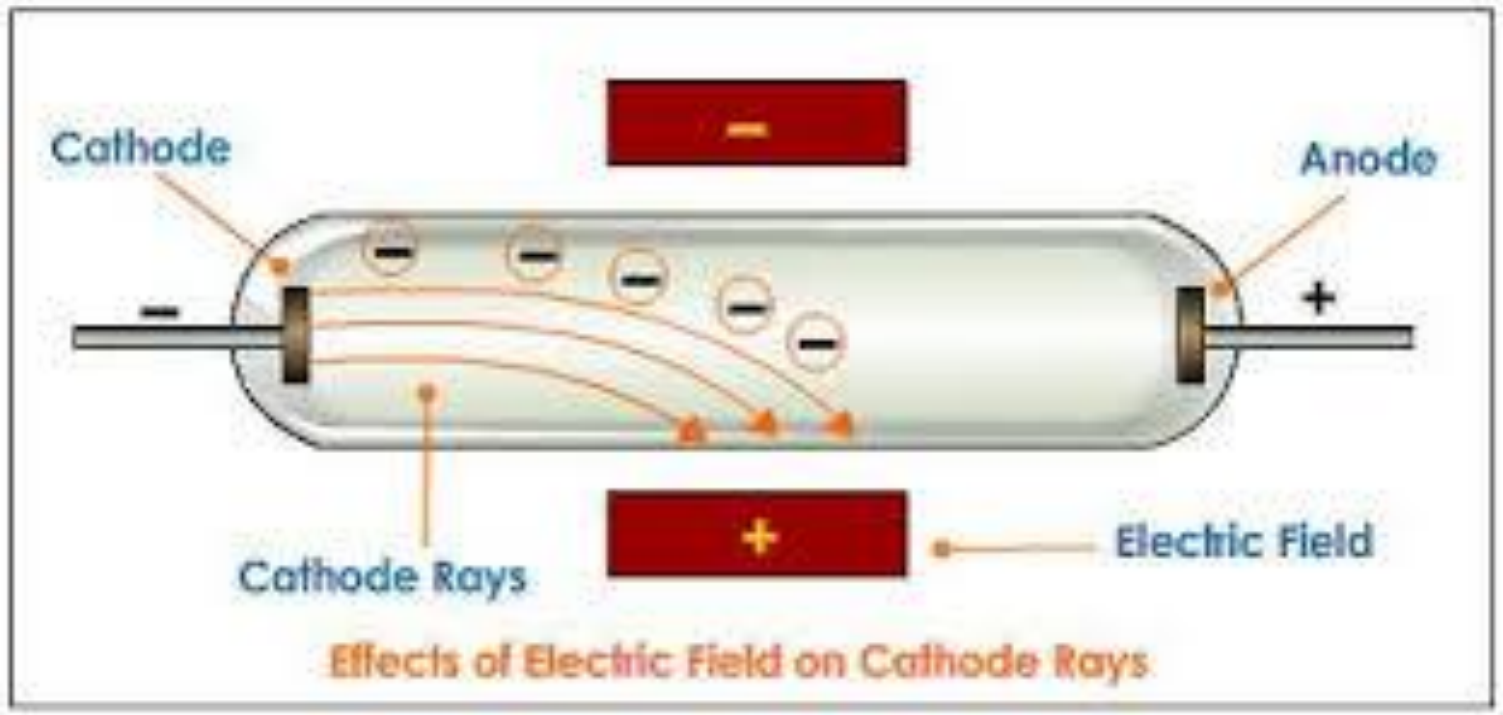


A paddle wheel placed in the path of the cathode rays turned. This proved that the cathode rays carried energy, and that they might be made of particles with mass & velocity.

This also indicates that the rays (particles) moved from the cathode to the anode.

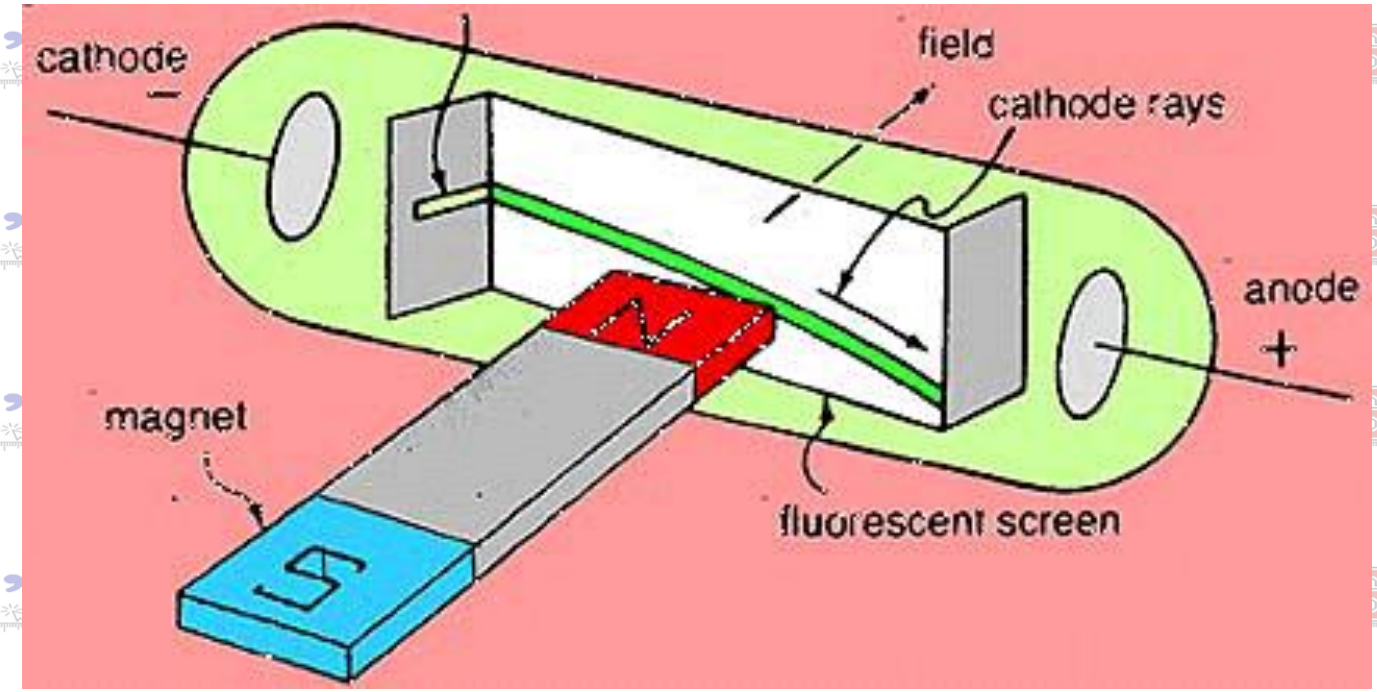
The emission of cathode rays is perpendicular to the cathode

Cathode rays are negatively charged.


Cathode
Anode
Cathode Rays
Electric Field
Effects of Electric Field on Cathode Rays

Crookes showed that the rays were deflected by a magnetic field.

Crookes noted that charged particles in a magnetic field experience a force. Cathode rays behaved as if they were negatively charged particles.


cathode
−
field
cathode rays
anode
+
magnet
N
S
fluorescent screen

Properties of cathode rays

Move along straight lines

The emission of cathode rays is perpendicular to the cathode

Cathode rays can create momentum(mv) which is the ability to create the mechanical force. (cathode rays have particle properties)

Cathode rays are negatively charged.

The properties of cathode rays are independent from the cathode material and the gas inside the cathode ray tube.

Cathode rays originate at the cathode and move towards the anode

Cathode rays can penetrate through thin Al foils.

Cathode rays can create light green glowings on scintillating(sparkling) material

Cathode rays can increase the temperature of an object during a collision.

Cathode rays can create images on photographic plates

Cathode rays can ionize gases

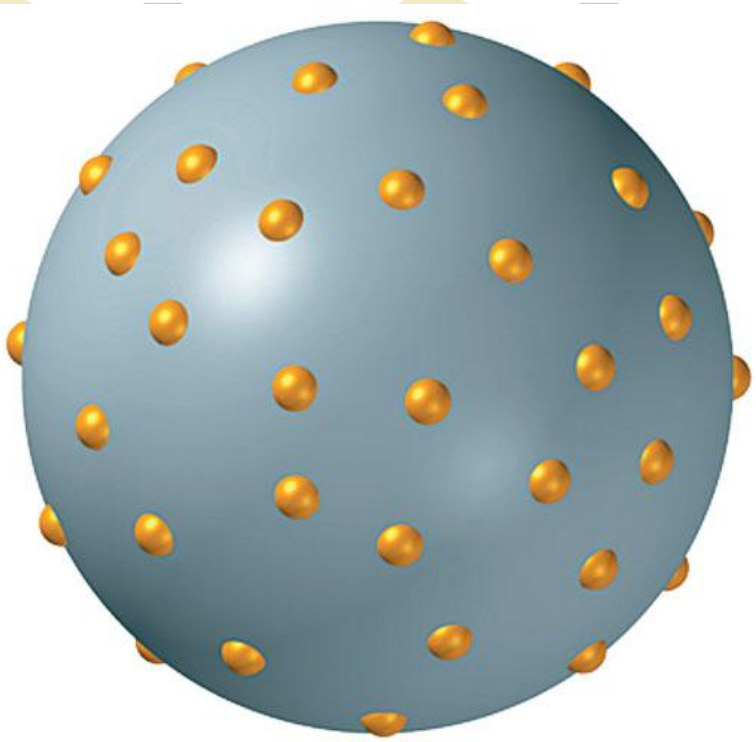
Velocity of cathode rays is less than that of light (1/10C=$3x10^{7}ms^{-1}$)

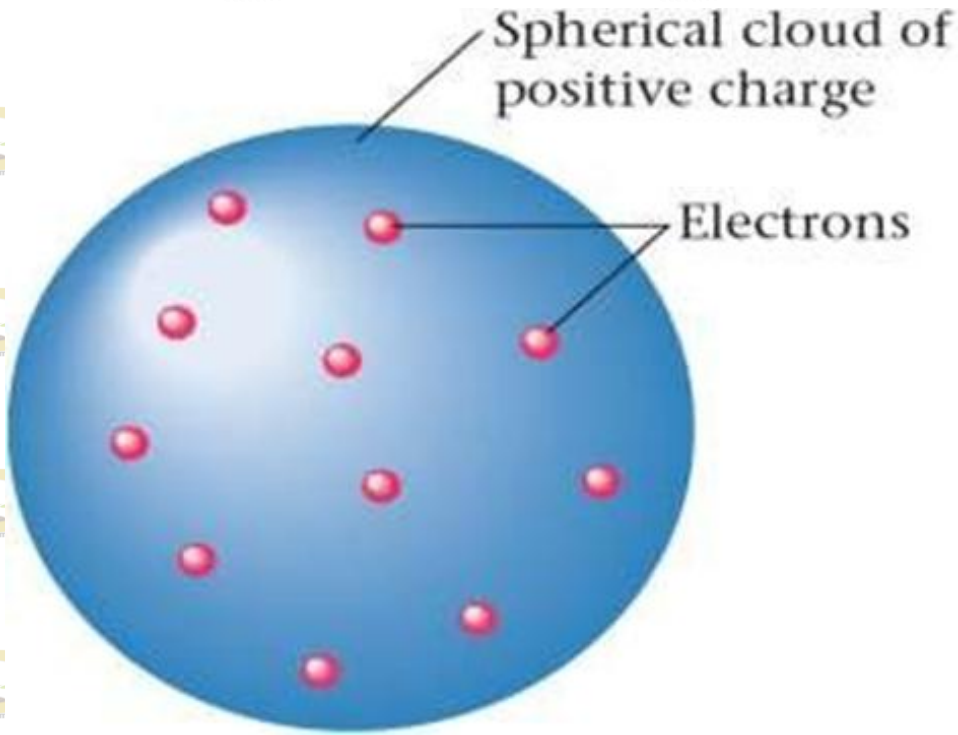
X rays can be generated after the collision of cathode rays with a metal target

e/m ratio of cathode rays is a constant. This was illustrated by J.J.Thompson.

Like Plums in a Pudding

After learning that atoms contain electrons, Thomson proposed a new model of the atom. This model was called the "Plum Pudding Model". Thomson thought that electrons were mixed throughout an atom, like plums in a pudding.





Rutherford's Experiment

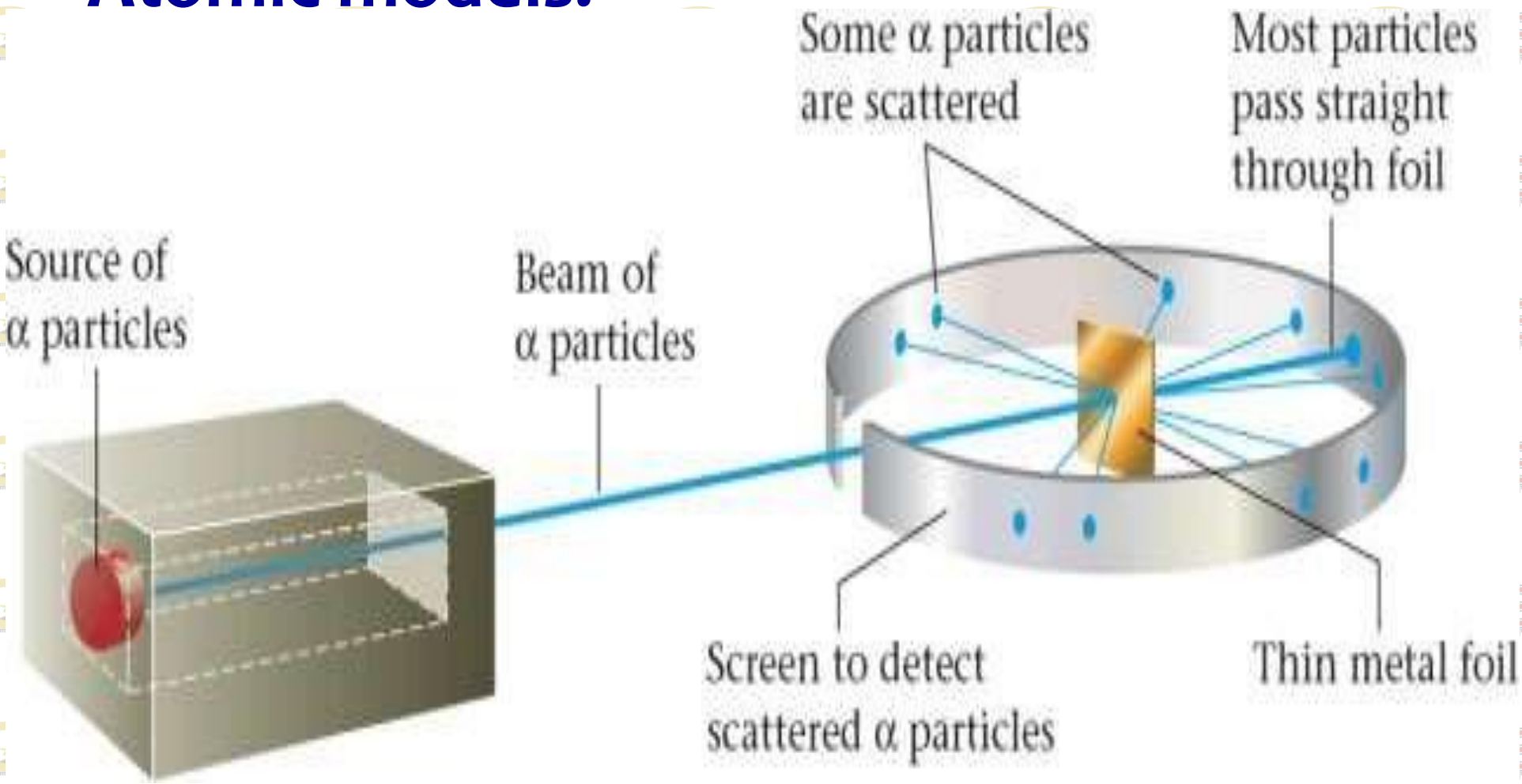
Student of Thomson, Conducted the Gold Foil Experiment in 1909 to disprove the Plum Pudding model

He performed the experiment on bombarding gold foil with alpha particles.

Observed that most (about 99.99%) of the particles passed through the film following a straight path, while some were deflected at large angles and few bounced back.

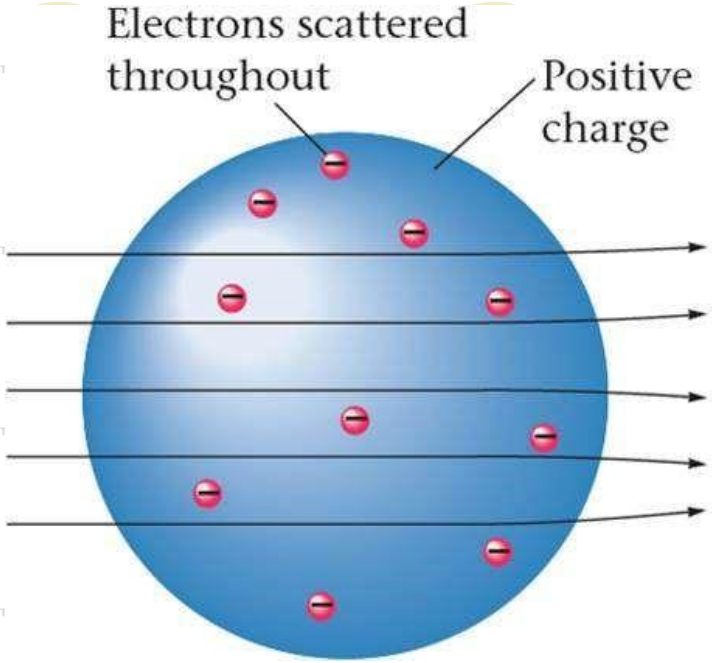
Atomic models:

Rutherford Gold foil experiment :

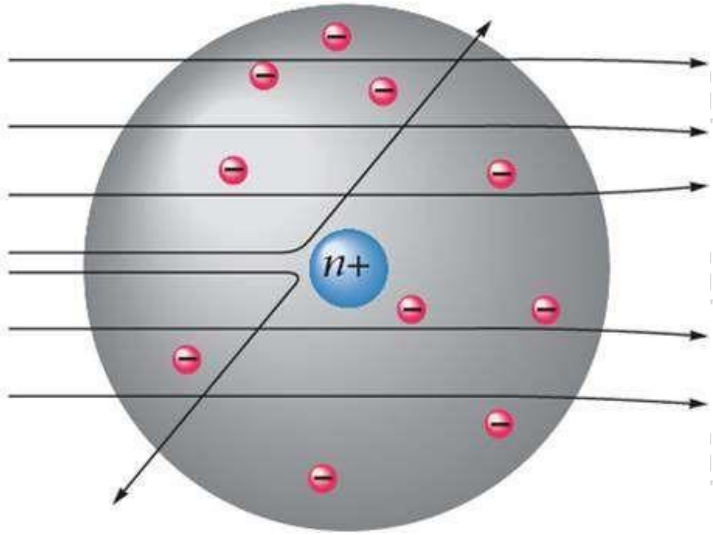


Sent a beam of + charges (alpha particles) through a very thin piece of gold foil & Angles of deflection were measured

Results of the Rutherford experiment



(a) The results that the metal foil experiment would have yielded if the plum pudding model had been correct.



(b) Actual results

Based on the results, Rutherford proposed the following

1. That the atom consists of a large a hollow sphere of radius 10^{-10} m where most of the particles went straight through.
2. That the atom consists of a very small region where its positive electricity is concentrated, hence, heavy. The particles that bounced back were presumed to have hit this region.
3. Those, which deflected, approached the positive nucleus; hence, there was repulsion since the alpha particles were also positive. The above reasons describe the central part of the atom, called nucleus, of radius 10^{-15} m

to be with a very small volume yet a massive one.

Drawback's of Rutherford's Model

Regarding stability of atom

- Electrons revolving around the nucleus have centripetal acceleration
- According to electrodynamics, accelerated charged particles radiate energy in the form of electromagnetic waves
- Hence electromagnetic waves should be continuously radiated by the revolving electrons
- Due to this continuous loss of energy of the electrons, the radii of their orbits should be continuously decreasing and ultimately the electron should fall into the nucleus
- Thus atom cannot remain stable
- **Rutherford's model also failed to explain the Line spectrum.**

PROTON –positive rays (Thomson)

In his experiments Thomson had noticed a red glow around the cathode. He used a central cathode with a hole to investigate this red glow. He found this was caused by rays which are deflected by the magnetic and electric field in the opposite direction to electrons. Thomson called these rays " Positive rays"

The lightest positive ions are produced when the gas in the tube is hydrogen. So the unit of positive charges is called " Proton" by Rutherford

$\frac{\text{Mass}}{\text{Charge}}$ =9.57×10*7 c/kg

Theories of Atomic models:

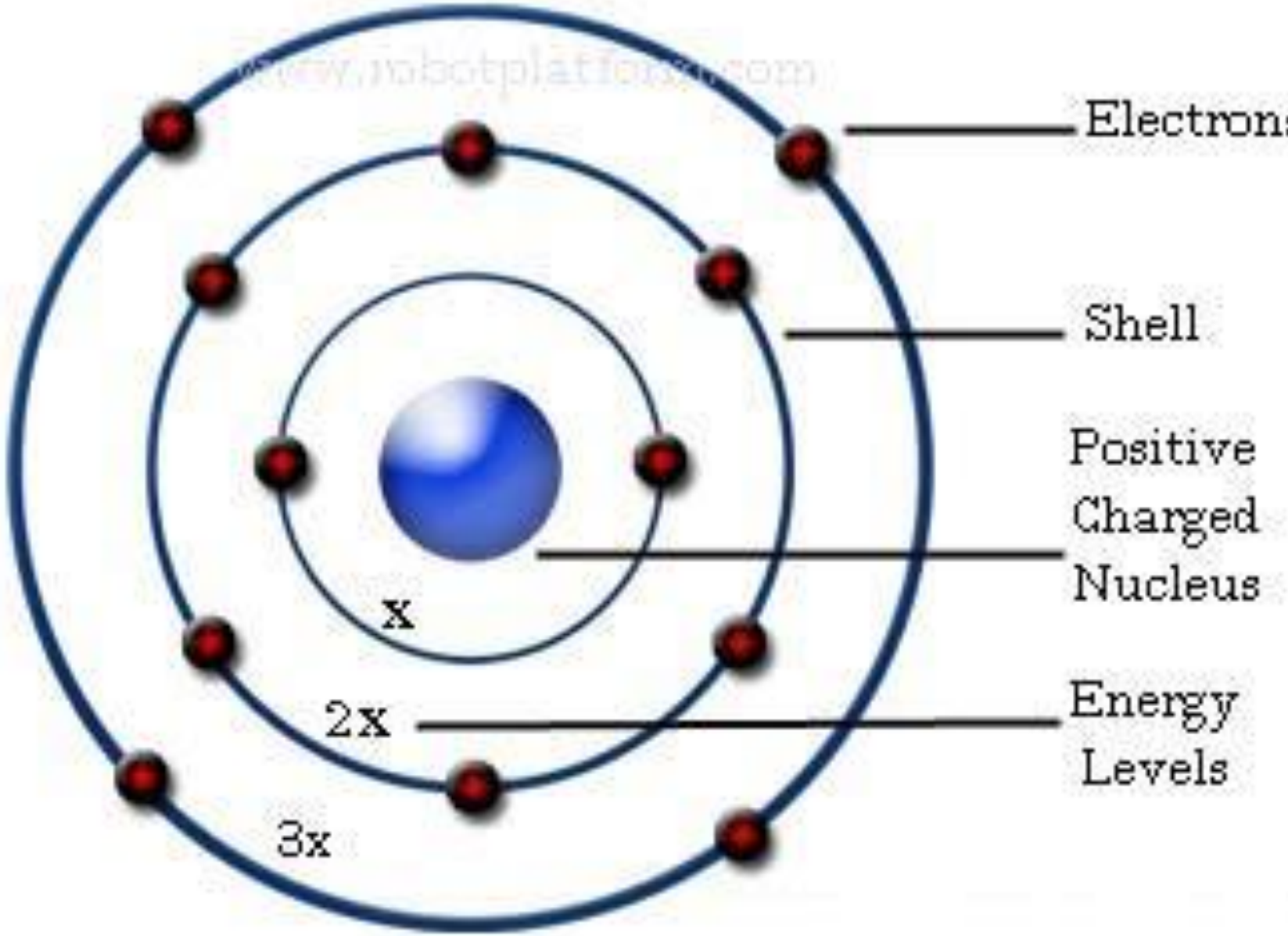
(1885 – 1962)

- NIELS DAVID BOHR A Danish physicist who developed Bohr model of atomic structure, in which he introduced the theory of electrons orbiting around the nucleus.

Bohr's theory (Postulates)

1. Fixed circular orbits :The electrons move around the nucleus in concentric circular orbits .
2. While revolving in stable orbits, the electrons do not radiate energy in spite of their acceleration towards the centre of the orbit.
3. Each of the fixed orbits is associated with a definite amount of energy called stationary energy.

   The energy levels are numbered as 1, 2, 3, 4… or designated as K,L,M, N …
4. Jumping of an electron from one energy level to the other (ground state and excited state) .
5. Principle of quantization of angular momentum of the moving electron an electron can move only in that orbit in which the angular momentum of the electron around the nucleus is an integral multiple of $h/2\pi$.


Electrons
Shell
Positive
Charged
Nucleus
Energy
Levels
x
2x
3x

Limitations of Bohr's Postulates

I. **No explanation for the spectra of multi electron systems**:

Eg: He, Li

II. **No explanation of fine spectrum of atoms:**

III. **No explanation for Zeeman and Stark effect** : effect of electric and magnetic fields on the spectral atoms.

- When a magnetic field is applied on an atom, its usually observed spectral lines split. This effect is known as **Zeeman's effect**
- Spectral lines also get split in the presence of electric field. This effect is known as **Stark effect.**

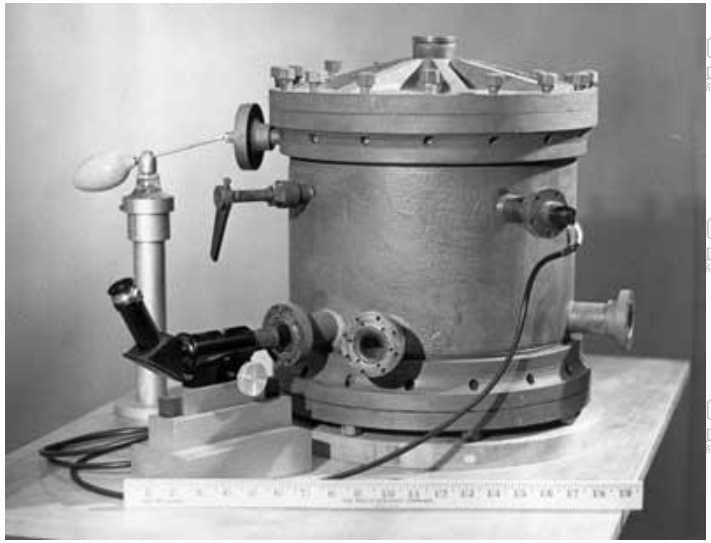
James Chadwick(1891-1974)

- English Physicist
- Discovered neutron in 1932
- Discovery of neutron (mass = 1.67493×10^{-24}g) explained the mass problem of many atoms.
- Nobel Prize in Physics 1935

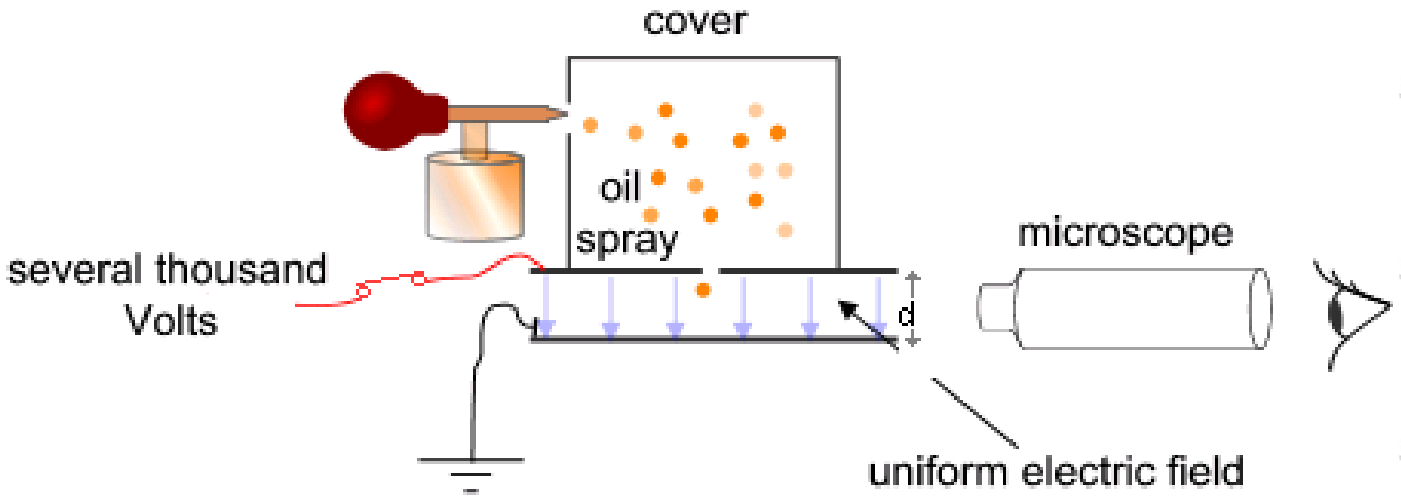
His Theory:

- Neutrons have no electrical charge.
- Neutrons have a mass nearly equal to the mass of a proton.
- Unit of measurement for subatomic particles is the atomic mass unit (amu).

Robert Millikan - 1909

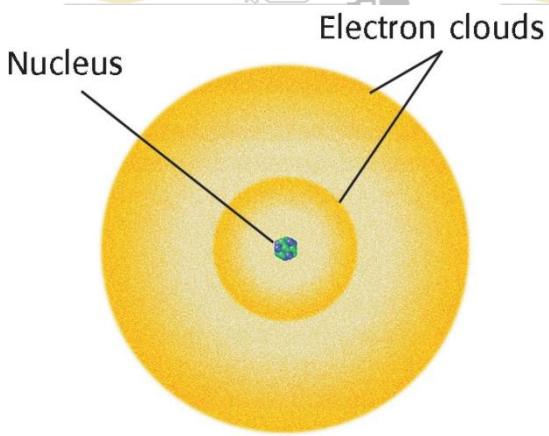


- Oil-drop Experiment determined the charge on an electron to be 1.602×10^{-19} coulomb. Based on that, the mass of the electron was calculated



The Modern Atomic Theory

An Austrian physicist named Erwin Schrodinger and a German physicist named Werner Heisenberg added to our current understanding of the atom.



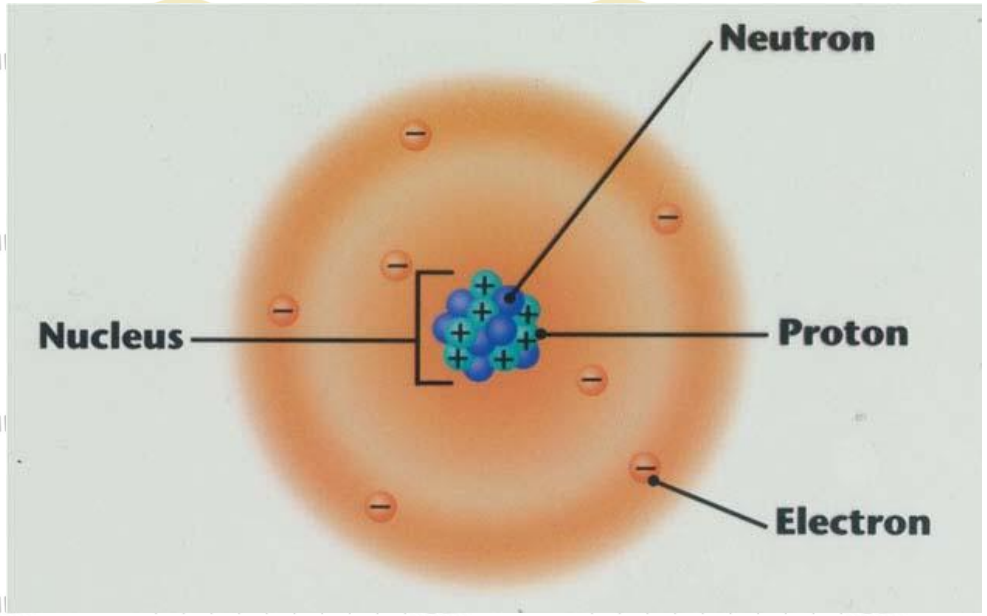
They explained that electrons do not travel in definite paths as Bohr suggested. In fact the exact path of an electron cannot be predicted. There are regions inside of an atom where electrons are likely to be found. This region is called an ***electron cloud***.

Erwin Schrodinger

Werner Heisenberg

Erwin Schroedinger

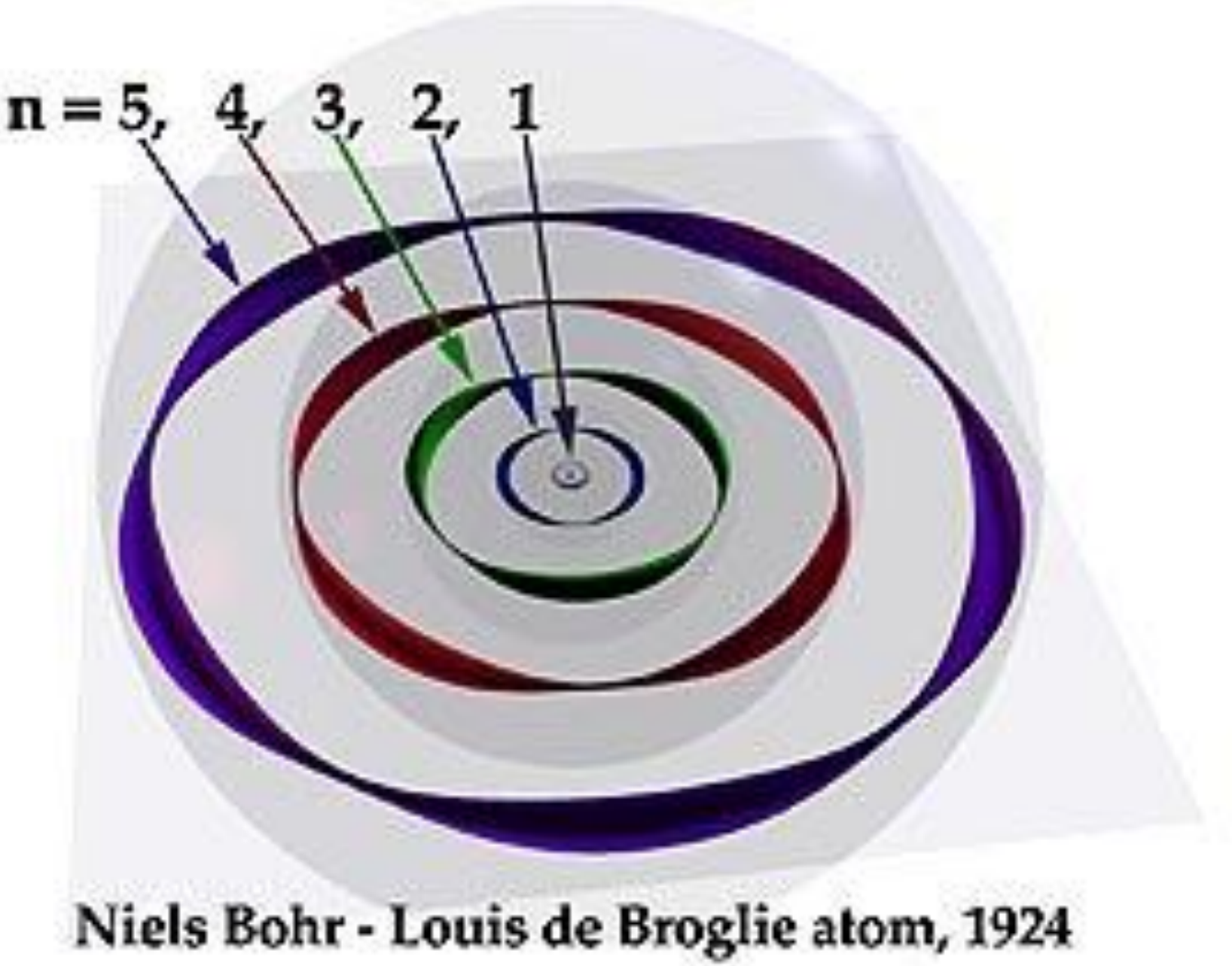
- 1926
- Modified atomic structure to include electron's location in a "cloud" or "shell" instead of a predictable orbit



Current Theory

- Louis de Broglie (1892-1987 AD)
  - Proposed that the electrons traveled in a wave-like orbits
  - Known as the Quantum Mechanical Model

Current Theory



Niels Bohr - Louis de Broglie atom, 1924

Quiz Time

1. Who was the first person to “discover” the atom?

   Democritus

2. Who suggested that elements combine in certain proportions because they are made of single atoms?

   Dalton

3. What error did Thomson find in Dalton’s atomic theory?

   Thomson discovered that atoms are made of smaller parts

4. What is the name of Thomson’s model of the atom?

   Plum Pudding model

5. What is the current model of the atom called?

electron – cloud model

6. True or False? The electron is where most of an atom's mass is located.

False

7. Which of the following scientists discovered that atoms contain electrons?

A. Dalton
B. Thomson
C. Rutherford
D. Bohr

B

Thank You!