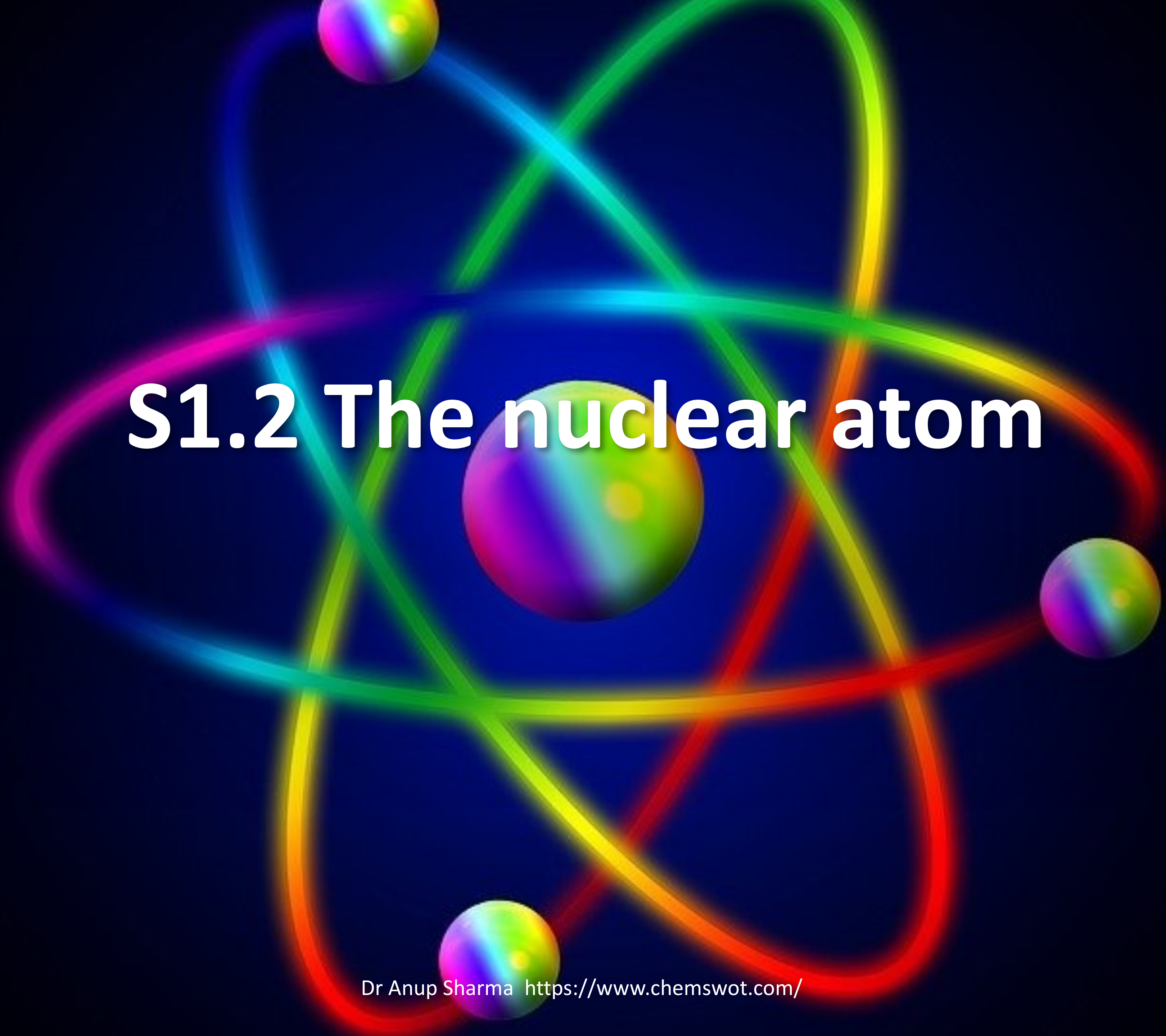
S1.2 The nuclear atom



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Guiding question for Structure 1.2—The nuclear atom
How do the nuclei of atoms differ?

Standard level and higher level : 2 hours for teaching and learning Structure 1.2—The nuclear atom

The students should understand the following concepts from Structure 1.2—The nuclear atom

Structure 1.2.1:
Atoms contain a positively charged, dense nucleus composed of protons and neutrons (nucleons). Negatively charged electrons occupy the space outside the nucleus.

Structure 1.2.2:
Isotopes are atoms of the same element with different numbers of neutrons.

Applications of the Structure 1.2—The nuclear atom
Use the nuclear symbol *AZ*X to deduce the number of protons, neutrons and electrons in atoms and ions.
Perform calculations involving non-integer relative atomic masses and abundance of isotopes from given data.

Guidance to the Teachers From the Structure 1.2—The nuclear atom
Relative masses and charges of the subatomic particles should be known; actual values are given in the data booklet. The mass of the electron can be considered negligible.
Differences in the physical properties of isotopes should be understood.Specific examples of isotopes need not be learned.
The operational details of the mass spectrometer will not be assessed.

Real life connections:

The extensive use of radio isotopes in medicinal diagnosis in scanning and treatment is very much evident now a day.

Nature of Science:

We have seen that the technology has improved so our instruments.

- **Linking Questions of Structure 1.2—The nuclear atom**

What determines the different chemical properties of atoms?

The number and arrangement of electrons in an atom's outermost energy level, known as the valence shell, also play a crucial role in determining its chemical properties.
Atoms with the same number of electrons in their valence shell tend to have similar chemical properties, which is why elements in the same column of the periodic table exhibit similar chemical behavior.

How does the atomic number relate to the position of an element in the periodic table?

Both Atomic number and the electronic configuration of an element determines its position in the periodic table.The atomic number or the proton number of an element is unique and decides its position in the periodic table.The Elements are arranged in periodic table in order of increasing atomic number. The table is divided into rows (periods) and columns (groups). The periods represent the number of electron shells or energy levels an atom has, while the groups represent the number of valence electrons, or electrons in the outermost shell, an atom has. Elements in the same group have the same number of valence electrons, and thus they exhibit similar chemical behavior. For example, all elements in Group 1, the alkali metals, have one valence electron, and they are highly reactive with water and oxygen. Elements in Group 18, the noble gases, have a full outermost shell and are highly unreactive.

How can isotope tracers provide evidence for a reaction mechanism?
Isotope tracers present an effective way of providing evidence for a reaction mechanism. Isotopes are atoms of the same element with differing atomic masses due to variations in neutrons and differ from non-isotopic elements. By substituting one isotope of an element for another during a chemical reaction, scientists can track the movements of that isotope and learn how reactions proceed. With this tactic, scientists can gain insight into which steps in the process are rate-limiting, identify potential intermediates involved in the reaction, and confirm if a reaction occurs via a specific mechanism such as a radical mechanism. In sum, isotope tracers offer an important tool to unlock valuable understanding about the fundamental chemistry of any given reaction.

How does the fragmentation pattern of a compound in the mass spectrometer help in the determination of its structure?

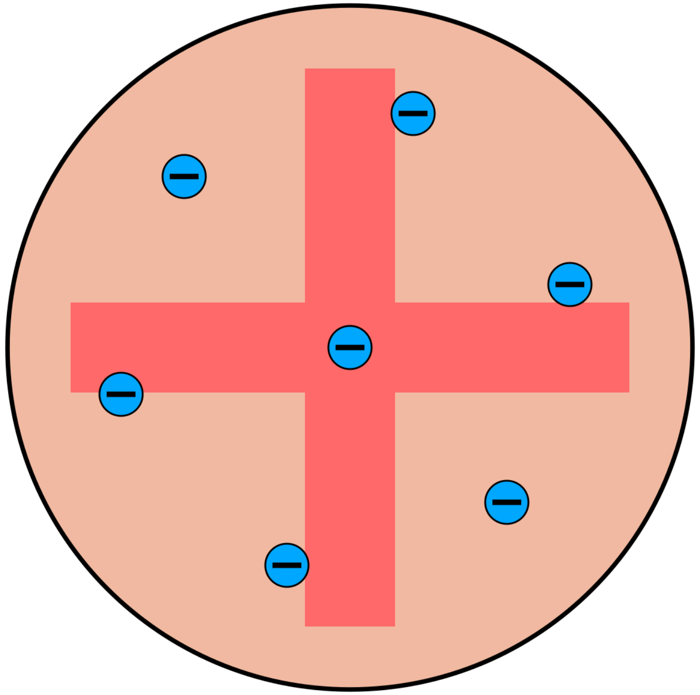
Can the fragmentation pattern of a compound in the mass spectrometer help in the determination of its structure? The answer is yes. Fragmentation patterns are generated when a compound is ionized and fragmented into smaller ions, which are then separated and detected based on their mass-to-charge ratios. Fragmentation patterns come from the cleavage of chemical bonds within the molecule, with different compounds having unique fragmentation patterns. By analyzing these patterns, scientists can identify functional groups within a molecule and determine its size and shape. This can be illustrated using an example: suppose a scientist wants to determine the structure of an unknown compound with a mass of 120 amu. After obtaining its mass spectrum, characteristic peaks for benzene ring (91 amu), methyl group (45 amu) and carbonyl group (58 amu) could be identified, enabling the scientist to infer that these groups were present in the molecule.

Keywords

Discrete,	Orbit,	Plank's Constant,
Subatomic,	Protones,	Neutrons,
Electrons,	Abundance,	Average Relative Atomic Mass

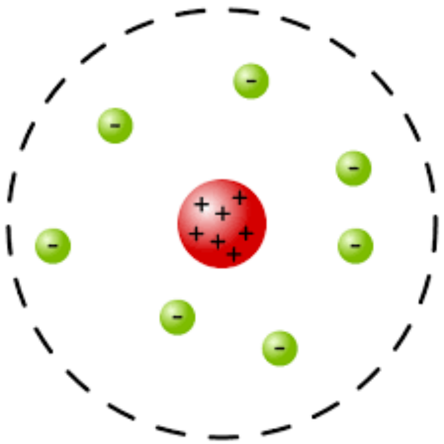
Thomson atomic model

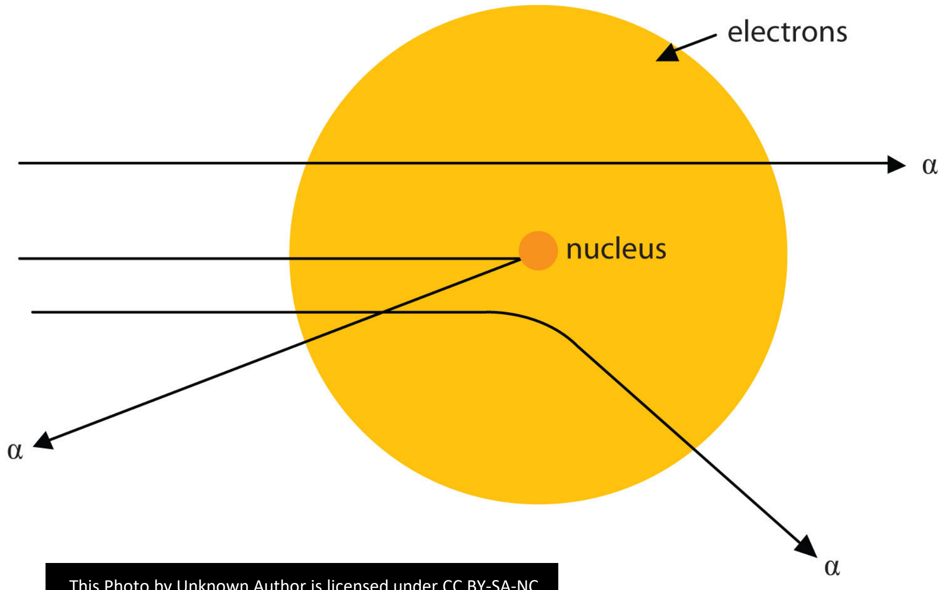
- Thomson atomic model says that An atom is similar to a watermelon in which electrons are like watermelon seeds and the flesh is positive sphere. Thus electrons are present in the positive sphere of atom.It is also known as Plum Pudding model.
- The over all atom is neutral because positive and negative charges are equal in number.
- The simulation for better understanding.



Rutherford's nuclear model

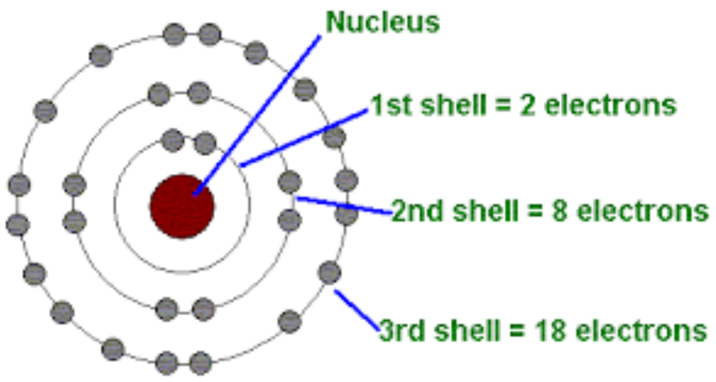
- He proposed the following Atomic model:
- Atom is mostly emplty or hollow except the dense center which is nucleus.
- Nucleus has protons(positively charged particles) and Neutrons(Neutral particles).
- Electrons (Negatively charged particles) revolve around the nucleus in fixed circular orbits.
- The simulation for better understanding.





Niels Bohr discovery

- Niels Bohr discovery improved Rutherford’s nuclear model by suggesting that the electrons revolve in the discrete energy orbits and they do not loose energy while they are in the orbit. Once they move from one orbit to another they emit energy.
- Niels Bohr $2n^2$ formula
- Electrons are found by $\mathbf{2n^2}$ formula in different shells where n=shell
- So n=1 , 2 electron,
- n=2, 8 electrons,
- n=3, 18 electrons,
- n=4, 32 electrons
- **He also suggested that outermost shell(orbit) cannot accommodate more than 8 electrons.**



Energy of electron

- Energy of electron E= hv where h= plank's constant and v is frequency of electron.
- C=vλ where c= speed of light and λ is wavelength . Thus frequency and wavelength are inversely proportional to each other.

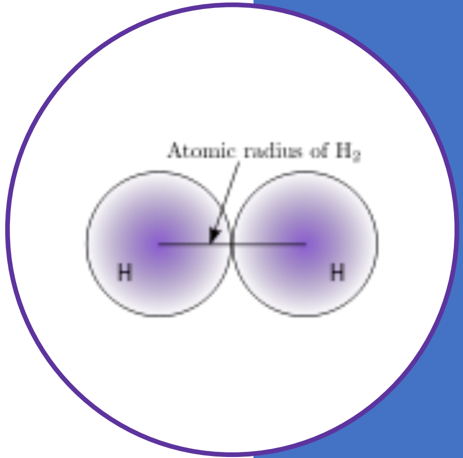
What is an Atom?

An Atom is the smallest particle of an element which can take part in a chemical reaction to form a new substance.

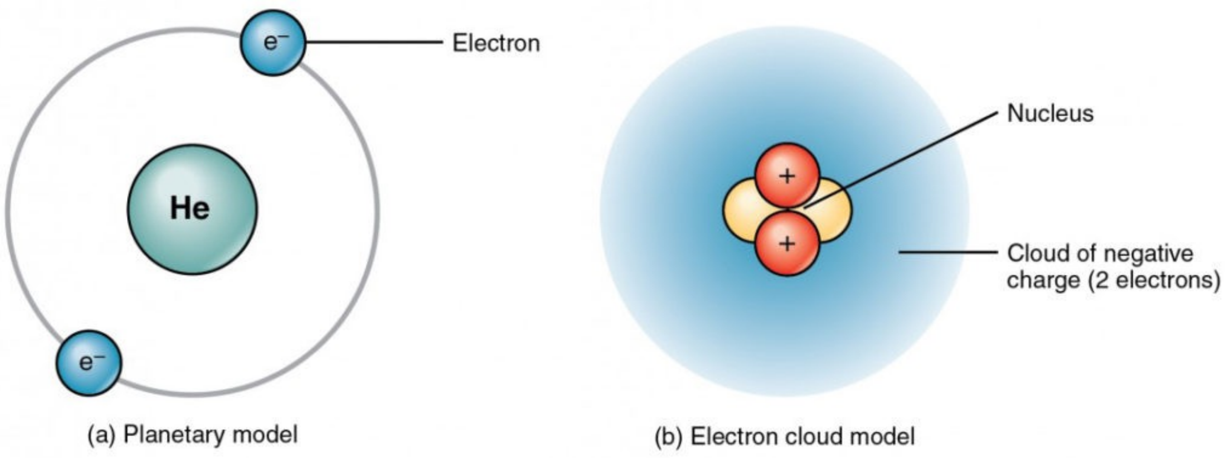
Atomic size or atomic radius : Atom is very tiny which cannot be seen by naked eyes. However the size can be measured in nanometer.

$1nm = 1/10^9$ m

Atomic radii of hydrogen atom = 1×10^{-10} m.



- **Sub-atomic particles:** As per IB guidance Relative masses and charges of the subatomic particles should be known, actual values are given in section 4 of the data booklet. The mass of the electron can be considered negligible.
- Protons-Positively charged(+1) particle- Inside the nucleus
- Neutrons – Neutral particle-Inside the nucleus
- Electron- Negatively charged(-1) particle-revolve around the nucleus
- The mass (nucleon) number, *A*, is the sum of the protons and the neutrons. (= 12 for Carbon)
- The atomic (proton) number, *Z*, of an element is the number of protons in the nucleus of the atom. In the neutral atom it is equal to the number of electrons. (6 for Carbon)



Isotopes: Atoms of same element with different number of neutrons or mass number.

Example: Isotopes of Hydrogen H^1 , H^2 , H^3

Isotopes of Chlorine Cl^{35} and Cl^{37}

Calculations involving non-integer relative atomic masses and abundance of isotopes from given data, including mass spectra.

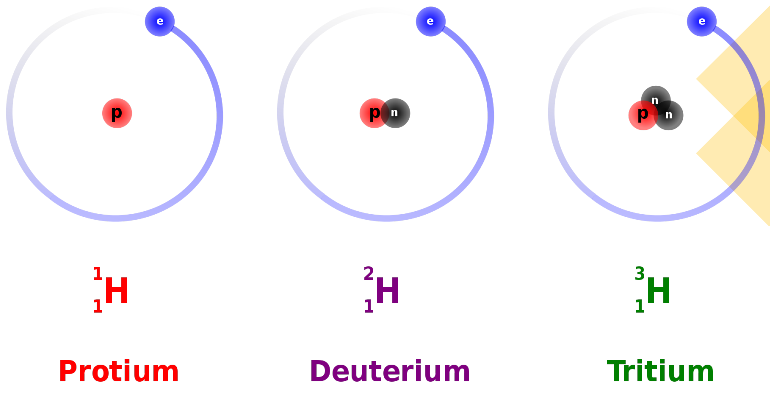
If the % abundance of Isotopes of Chlorine Cl^{35} and Cl^{37} are 75% and 25% respectively.

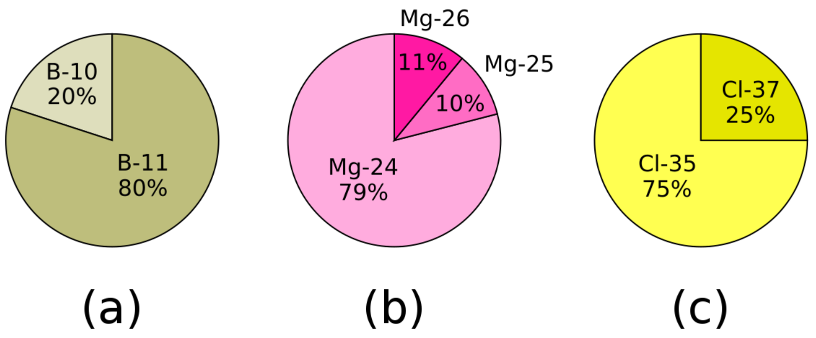
The average relative atomic mass= (35x75) + (37x25)/100= 35.5

Use of the nuclear symbol notation to deduce the number of protons, neutrons and electrons in atoms and ions.

$_{11}Na^{23}$ is the nuclear symbol of Sodium where Z= 11 and A= 23.

The simulation for better understanding.





Properties of Isotopes

- These include different atomic mass as well as radioactivity, density, melting and boiling points, and magnetic properties.
- Carbon-14 is a radioactive isotope that is used in radiocarbon dating and deuterium (a hydrogen isotope) has a higher density than plain hydrogen.
- Heavy water - containing the isotope deuterium - has an increased boiling point compared to regular water(containing Protium).
- Carbon-13 also has a special uses for its nuclear spin of 1/2; it produces a strong magnetic field and is used in MRI scanners.