A 300 Level Course: POST-SIWES SEMESTER

PHYS 340: NUCLEAR AND PARTICLE PHYSICS I

Credit: 2 units. Duration of Course: 8 weeks of didactic lectures

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SEMESTER FOCUS!

Nuclear structure.

Nuclear masses.

Nuclear Forces.

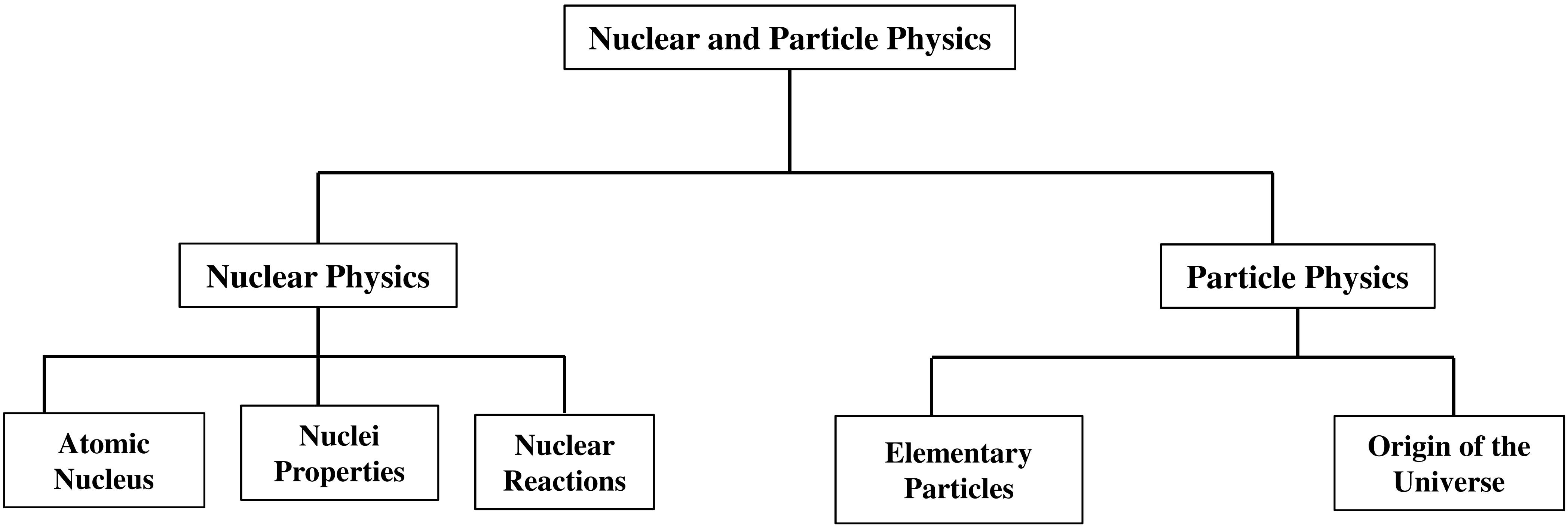
Nuclear-nucleon Scattering.

Nuclear models.

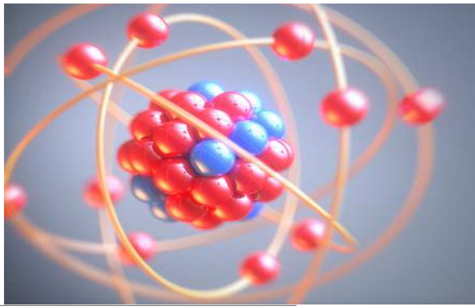
Radio-active Decay: Alpha, beta, gamma decays.

Nuclear reactions.

ORGANOGRAM: INTRO. TO COURSE DESCRIPTION



NUCLEAR PHYSICS

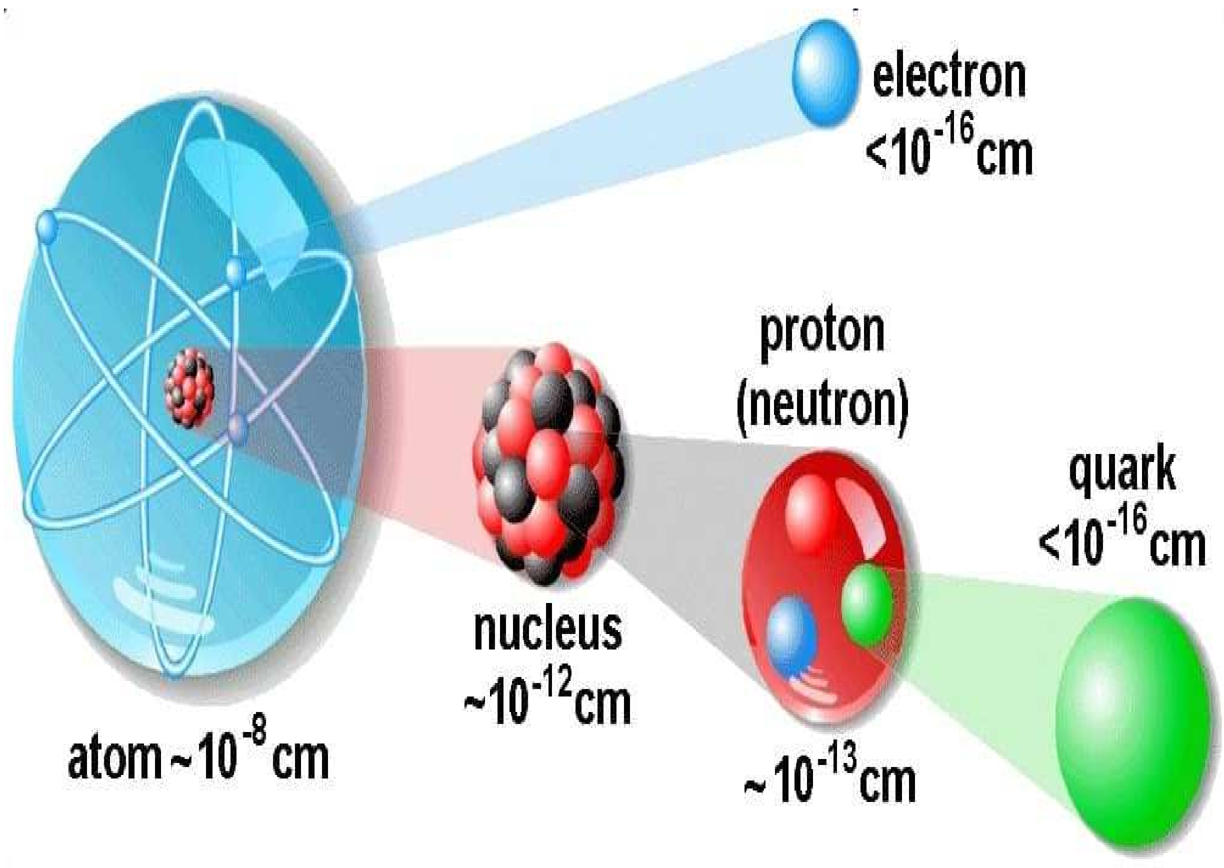


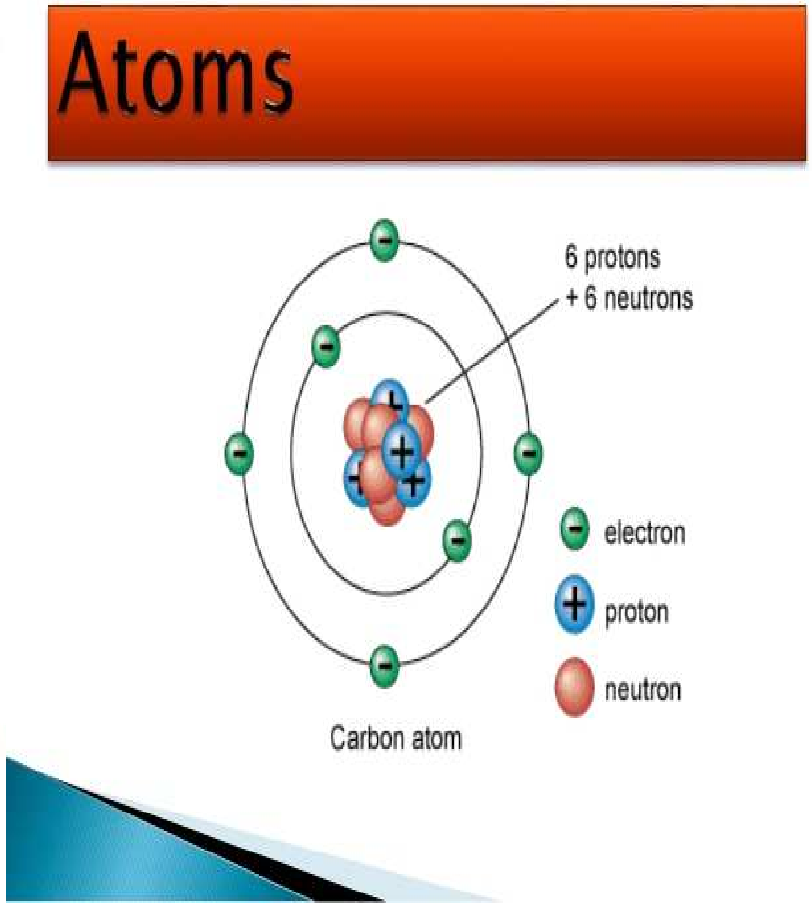
What is Nuclear Physics?

It is a branch of physics that deals with the following:

- Properties of an atomic nucleus, such as mass, charge, size, nucleons (neutrons and protons) and their binding energies.
- Nuclear structure.
- Bound and excited energy levels, spin states.
- Interaction behavior with gamma rays, with other particles and with other nuclei, variation of such behavior with energy and angle of interaction.
- Nuclear stability, radioactivity of excited and unexcited nucleus, decay half-lives, decay particles and their energies, nuclear transmutations and everything about the nucleus.

So, let's look at the ATOM!





Structure of the atom

The atom is the smallest division of an element in which the chemical identity of the element is maintained.

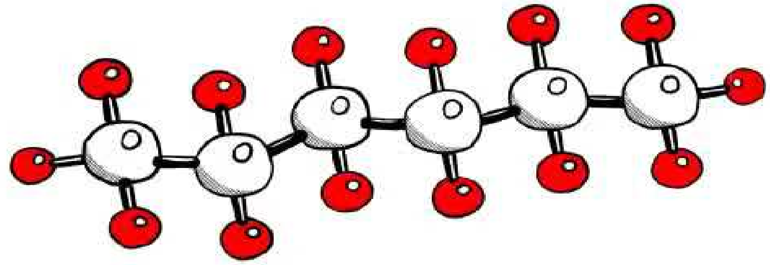
The atom is composed of an extremely dense positively charged nucleus, containing protons and neutrons, and an extra-nuclear cloud of light negatively charged electrons.

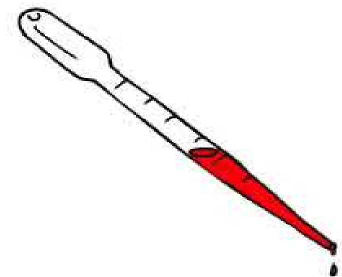
In its non-ionized state, an atom is electrically neutral because the number of protons equals the number of electrons.

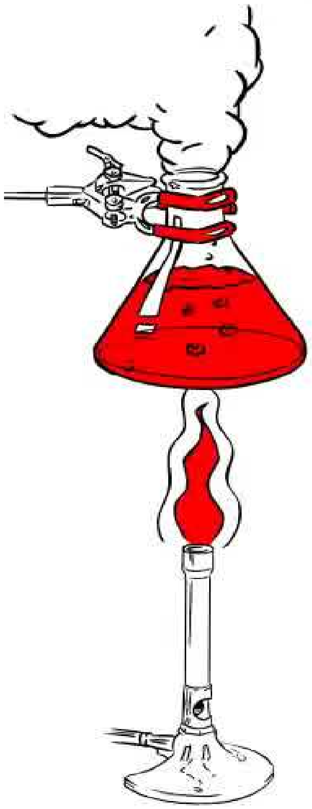
The radius of an atom is approximately 10^{-10} m, whereas that of the nucleus is only about 10^{-10} m.

Thus, the atom is largely unoccupied space, in which the volume of the nucleus is only 10^{-12} (a millionth of a millionth) the volume of the atom.

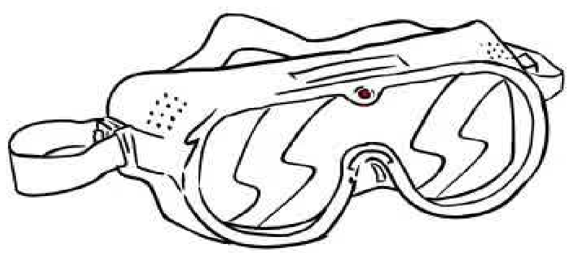
If the empty space in an atom could be removed, a cubic centimeter of protons would have a mass of approximately 4 million metric tons!

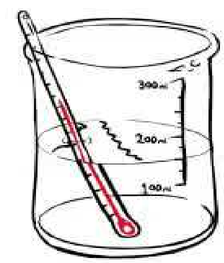


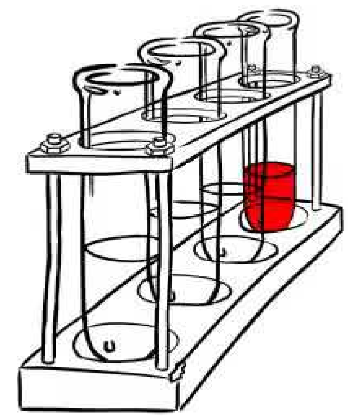




Parts of an atom







Electronic Structure

In the Bohr model of the atom (Neils Bohr 1913), electrons orbit around a dense, positively charged nucleus at fixed distances (Bohr radii).

Bohr combined the classical Newtonian laws of motion and Coulomb's law of electrostatic attraction with quantum theory.

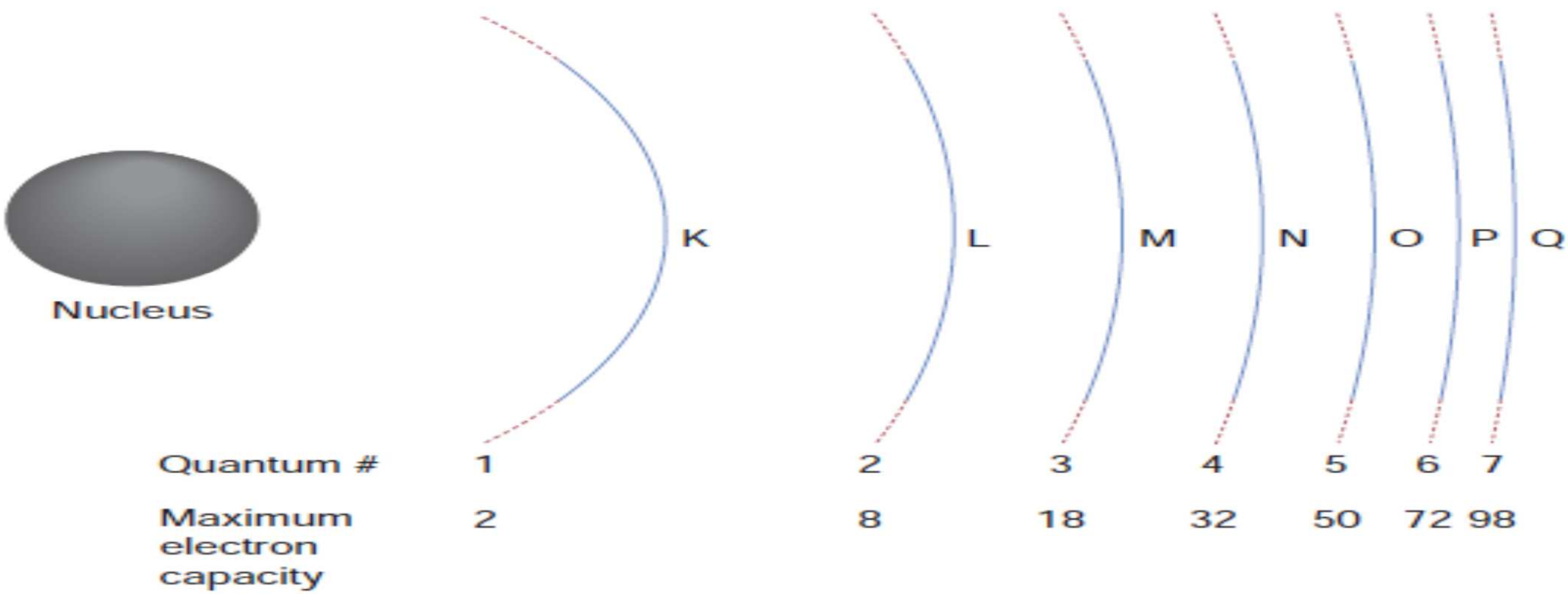
In this model of the atom, each electron occupies a discrete energy state in a given electron shell.

These electron shells are assigned the letters *K L*, *M*, *N*,…, with *K* denoting the innermost shell, in which the electrons have the lowest energies.

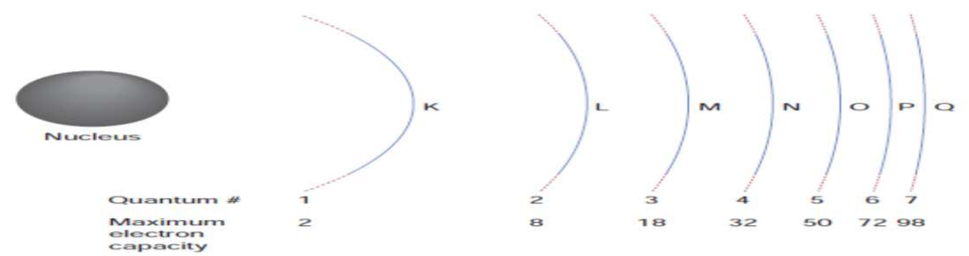
The shells are also assigned the *quantum numbers* 1, 2, 3, 4,…, with the quantum number 1 designating the *K* shell.

Each shell can contain a maximum number of electrons given by $(2n^2)$, where n is the quantum number of the shell.

Electronic Structure: diagram showing electron shell designations and orbital filling rules.



Electronic Structure



Thus, the K shell ($n = 1$) can only hold 2 electrons, the L shell ($n = 2$) can hold $2(2)^2$ or 8 electrons.

The outer electron shell of an atom, the ***valence shell***, determines the chemical properties of the element.

The energy required to remove an orbital electron completely from the atom is called its ***orbital binding energy***.

Due to the closer proximity of the electrons to the positively charged nucleus, the binding energy of the K-shell is greater than that of outer shells.

For a particular electron shell, binding energy also increases with the number of protons in the nucleus (i.e., atomic number).

Nuclear Structure

Understanding the structure of the atomic nucleus is one of the central challenges in nuclear physics.

It is firmly established that there are three fundamental particles: neutron, proton and electron.

Positrons, neutrinos, mesotron, deuteron and alpha particles e.t.c are all complex particles.

The nucleus is composed of protons and neutrons, known collectively as *nucleons*

The number of protons in the nucleus is the *atomic number* (Z), and the total number of protons and neutrons within the nucleus is the *mass number* (A).

J.J Thompson in 1898 proposed that the nucleus of an atom consists of protons and electrons and its size as almost as big as that of an atom.

Nuclear Structure

Geiger and Marsden in 1911 performed an experiment on the scattering of α-particles by gold foil under the guidance of Rutherford. The experiment showed that the gold nucleus has a positive charge of 79 e and a radius of about $5 \times 10^{-15} m$

Due to the experiment above, Lord Rutherford proposed that the nucleus of an atom is heavy and positively charged.

Until Chadwick discovered neutrons in 1932, the large mass of the nucleus remained a mystery.

The atomic nucleus is then proposed to consist of protons and neutrons.

The charge of the nucleus is just the sum of the proton charges.

The neutron is uncharged and this has been confirmed experimentally: neutron charge is less than $2 \times 10^{-21} e$.

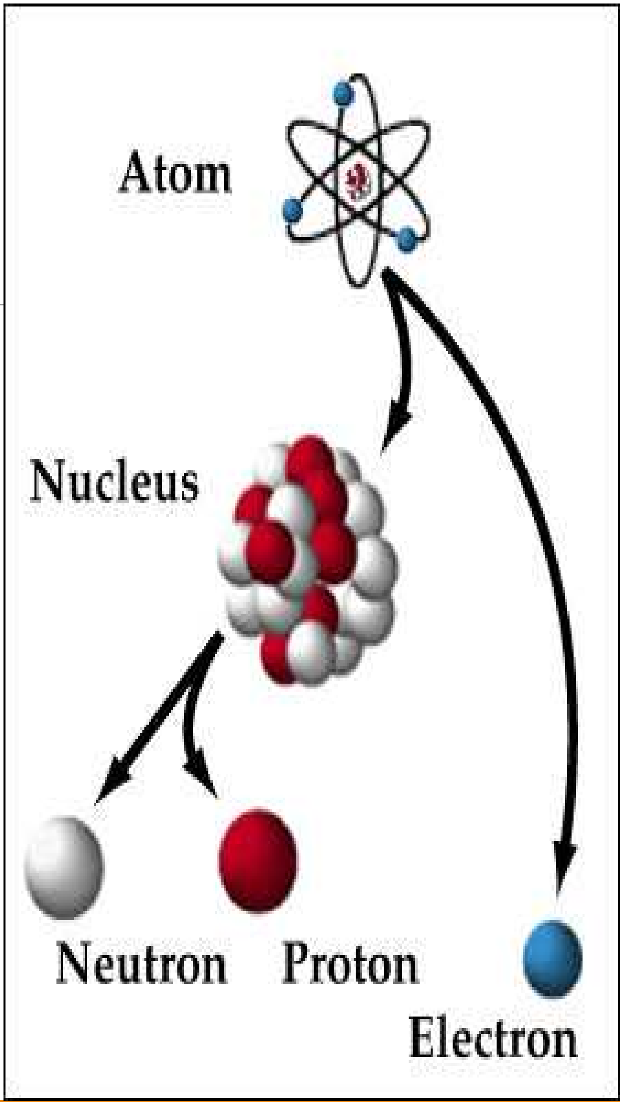
More about the ATOM!

About 2500 known nuclides are available and fewer than 300 are stable elements.

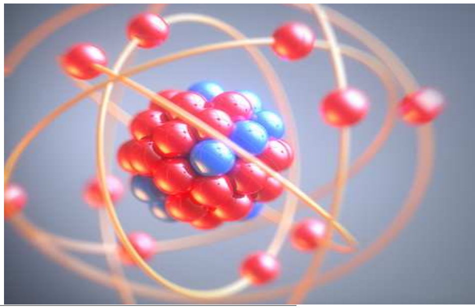
Nuclides: atomic species characterized by the specific constituents of its nucleus i.e № of protons Z and № of neutrons N.

The rest (*2200*) are unstable because they decay to form other nuclides by emitting particles and electromagnetic radiation; a phenomenon called radioactivity.

Radioactivity: It is the spontaneous disintegration or breakdown of the nuclei of the atom of a natural occurring substance with emission of particles or radiation.



ATOMIC NUCLEUS



The atom is composed of an extremely dense positively charged **nucleus** containing **protons** and **neutrons**.

Also an extra-nuclear cloud of light negatively charged **electron** orbit the **nucleus**.

In a non-ionized state, the atom is electrically neutral because the number of **protons** equals the number of **electrons**.

Protons are **positively** charged.

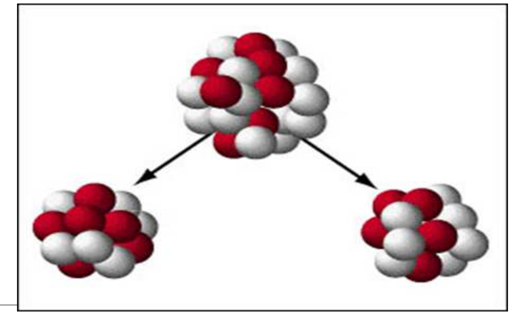
Electrons are **negatively** charged.

Neutrons have **no/neutral** charge.

Protons and neutrons form the nucleus and these particles are called **nucleons**.

Nucleons = p + n.

ATOMIC NUCLEUS



The mathematical equation for the Nucleons is expressed as: **N = p + n**

The total number of protons is called **Atomic Number** and the atomic number is symbolized as **Z**.

The nuclide of an atom is always represented as $^{A}_{Z}X$.

Let's look at Carbon:

$^{A}_{Z}X$ nuclide for carbon is represented as: $^{14}_{6}C_{8}$

Mass Number

Neutron Number

Atomic Number

ATOMIC NUCLEUS

The atomic number is different from the atomic mass (amu).

Atomic Mass: It is the actual mass of the atom. Different element have their mass.

E.g: Oxygen atomic mass as: 15.9949 amu.

Where 1 atomic mass unit = $1.6606 \times 10^{-27} kg$

Let's look at classification of nuclides: What is a nuclide?

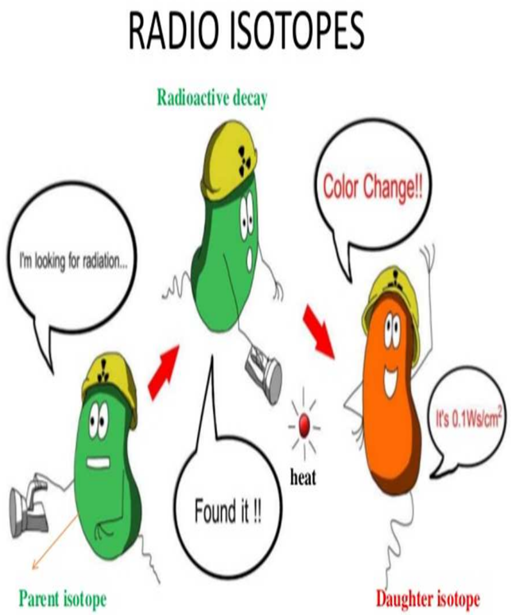
We have four different classifications:

1) Isotopes

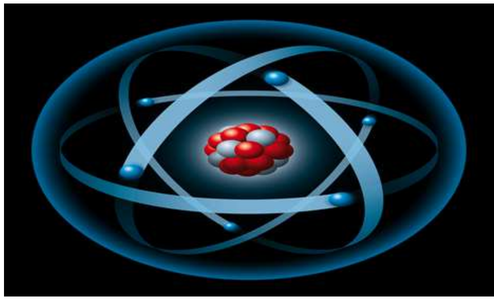
2) Isobars

3) Isotones

4) Isomers



ATOMIC NUCLEUS: Classification of Nuclides



1) Isoto**p**es: same number of protons or same atomic number but different mass number.

E.g: ${}^{35}_{17}CL$, ${}^{37}_{17}CL$, ${}^{1}_{1}H$, ${}^{2}_{1}H$, ${}^{3}_{1}H$, ${}^{12}_{6}C$ and ${}^{13}_{6}C$

Deuterium **Tritium**

2) Isob**a**rs: atoms with the same atomic mass number.

3) Isoto**n**es: atoms with the same neutron number.

4) Isom**e**rs: atoms with the same nuclear energy states.

TABLE 2-2 NUCLEAR FAMILIES: ISOTOPES, ISOBARS, ISOTONES, AND ISOMERS

FAMILY	NUCLIDES WITH SAME	EXAMPLE
Isoto*p*es	Atomic number (Z)	I-131 and I-125: Z = 53
Isob*a*rs	Mass number (A)	Mo-99 and Tc-99: A = 99
Isoto*n*es	Number of neutrons (A–Z)	$_{53}$I-131: 131 – 53 = 78 $_{54}$Xe-132: 132 – 54 = 78
Isomers	Atomic and mass numbers but different energy states in the nucleus	Tc-99m and Tc-99: Z = 43 A = 99 Energy of Tc-99m > Tc-99: ΔE = 142 keV

Note: See text for description of the italicized letters in the nuclear family terms.

NUCLEAR FORCE

The force that binds protons and neutrons together in the nucleus, despite the electric repulsion of the protons is an example of a strong interaction.

In the context of the nuclear structure, this interaction is called the **nuclear force.**

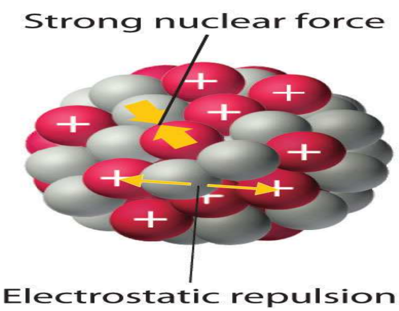
Characteristics of Nuclear Force:

1) It does not depend on the charge.

2) It has a short range, of the order of nuclear dimension $10^{-15}m$. ***But within this range, the nuclear force is much smaller than electric forces.***

3) The nearly constant density of nuclear matter and the nearly constant binding energy per nucleon of larger nuclides show that a particular nucleon cannot interact simultaneously with all the other nucleons in a nucleus, but only with those in its immediate vicinity.

ATOMIC NUCLEUS: Properties of the Nuclei



Rutherford found out that the nucleus is tens of thousand times smaller in radius than the atom itself.

He found out that the radius of nucleus is dependent on the total number of nucleons (neutrons & protons) in the nucleus. Remember that the **nucleons** is also known as the mass number (A).

The radius of the atomic nucleus is expressed as:

$$R = R_0 A^{1/3}$$

Where R = radius of the atomic nucleus.

R_0 = experimentally determined constant = $1.2 \times 10^{-15} m \approx 1.2\ fm$

A = mass number // atomic mass number // nucleons

Work Problems

1) The nucleus of a certain iron has a mass number of 56. Find the radius, approximate mass and approximate density of the nucleus.

2) The radius of a carbon nucleus is about 3×10^{-15}m and its mass is 12u. a) Find the average density of the nuclear material. b) How many more times than water is this?

Answers:

1) a) r = $4.6fm$ b) m = $9.3 \times 10^{-26}\ kg$ c) $\rho = 2.3 \times 10^{17} kg/m^3$

2) a) $\rho = 1.8 \times 10^{17} kg/m^3$ b) 2×10^{14}

ASSIGNMENT

1) Calculate the energy of electron at rest.

2) Estimate the A value and identify the nucleus if its radius is given to be 3.46 fm.

3) Assume 1 $amu = 1.66 \times 10^{-27} kg$. Estimate the density of the nuclear matter.

4) Find the nuclear density of ^{235}U given that the value of $R_0 = 1.2 fm$.

5) The radii of oxygen and lead nuclei are found to be 3 fm and 7 fm respectively. Their masses are $2.7 \times 10^{-27} kg$ and $3.4 \times 10^{-27} kg$ respectively. Calculate their densities.

6) Determine the radius of ^{208}Pb.

ASSIGNMENT

7) Iodine has a half-life of 8.05days. Calculate the decay constant.

8) A radium source has a disintegration constant of $1.36 \times 10^{-11}/s$. Calculate the half-life of radium.

9) The half-life of tritium is 12.33 years. What is the number of tritium nuclei that will have an activity of $3.70 \times 10^{-10}/s$?

10) Explain why the nucleus of an Hydrogen atom does not have neutrons.

Table 43.1 Compositions of Some Common Nuclides

Z = atomic number (number of protons)

N = neutron number

$A = Z + N$ = mass number (total number of nucleons)

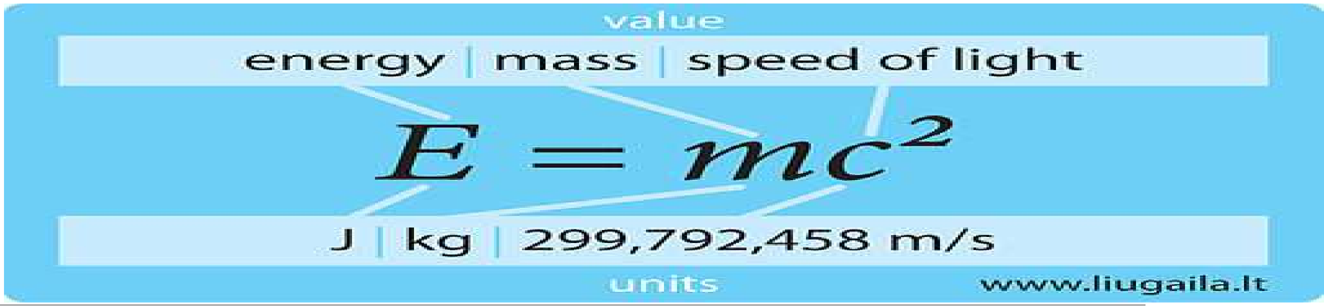
Nucleus	Z	N	$A = Z + N$
$^{1}_{1}H$	1	0	1
$^{2}_{1}H$	1	1	2
$^{4}_{2}He$	2	2	4
$^{6}_{3}Li$	3	3	6
$^{7}_{3}Li$	3	4	7
$^{9}_{4}Be$	4	5	9
$^{10}_{5}B$	5	5	10
$^{11}_{5}B$	5	6	11
$^{12}_{6}C$	6	6	12
$^{13}_{6}C$	6	7	13
$^{14}_{7}N$	7	7	14
$^{16}_{8}O$	8	8	16
$^{23}_{11}Na$	11	12	23
$^{65}_{29}Cu$	29	36	65
$^{200}_{80}Hg$	80	120	200
$^{235}_{92}U$	92	143	235
$^{238}_{92}U$	92	146	238

Table 43.2 Neutral Atomic Masses for Some Light Nuclides

Element and Isotope	Atomic Number, Z	Neutron Number, N	Atomic Mass (u)	Mass Number, A
Hydrogen (^1_1H)	1	0	1.007825	1
Deuterium (^2_1H)	1	1	2.014102	2
Tritium (^3_1H)	1	2	3.016049	3
Helium (^3_2He)	2	1	3.016029	3
Helium (^4_2He)	2	2	4.002603	4
Lithium (^6_3Li)	3	3	6.015122	6
Lithium (^7_3Li)	3	4	7.016004	7
Beryllium (^9_4Be)	4	5	9.012182	9
Boron ($^{10}_5B$)	5	5	10.012937	10
Boron ($^{11}_5B$)	5	6	11.009305	11
Carbon ($^{12}_6C$)	6	6	12.000000	12
Carbon ($^{13}_6C$)	6	7	13.003355	13
Nitrogen ($^{14}_7N$)	7	7	14.003074	14
Nitrogen ($^{15}_7N$)	7	8	15.000109	15
Oxygen ($^{16}_8O$)	8	8	15.994915	16
Oxygen ($^{17}_8O$)	8	9	16.999132	17
Oxygen ($^{18}_8O$)	8	10	17.999160	18

Source: A. H. Wapstra and G. Audi, *Nuclear Physics* **A595,** 4 (1995).

BINDING ENERGY



Recall:

From the Einstein's Theory of Relativity: He explains that mass is a form of energy and that a mass (m) equivalent to an amount of energy (E).

$E = mc^2$

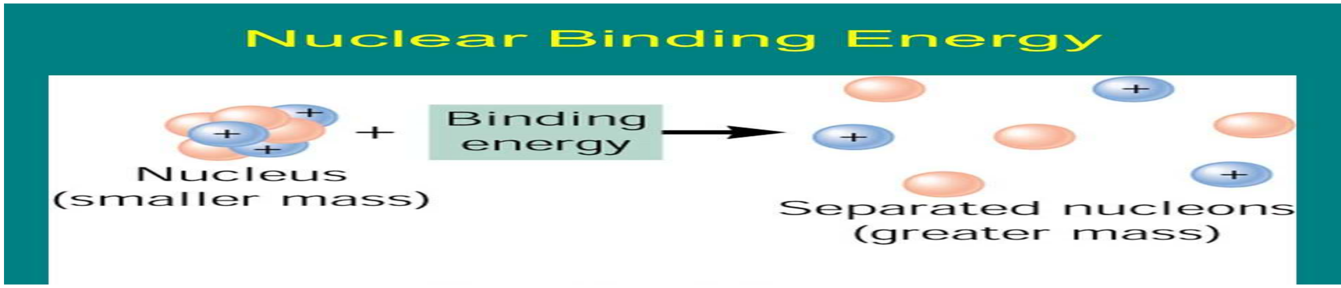
If the mass of an atom is slightly less than the sum of masses of its component particles, there is a difference between the two masses (Δm).

$\Delta E = (\Delta m)c^2$

$\Delta E =$ binding energy (E_B).

Binding Energy $(E_B) =$ Energy that must be added to separate the nucleons.

BINDING ENERGY



When the nucleons are separated, the total rest energy (E_0) of the separated individual protons and neutrons is greater than the binding energy.

E_0 - E_B

E_0 = rest mass of the individual protons and neutrons.

$E_B = (ZM_H + NM_n - {}_Z^AM)\ c^2$

E_B = binding energy of a nucleus with Z protons and N neutrons.

Z = atomic number. N = neutron number M_H = mass of the hydrogen atom.

M_n = neutron mass ${}_Z^AM = mass\ of\ neutral\ atom\ containing\ the\ nucleus.$

c^2 = speed of light in vacuum $\approx 931.5\ MeV$/u

Nuclear Size

A nucleus of an atom except hydrogen, consists of neutrons and protons.

The protons being positively charged, give rise to an electrostatic coulomb potential about the nucleus.

Also, both the neutrons and protons give rise to the nuclear potential due to the strong nuclear forces.

The different types of radii that can be attributed to a nucleus are:

1) radius of neutron distribution R_n

2) radius of proton or charge distribution R_p

3) coulomb potential radius R_c

4) nuclear potential radius R_N

Nuclear Size

If the density of protons inside the nucleus is uniform throughout, the Coulomb potential radius R_c and the proton distribution radius R_p would be the same.

If the proton density is not uniform, then the two radii R_c and R_p would be different.

Early measurements by Rutherford, Geiger and Marsden using alpha particle scattering indicated that nuclei had a size of about $10^{-14}m$.

There are two basic methods to determine nuclear sizes:

1) Electromagnetic methods: These give the charge distribution. Examples are: electron scattering, x-ray spectra of mesonic atoms and mirror nuclei.

2) Nuclear methods: These give the matter distribution. Examples are: Alpha scattering, proton scattering, neutron scattering and absorption and lifetimes of alpha particle emitters.

Nuclear Size Determination: Electron Scattering Method (ESM)

The only way electrons can interact with the nucleus is through electromagnetic interaction.

In the ESM, electron scattering of high energy electrons is studied and from the knowledge of the scattered electrons, the radius constant R_0 is computed.

A beam of high energy electrons is incident on a target and the angular distribution of the scattered electrons is studied.

An electron of energy $10^9 eV$ has a deBroglie wavelength = $\frac{\lambda}{2\pi}$ can be used to study the nuclear charge distribution.

The ESM experiments to determine the nuclear charge distributions were carried out at the Stanford Linear Accelerator Center by Robert Hofstadter and others and was awarded a Nobel Prize for this 1961.

Nuclear Size Determination: Electron Scattering Method (ESM)

In this experiment, a beam of electrons of known energy incident on a thin target of the element under study. The scattered electrons were analyzed for their momentum in a magnetic spectrometer.

The electron beam from a linear accelerator after momentum analysis is allowed into the scattering chamber with the help of two deflecting magnets.

In the center of the scattering chamber, the beam passes through a thin gold foil (any scattering material can be used) and the electrons scattered by the electric fields of the nuclei then fall on a magnetic spectrometer when they again undergo momentum analysis to record only the elastic events.

The spectrometer can be rotated about an axis through the target so that the intensity of scattered electrons can be observed as a function of angle θ.

Nuclear Size Determination: Electron Scattering Method (ESM)

In the electron-nucleus collision, electron loses kinetic energy and the nucleus recoils.

The energy of the recoil nucleus E_n can be calculated by treating the electron-nucleus to be similar to a photon-electron Compton collision.

From the theory of Compton effect:

$$E_n = \frac{E^2}{Mc^2} \cdot \frac{(1 - cos\theta)}{1 + \frac{E}{Mc^2(1-cos\theta)}}$$

$E_n = Energy\ of\ the\ recoil\ nucleus,$

$E = Energy\ of\ the\ incident\ electron$

M = Mass of the nucleus

θ = Scattering angle.

Nuclear Size Determination: Electron Scattering Method (ESM)

The energy of scattered electron E is thus given by $E' = E - E_n$

Hofstadter and others assumed that the density of charge in the nucleus is best given by:

$P\ (r) = \frac{P_o}{1 + e^{k(r-e)}}.$

Where: P_0 and k are constants.

The experimental results with gold were analyzed in terms of the above equation and the results for a wide range of nuclei indicated c to be proportional to $A^{1/3}$ and it was found that the results fit well within the formula: $R - R_0 A^{1/3}$

Nuclear Size Determination

There are two basic methods to determine nuclear sizes:

1) Electromagnetic methods: These give the charge distribution. Examples are: electron scattering, x-ray spectra of mesonic atoms and mirror nuclei.

2) Nuclear methods: These give the matter distribution. Examples are: Alpha scattering, proton scattering, neutron scattering and absorption and lifetimes of alpha particle emitters

Nuclear Size Determination: Alpha Scattering Method (ASM)

The theory of α-particle scattering was first developed by Rutherford, Geiger and Marsden in 1911.

In this experiment, a collimated beam of α-particles emitted from a radon tube was incident on a thin foil of gold.

The number of α-particles scattered by the foil at different angles was detected by the scintillations they produced in a ZnS screen observed through a microscope.

Note: The gold foil scatterer can be replaced by foils of other metals.

The energy of the α-particles can be changed by placing very thin metal foils of known thickness in front of the α-particle source. The arrangement of the α-particle source, the scatterer and the ZnS screen was placed in high vacuum.

The experiment was performed in a photographic dark room to ensure that the light produced by the α-particles on the ZnS screen can be very faint.

Nuclear Size Determination: Alpha Scattering Method (ASM)

When α-particles strikes matter, some of them scatter to a greater angle while others to a small angle.

Rutherford explains the large scattering through the following assumption:

1) The scattering is due to a single encounter between the α-particle and the atom.

2) The whole mass of the atom is concentrated in the core called the nucleus.

3) The nucleus is a positively charged body of size $\approx 10^{-13} cm$.

4) The α-particle penetrates very close to the nucleus until the repulsive force on it becomes very large and the particle is scattered to large angle.

5) The α-particle when near the nucleus is relatively very far from the negative charges which are spread over a much larger volume so that the attractive forces exerted by the electrons are negligible.

Nuclear Size Determination: Alpha Scattering Method (ASM)

The Rutherford Alpha Scattering formula is expressed as: $N' = \frac{Qnt(Ze)^2.E^2}{4r^2M^2V^4}\cos ec^4\frac{\emptyset}{2}$

This formula states that the number of α-particles N' striking unit area of a fluorescent screen at a distance r from the point of scattering must be proportional to:

1) $\cos ec^4\frac{\emptyset}{2}$

2) The thickness t of the scatterer.

3) The square of the nuclear charge $(Ze)^2$.

4) Inversely to the square of the initial kinetic energy.

Nuclear Size Determination: Alpha Scattering Method (ASM)- Work Problem

1) Using the Rutherford scattering of α-particles method, determine the radius of copper nuclei. Given that Z for copper is 29, E for α-particle = 2e = $2 \times 4.8 \times 10^{-10} e.s.u$, M for α-particle = $4 \times 1.67 \times 10^{-24} gm$, V for α-particles from Radon = $1.6 \times 10^{9} cm/sec$.

Solution.

The quantitative information about the size of the nucleus was first obtained from the Rutherford's approach. Hence, the quantity $\boldsymbol{b} = \frac{\boldsymbol{2Ze.E}}{\boldsymbol{MV^2}}$ gives the distance of closet approach of the α-particle to the nucleus.

Answer: = $1.7 \times 10^{-12} cm$.

Hence the radius of the copper nuclei is of the order of $10^{-12} cm$

Nuclear Size Determination: Assignment

WRITE A TOWN-PAPER ON THE FOLLOWING NUCLEAR SIZE DETERMINATION METHODS:

1) MIRROR NUCLEI METHOD

2) MESONIC X-RAY METHOD.

3) NEUTRON SCATTERING METHOD

4) PROTON SCATTERING METHOD

DATE OF SUBMISSION: NEXT CLASS!

NUCLEAR MASS

After the pioneer experiments of J.J Thompson, showing the presence of isotopes in neon, great efforts were devoted in developing mass spectrometers (mass spectroscopes).

Mass spectrometers were extensively used for measuring atomic masses and isotopic abundance ratio in elements.

They are also used in identification of products of nuclear reactions, chemical analysis of complicated vapour mixtures and routine testing of gas leaks and vacuum chambers.

NUCLEAR MASS: Physical Principle of Mass Spectrometer

A mass spectrometer consists of:

- ion source: which produces a positively charged ions of the atoms.

- arrangement of electrostatic and magnetic fields: to measure the energy and momentum of ions.

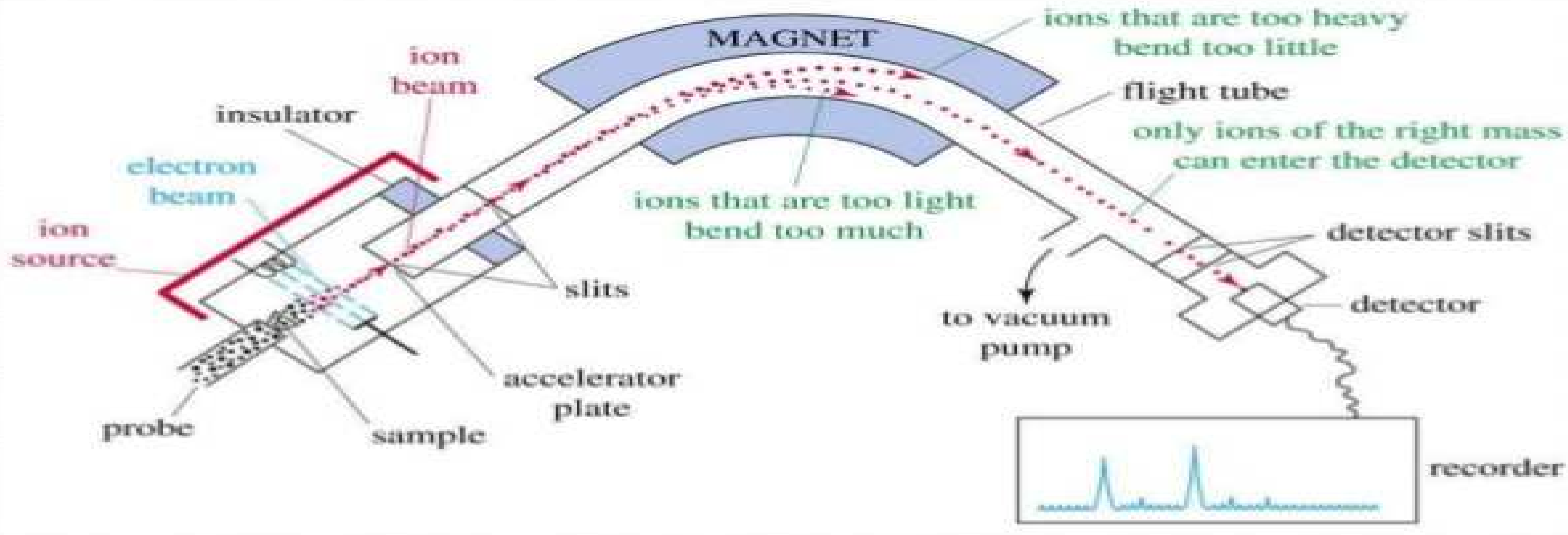
The electric and magnetic fields bring to a focus, ions of the same mass and varying speeds and directions within a small range.

An ion is associated with the following: mass M, charge Q, momentum p, and kinetic energy W_k

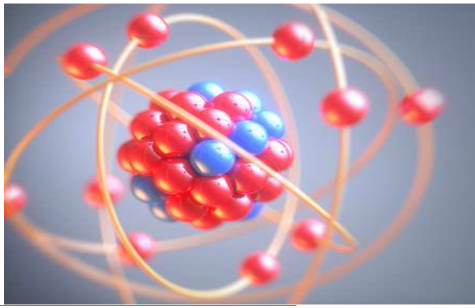
If an ion beam passes through crossed electric field E and magnetic field B, perpendicular to the beam, the velocity v of the ions which remains deflected is given as:

$$v = c\frac{E}{B}$$

1) Magnetic Deflection Mass Spectrometer



NUCLEAR MASS



The equivalence of one atomic mass unit to 931.48 MeV follows from Einstein's mass energy equivalence equation ($E = mc^2$)

The masses of some particles and energy equivalent are given below:

$$Mass\ of\ electron, M_e = 0.000548u$$

$$= 0.511\ MeV$$

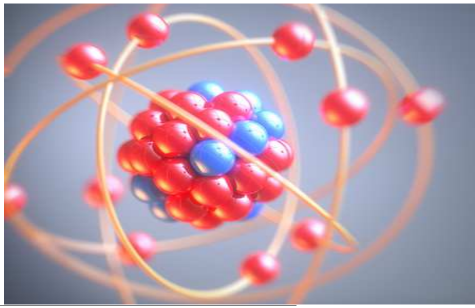
$$Mass\ of\ proton, M_p = 1.0072766u$$

$$= 938.25\ MeV$$

$$Mass\ of\ neutron, M_n = 1.008665u$$

$$= 939.55\ MeV$$

ATOMIC MASS



Atomic mass or atomic weight is the average mass of atoms of an element and it is calculated using the relative abundance of isotopes in a naturally-occurring element.

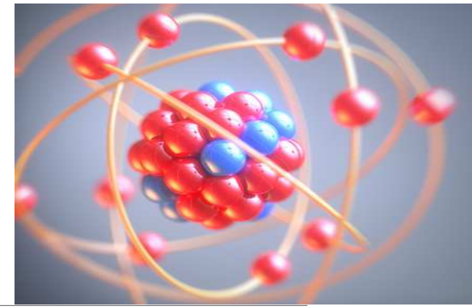
The mass of different isotopes of the elements is different from each other.

Since, the atom is made up of nucleus and nucleus made up protons and neutrons, hence atomic mass is also defined as the sum of masses of protons, neutrons and electrons present in an atom.

The atomic mass is measured in atomic mass unit (amu).

Standard atomic weight is the average relative atomic mass of an element in the crust of the earth and its atmosphere.

ATOMIC RADII



The atomic radii is the half of the distance between the nuclei of identical neighbouring atoms in the solid form of an element.

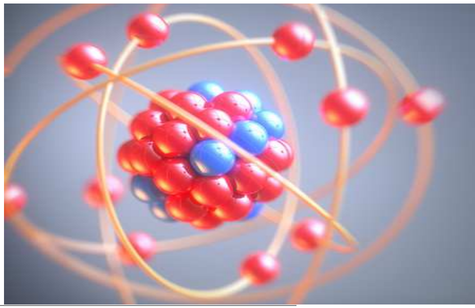
The value of atomic radii depends on the type of chemical bond in which the atoms are involved (metallic, ionic or covalent bonds).

The distances between atoms and ions have been determined very accurately by X-ray diffraction analysis of crystals.

Typical atomic radii have values of about one or two angstrom units. ($1\,\dot{A} = 10^{10} m$).

The atomic radius may be referred to as: ionic radius, covalent radius and metallic radius

ATOMIC RADII

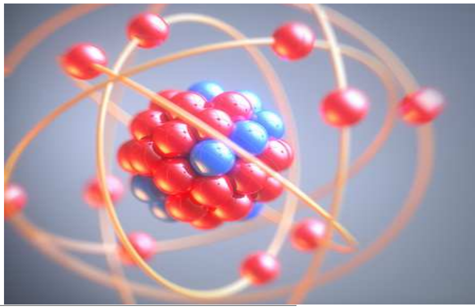


Ionic Radius: The ionic radius is the radius of ion of an atom. The ion or the atoms doesn't have definite shape or boundary, since the nucleus and electrons are bounded by the atomic bonds. The ionic radius are measured in picometers (30 -200 pm) or in Armstrong.

Covalent Radius: The covalent radius of an atom is defined as the radius of the atom which is under the covalent bond with another atom of the same element. The covalent radius are measured in picometers or in Armstrong.

Metallic Radius: It is half-the-distance between the neighbouring atoms in the metals. The atoms in the metals might be bonded by the metallic bonds. The metallic radius is more appropriate for measuring the atomic radii.

TUTORIALS



1) Write a short essay on the structure of the atom, describing the constituents, charge, mass, density and electronic structure.

2) Using the Neils Bohr's atomic model, calculate the maximum electron capacity in the electron shells starting from the innermost shell to the outermost shell.

3) Distinguish between the orbital binding energy and the nucleon binding energy.

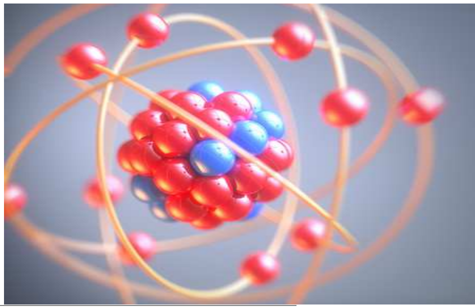
4) List the fundamental and elementary particles in the universe.

5) Define Radioactivity and explain the four classifications of nuclides with examples.

6) List three characteristics of nuclear force.

7) The radius of a carbon nucleus is about 3×10^{-15}m and its mass is 12u. a) Find the average density of the nuclear material. b) How many more times than water is this

TUTORIALS



8) The half-life of tritium is 12.33 years. What is the number of tritium nuclei that will have an activity of $3.70 \times 10^{-10}/s$

9) Use a mathematical expression to explain the binding energy of the nucleus of an atom.

10) List the different types of radii that can be attributed to a nucleus.

11) List and define the methods of nuclear size determination and give three examples each.

12) Using the Robert Hofstadter's experiment, explain the electron scattering method to determine the size of the nucleus.

13) List the five Rutherford's assumption that explains the scattering of alpha-particles at large angle during alpha-scattering method.

14) Explain the following terms: ionic radius, covalent radius and metallic radius.

NEXT TOPICS

NUCLEAR MODELS

NUCLEAR TRANSMUTATIONS: RADIOACTIVE DECAY

NUCLEAR REACTIONS.

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2) Fundamentals of Nuclear Physics by Jagdish Varma, Roop Chand Bhandari and D.R.S Somayajulu

3) Nuclear and Particle Physics: An Introduction by Brian R Martin

4) Introduction to Nuclear Physics and Chemistry by Bernard G. Harvey

5) Nuclear Reactor Physics by Weston M. Stacey

6) University Physics with Modern Physics by Hugh D. Young and Roger A. Freedman

About Lecturer:

Opadele A.E is a physics enthusiast with special interest in Medical Physics. He loves to present the complex theories in physics in seemingly simple approach for effectual understanding.

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If you have any questions, let me know