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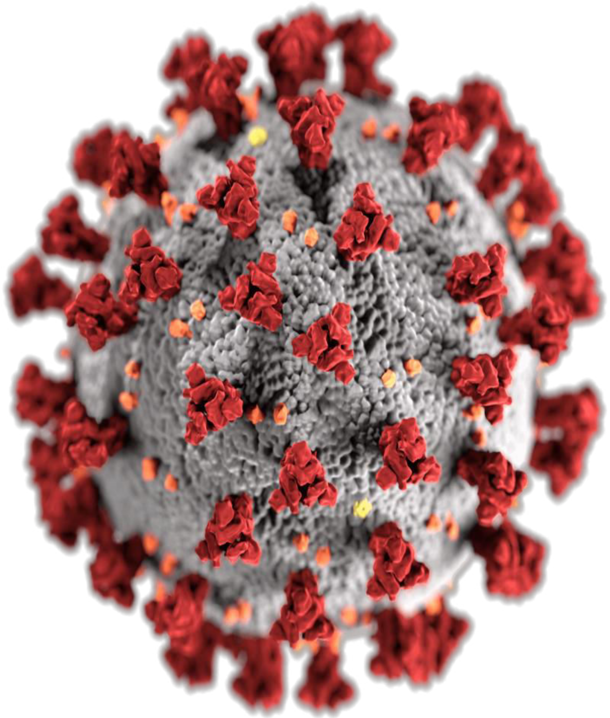
Welcome to my Class

Physics Ph 1205

09:15 AM
March 21, 2021

COVID-19 Precautions



- Don’t be afraid
- Be aware of the pandemic
- Use appropriate outfits if you compelled to go out
- Try to maintain proper diet
- Do not forget to exercise (at least one hour) regularly
- Try to follow the guidelines of WHO and Bangladesh Government
- Try to stay at home

Theories of Nuclear Composition

Most of the physical and chemical properties of matter which we are familiar with are a result of the number and configuration of atomic electrons.

Nevertheless, atomic nuclei are vitally important for a number of reasons, including:

The number of electrons an atom can have depends on how many protons the nuclei has.

Thus, the nucleus plays a large, if indirect, role in determining atomic structure.

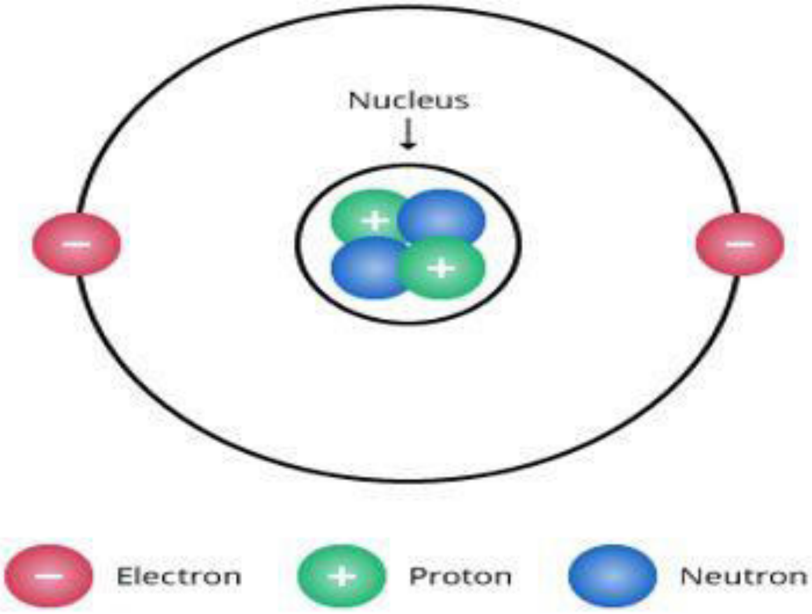
Most of the energies liberated in everyday processes involve nuclear reactions.

Proton-neutron Theory

In 1932, scientist Chadwick discovered neutron. Neutron is a charge less particle whose mass is about the same mass of the proton.

After the discovery of the neutron, scientists came to the conclusion that other than hydrogen all other nucleus consists of proton and neutron. This is the proton-neutron theory.

Let consider a helium nucleus. In its nucleus, there are two protons and two neutrons. Two positive charges of the proton are neutralized by the negative charge of electrons outside the nucleus; as a result, the atom becomes electrically neutral.



Formation of He-nucleus according to proton-neutron theory

A nucleus is expressed by two numbers. One is mass number A and the other one is atomic number Z.

Apart from mass number A and atomic number Z, there are $(A - Z) = N$ number of neutrons and outside the nucleus, there is Z number of electrons.

In natural radioactivity, following explanations for the emission of beta particle i.e., electron and emission of a positron (i.e., positively charged electron or anti-electron) can be given.

Actually, electrons do not stay inside the nucleus but during the transformation of the neutron into proton electrons are emitted.

$$n \rightarrow p^+ + e^-$$

Again, if the proton is transformed into the neutron, the position is emitted.

$$p^+ \rightarrow n + e^+$$

By the help of proton-neutron theory for the structure of the nucleus, many complicated phenomena of atom and nucleus can be explained.

General Properties of a Nucleus

Nuclear Mass

Nuclear Charge

Nuclear Radius

Experimentally, using neutrons of energy 20 MeV or more, it is found that the volume of a nucleus is proportional to the number of nucleons (neutrons and protons) it contains.

Since the mass number A is proportional to volume and volume is proportional to the R^3, where R is the nuclear radius, it follows that R is proportional to $A^{1/3}$. We usually write

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

where R_0 is a constant approximately equal to 1.2×10^{-15} m.

Nuclear density

Nuclear Quantum States

Nuclear Spin and Magnetic Moment

Since nucleus has finite size, it posses, just like orbital electrons, spin motion and the consequent magnetic moment.

Many spectral lines were found to have a fine structure which was explained due to electron spin. Many of these fine structure lines show still finer structure called hyperfine structure which has been attributed to the nuclear spin.

Experimental evidence shows that the constituent particles inside the nucleus are in continuous motion in discrete quantized orbits.

This orbital motion endows the nucleons with mechanical angular momentum because of which protons additionally posses magnetic moment.

Over and above these orbital motions, the nuclear particles spin about their own axes and so posses spin angular momentum and an associated magnetic moment.

Hence, the nucleus as a whole will posses the following:

Resultant angular momentum which is the resultant of the orbital and spin momenta of different constituent particles. It is referred to as nuclear spin.

Resultant magnetic moment called nuclear magnetic moment which is the resultant of the moments due to the orbital and spin motions of protons inside the nucleus.

The nuclear spin or angular momenta of nuclei, in general, is given by

$$p_I = I.\frac{h}{2\pi}$$

Where I is the nuclear spin quantum number. This quantum number I has half integral values for all isotopes of odd mass numbers and whole number or integral values for all those with even mass numbers.

It may be noted that magnetic moment of nuclei in general are very small as compared to those associated with extra nuclear electrons.

For all nuclei the magnetic moments given by

$$\mu_I = g.\frac{h}{2\pi}.\frac{e}{2M}$$

Where g-factor varies from nucleus to nucleus and M is the mass of a proton. The product $\frac{h}{2\pi}.\frac{e}{2M}$ is know as nuclear magneton.

$$\mu_n = \frac{h}{2\pi}.\frac{e}{2M}$$

$$= 5.05 \times 10^{-27} A.m$$

Packing Fraction

Although atomic masses are close to whole numbers , they almost invariably differ from integers by small amounts. This divergence of the mass of a nuclide from whole number is expressed in the form of a quantity know as packing fraction.

Packing Fraction,

$$f = \frac{M - A}{A}$$

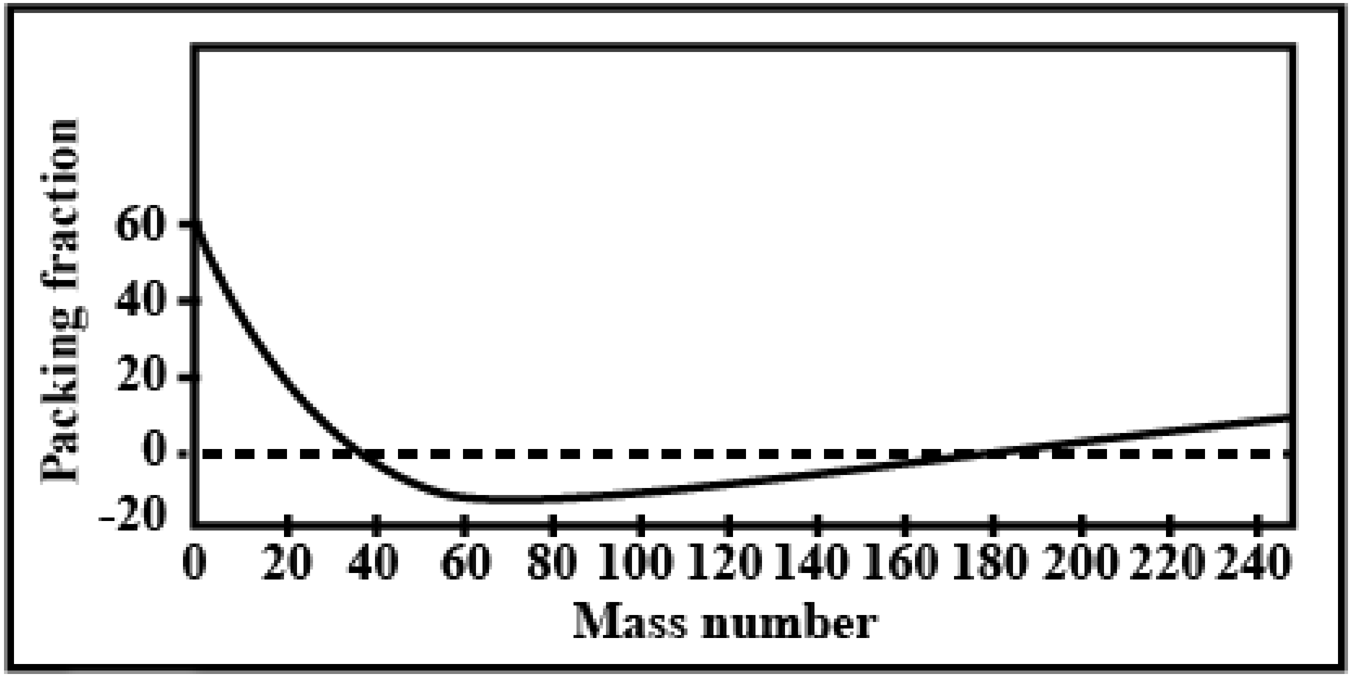
Where M= Actual isotopic mass of the nuclide in a. m. u.

A= mass number (i.e. isotopic mass rounded off to the nearest integer)

The difference between atomic mass (M) and mass number (A) is called mass defect. Obviously, mass defect

$$\Delta m = M - A$$

$$\therefore \quad f = \frac{\Delta m}{A}$$



Variation of packing fraction with mass number

Mass Defect and Atomic Binding

When nucleons are bound together into a nucleus , the mass which disappears is converted into energy and is known as the binding energy of the nucleus. Conversely, the same amount of energy would be required to break the nucleus into its constituent particles.

The difference between the measured mass M and the mass number A of a nuclide is called the mass defect.

$$\therefore \quad mass\ defect, \qquad \Delta m = (M - A)$$

The equivalent energy which is known as binding energy may be found by using the relation

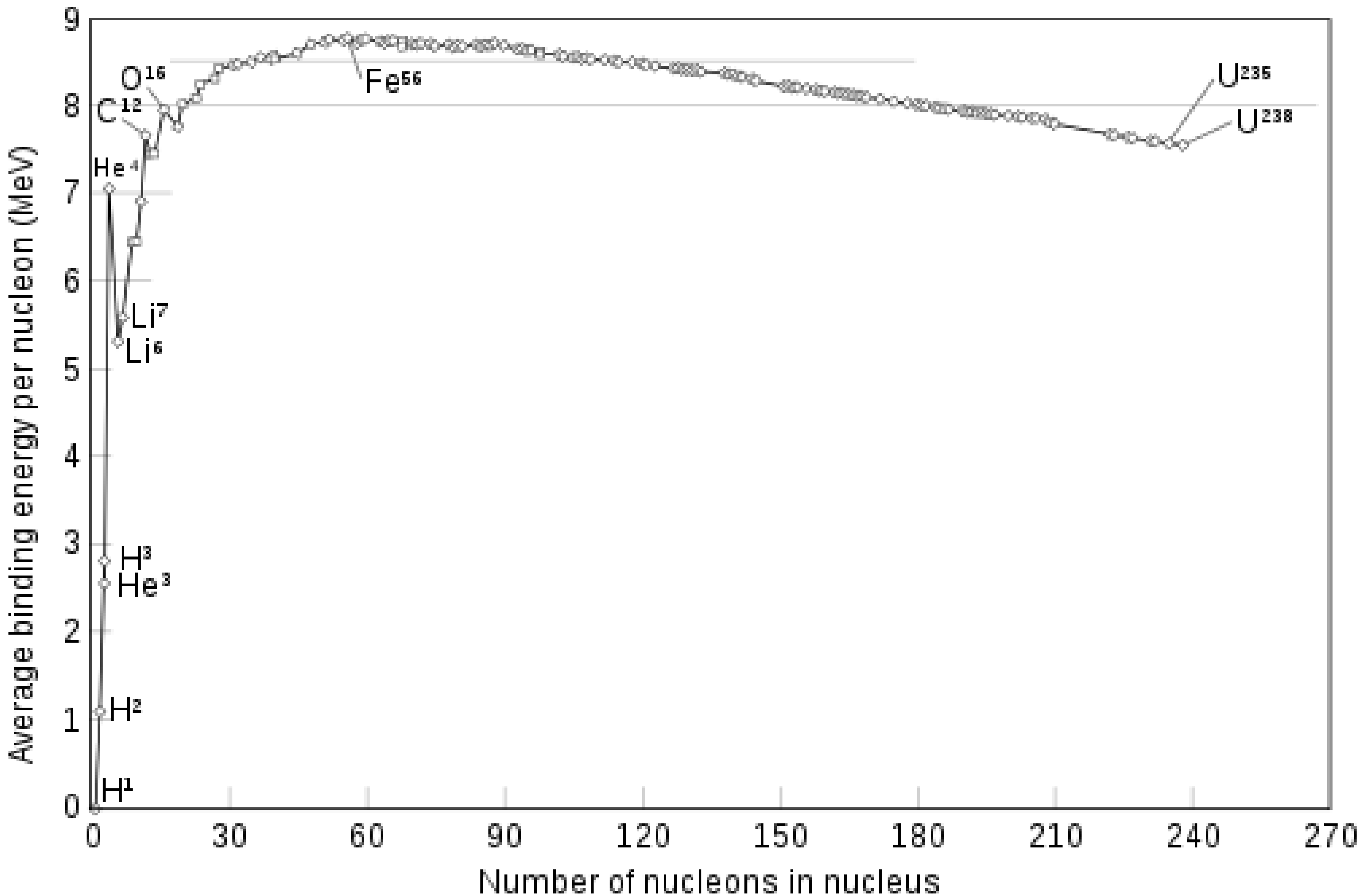
$$\Delta E = 931 \times \Delta m\ MeV$$

Accurate Expression for Mass Defect

$$True\ mass\ defect = Z.m_H + (A - Z)m_n - M$$

$$Binding\ Energy = 931[Z.m_H\,.(A - Z)m_n - M]$$

Variation of Binding Energy



Nuclear Force

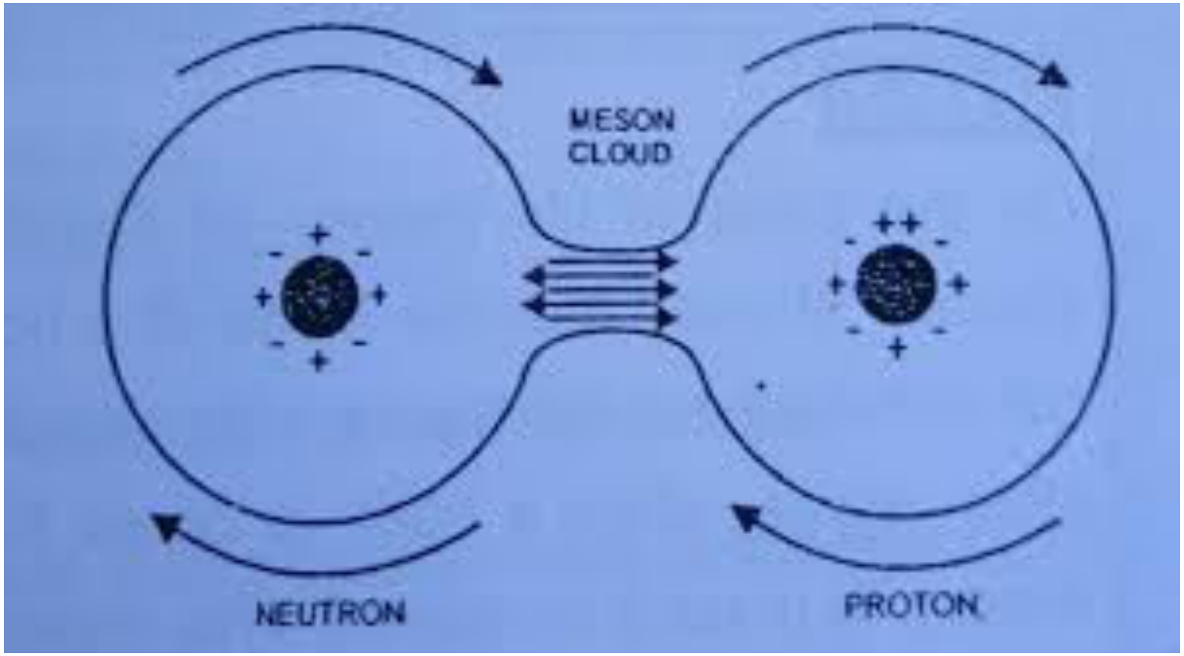
The nuclear force is the force between two or more nucleons. It is responsible for binding of protons and neutrons into atomic nuclei.

The force is powerfully attractive between nucleons at distances of about 1 femtometer (fm) between their centers, but rapidly decreases to insignificance at distances beyond about 2.5 fm.

At very short distances less than 0.7 fm, it becomes repulsive, and is responsible for the physical size of nuclei, since the nucleons can come no closer than the force allows.

At short distances (less than 1.7 fm or so), the nuclear force is stronger than the Coulomb force between protons; it thus overcomes the repulsion of protons inside the nucleus.

Meson Theory of Nuclear Forces



Radioactivity

The radiations emitted by the radioactive elements are found to consist of the following:

Alpha (α) rays or α-particles

Beta (β) rays or β -particles

ϒ-Rays or photons

Natural and Artificial Radioactivity

The natural radioactivity is that which is exhibited by elements as found in nature. It is always found in heavier elements in the periodic table.

However modern techniques of artificial transmutation of elements have made it possible to produce radioactivity in many other elements much lighter than those that occur in Nature. Such type of radioactivity is known as artificial or induced radioactivity.

But whatever its origin, the activity itself is always spontaneous.

Laws of Radioactive Disintegration

Radioactive disintegration is found to obey the following two laws:

Atoms of all radioactive elements undergo spontaneous disintegration to form fresh radioactive products with the emission of α, β and ϒ-rays.

The rate of radioactive disintegration i.e. the number of disintegration per second is not affected by environmental factors (like temperature, pressure and chemical combination etc.) but depends on the number of atoms of the original kind present at any time.

Suppose at the beginning of disintegration i.e. at t=0, the number of radioactive atoms present in a sample is N_o. As time passes, the number of the original atoms decreases due to continuous disintegration.

At any time t, let the number of atoms of the original kind be N. At this instant, the rate of disintegration (-dN/dt) which is called activity is proportional to N

$$-\frac{dN}{dt} \propto N$$

$$or \quad -\frac{dN}{dt} = \lambda N \qquad (1)$$

Where λ is the constant of proportionality and is known as the disintegration or decay constant or radioactive constant.

Rearranging the above equation, we get

$$\frac{dN}{N} = -\lambda dt$$

$$\therefore \quad \int_{N_o}^{N} \frac{dN}{N} = -\lambda \int_{0}^{t} dt$$

$$[\log_e N]_{N_o}^{N} = -\lambda [t]_0^t$$

$$\therefore \quad \log_e \frac{N}{N_o} = -\lambda t$$

$$or \quad \frac{N}{N_o} = e^{-\lambda t}$$

$$\therefore \quad N = N_o e^{-\lambda t} \qquad (2)$$

This decay equation may be used to fined the number of the atoms of the original kind still present at any time t.

If M_o is the original mass of the material and M its present mass, then

$$M = M_o e^{-\lambda t}$$

Radioactive Decay Constant

Eqn. (1) above may be written as

$$\lambda = \frac{-d\,N/d\,t}{N}$$

Hence radioactive constant may be defined as the ratio of the amount of the substance which disintegrates in a unit time to the amount of the substance present.

Suppose we put t=1/λ in eqn. (2) then the number of the original atoms present after this time is

$$N = N_o e^{-\lambda \times 1/\lambda}$$

$$= N_o e^{-1}$$

$$= \frac{N_o}{e} = \frac{N_o}{2.718}$$

$$N \cong 0.368 N_o$$

Hence, radioactive constant may also be defined as the reciprocal of the time during which the number of atoms of a radioactive substance falls to 37 percent of its original value.


I Thank you