Let radius of universe be R and age of universe be T_o. The galaxy at farthest region is receding from us with velocity v

$R = v/H_o$ $\quad$ $R = vT_o$

$\frac{v}{H_o} = vT_o$ $\quad$ $\therefore T_o = \frac{1}{H_o}$ $\quad$ $\therefore T_o = \frac{1}{2.4\times10^{-18}} = 14$ billion years.

NUCLEAR PHYSICS

Nuclear Physics deals with the study of atomic nuclei and their interactions especially in generations of nuclear energy.

Nuclear energy is energy that is released in significant amounts in processes involving nucleus.

$1u = 1/12$ mass of a neutral C-12 atom in its ground state.
$1u = 1.66\times10^{-27}$ kg (Atomic mass unit)
An isolated proton has mass 1.00727646677u and isolated neutron has mass 1.008665 u.

Isotopes are atoms of ~~same~~ element having same proton number but different neutron number. They have same chemical properties but different physical properties.

Einstein's mass-energy relation.

- Mass and energy are interconvertible
- Total mass and energy of a system remains constant.
- Mass converted to energy and vice-versa
- $E = mc^2$

$C + O_2 \longrightarrow CO_2 + energy$

mass of CO_2 < mass of carbon + oxygen cas some reactant mass is converted into energy.

~~Bind~~ O-16 has 8p and 8n

Binding energy $= \Delta m c^2$

$= (8 \times M_n + 8 \times m_p - M_{nucleus}) \times c^2$ (BE)

Binding energy per nucleon $= \dfrac{BE}{\text{no. of nucleons}} = \dfrac{BE}{16}$

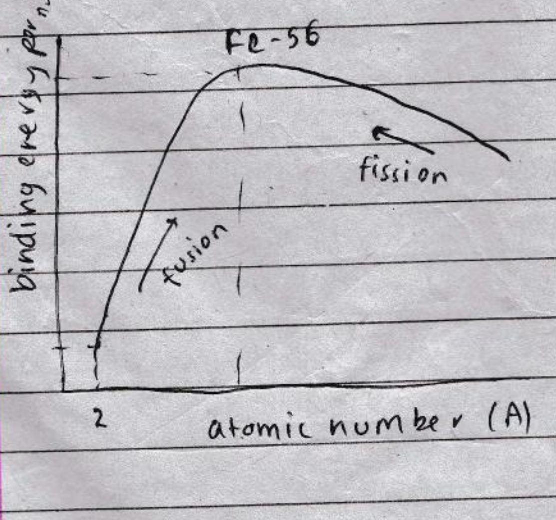
∴ 1u converts to 934 MeV of energy.

Binding energy is the min. external energy required to separate each ~~nu~~ nucleons from nucleus to infinity.

Strong nuclear force binds nucleons together and is greater than $p^+ - p^+$ repulsion.

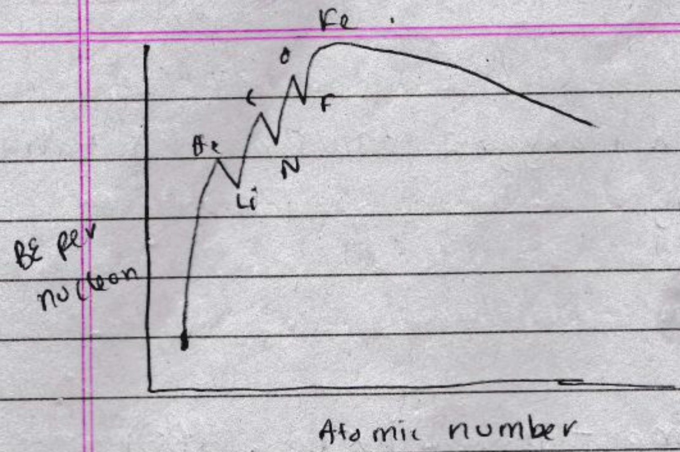
Iron has the maximum binding energy per nucleon.

Fe-56 - 8.72 MeV.



Hydrogen-1 has no binding energy as it is only one proton.
It's not on the graph.
For A > 80, binding energy per nucleon gradually decreases as ~~the~~ atom gets larger in size and ~~a~~ strong nuclear force only acts over small distances. ($1fm = 10^{-15} m$)

So, heavy nuclei have lesser stability.



He, C, and O have ~~h~~ peaks in graph as 2p, 2n, 3p, 3n and 4p, 4n, which is an incredibly stable nuclear ~~confogi~~ configuration.

Fission process is breaking of a heavy nuclei to a light nuclei.
Fusion process is fusing light nuclei to form a heavy nuclei.

NUCLEAR PHYSICS

→ Nuclear fission is a decay process in which an unstable nucleus splits into two fragments of comparable mass and binding energy per nucleon increases, which releas energy and makes nucleons stable.

$$_{0}^{1}n + _{92}^{235}U \longrightarrow _{92}^{236}U \longrightarrow _{56}^{141}Ba + _{36}^{92}Kr + 3\,_{0}^{1}n$$

The $3\,_{0}^{1}n$ excite other $_{92}^{235}U$ nuclei and it causes a chain reaction liberating energy.

Uncontrolled chain reaction is the mother of destruction while controlled ones give energy in reactors.

Only low energy neutrons (thermal neutrons) can be captured in this way.

→ Nuclear fusion is a process of building up nuclei by bringing together individual protons and neutrons, or building larg nuclei by combining small nuclei.

* Total binding energy of fused nuclei is larger than the sum of total binding energy of sum of component nucle

The only way to make them fuse ~~to~~ is to bring them close together, within a few 10^{-15} m so that the short range strong nuclear force can attract them to a larger nucleus.

As the nuclei have +ve charges that repel each other enorm at small distances, so it requires high velocity of nucle random motion which can be achieved by increasing temp to about 10^{9} K.

It requires high temp, pressure and density.

Date
Page

Two protons fuse together to form a deuterium nuclei positron and a neutrino along with 2.2 MeV of energy.
The deuterim fuses with a proton to form He-3 and releases 5.5 MeV of energy is released.

$${}^{1}_{1}p + {}^{1}_{1}p \longrightarrow {}^{2}_{1}H + {}^{0}_{+1}e + \nu \qquad {}^{2}_{1}H + {}^{1}_{1}p \longrightarrow {}^{3}_{2}He + \gamma$$

$${}^{3}_{2}He + {}^{3}_{2}He \longrightarrow {}^{4}_{2}He + {}^{1}_{1}H + {}^{1}_{1}H + \gamma$$ ← 12.9 MeV energy released.

$${}4\,{}^{1}_{1}H \longrightarrow {}^{4}_{2}He + 2\,{}^{0}_{+1}\beta + 2\nu + \gamma$$ ← were ν is electron neutrino.

The $2\,{}^{1}_{1}H$ produced again repeat the cycle. This cycle is called proton-proton cycle or hydrogen-burning cycle.

Radioactive decay

The spontaneous emission of particles and energy from an unstable nucleus is radioactive decay.
This is a naturally occuring process in which the nucleus of an unstable atom spontaneously change into a different nuclear configuration by the emission of different types of radiation. (alpha, beta, gamma)

Many unstable atoms occur in nature and such radioactivity is called natural radioactivity. (A > 209, Polonium onwards)

The nuclei that decays is parent nuclei and the nuclei formed is daughter nuclei. The daughter nuclei may also be unstable and undergoes further disintegration.

The nucleons are bound together by strong nuclear force which overcomes electrostatic force between protons.
Nuclei ~~a~~ with equal no. of protons and neutrons are highly stable.
For instance C-12 is stable but not C-14

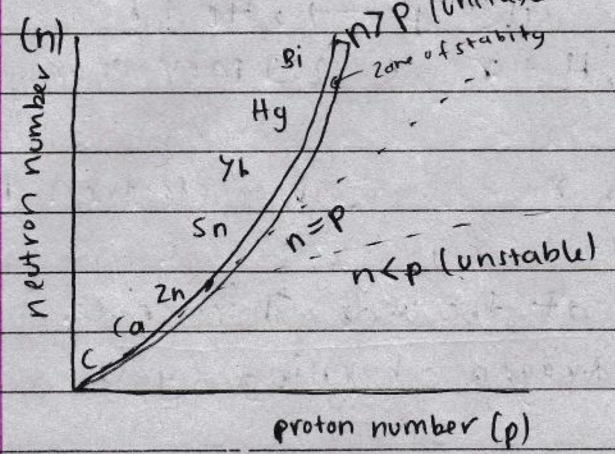


Fig. Stability line

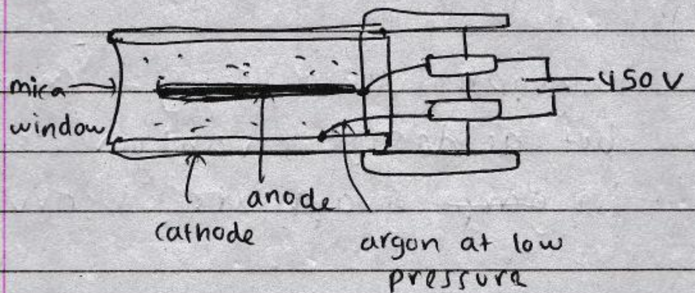
~~B~~ The ~~eter~~ atoms like Ca, C lie on the n = p line as their n = p and are much more stable.
Zone of stability has tendency to become stable.

When n>p, n converts to p (unstable)
when n<p, p converts to n (unstable)
~~Heavier~~ Upto Bismuth, beta decay occurs to become stable however heavier nuclei like U, become stable due to α-decay.

Radium-226 → emits α, β, γ
Americium-241 → emits α mostly
Cobalt-60 → emits γ mostly

Geiger-Muller (G-M) Tube

Very sensitive type of ionization chamber which can detect a single ionization event.



When a ionizing radiation enters, the argon ionizes and a pd arises between cathode and anode.

Mica window is a very thin window such that only radiation can pass ~~from~~ through it.

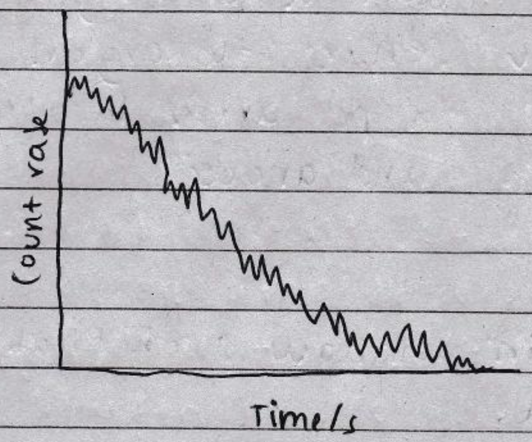
They are used to:

- Detect radioactive rocks and minerals in mines
- For Hazard management of radioactive waste.
- ~~To~~ check for radioactive contamination of clothes and shoes
- Check possible leakage or exposure to x-rays in a medical facility.

The counts / clicks from a G-M tube do not show a regular pattern i.e the clicks are random. This suggests that the radioactive nuclei themselves also decay in a random manner. Thus decay is a random and spontaneous process.

Random : we can't predict when a particular nucleus in a sample will decay or which one will decay next.
each nucleus within a sample has the same chance of decaying per unit time.

Spontaneous: the decay of nuclei is not affected by presence of other nuclei in sample and/or the chemical rxn or external factors such as temp. or pressure



The graph follows a $y = 1/n$ nature but as decay is random, spikes in ~~garp~~ graph are observed.

Count rate is the no. of nuclei decayed per unit time.

The decay of a specific nucleus is unpredictable and can happen at any time. However, you can accurately predict how many nuclei in a sample will decay in a given time. Successive half-lives are constant for decay.

The decay constant (λ) is the probability of any given nucleus decaying per unit time. SI unit is s^{-1}. This is a property of a particular isotope.

For instance, radium 226 has a λ of $1.4 \times 10^{-11} s^{-1}$ which means each individual nucleus of radium-226 has a prob. of 1.4×10^{-11} of decaying in 1s.
The greater the decay constant, faster an isotope will decay.

PTO-1

The activity (A) or decay rate is the no. of nuclei in a sample that decay per unit time. $A = dN/dt$.
It is usually measured in decays per second (disintegration / second or Becquerel (Bq).
$1 Bq = 1$ decay per second.
~~It was~~ is also measured in Curie (Ci)
$1 Ci = 3.7 \times 10^{10}$ Bq (amount of decay that occurs in 1gm of Radium per second.)
A highly radioactive sample has many decays per second.

$A = \lambda N$
where N is no. of radioactive nuclei

Although we can't predict or influence when a particular nucleus will decay, we know that the no. of nuclei that will decay per second is proportional to the no. of nuclei in sample not yet decayed.
The rate of disintegration of a given nuclide at any time is directly proportional to no. of nuclei N of the nuclides present at that time.

$\frac{dN}{dt} \propto N$ $\therefore \frac{dN}{dt} = -A$

$\frac{dN}{dt} = -\lambda N$ (-ve sign indicates that N is decreasing as t is increasing.)

Activity (A) is a variable quantity and depends on N.

NUCLEAR PHYSICS...

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

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

or, $$\int \frac{dN}{N} = -\lambda \int dt$$

$\therefore$ $\ln N = -\lambda t + C$

Initially when $t = 0$, $N = N_0$

$\therefore C = \ln N_0$

$\ln N = -\lambda t + \ln N_0$

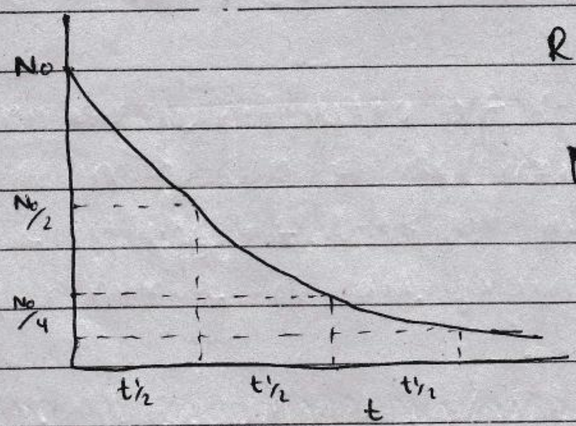
or, $\ln N/N_0 = -\lambda t$

or, $N/N_0 = e^{-\lambda t}$

$\therefore N = N_0 e^{-\lambda t}$ → decay law

This decay law says that a radioactive substance decays exponentially.

N is no. of undecayed ~~sample~~ no. of nuclei left in sample.



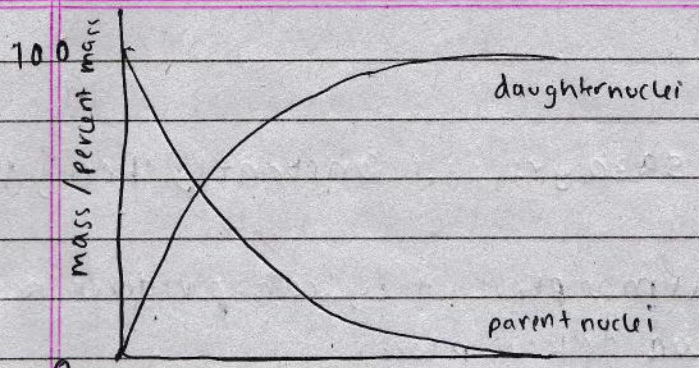
Rate of decrease is fast at beginning and very slow later.

The successive half lives are the same (equal.)

As $A \propto N$, $A = A_0 e^{-\lambda t}$

Whilst using GM tube, we first measure count rate of laboratory because there is cosmic radiation as well. Then we measure of radioactive sample and subtract lab count rate. If count rate is R, then.

$R = R_0 e^{-\lambda t}$ (Since $R = KA$ where A is activity and K is a constant



$N = N_0 e^{-\lambda t}$

If $t = t_{1/2}$ $N = \frac{1}{2} N_0$

or, $N_0/2 = N_0 e^{-\lambda t_{1/2}}$

or, $1/2 = e^{-\lambda t_{1/2}}$

or, $\ln 1/2 = -\lambda t_{1/2}$

$\therefore t_{1/2} = \dfrac{0.693}{\lambda}$ //

Strontium-90 has half life of 29 yrs and a school source has a mass of 0.1 μg.

$\therefore \lambda = \dfrac{0.693}{29 \times 365 \times 24 \times 3600} = 7.58 \times 10^{-10}\ s^{-1} \approx 7.6 \times 10^{-10}\ s^{-1}$

How much will remain after 70 yrs

$m = m_0 e^{-\lambda t}$

or, $m = 0.1 \times e^{-7.6 \times 10^{-10} \times 70 \times 24 \times 365 \times 3600}$

$\therefore m = 0.019\ \mu g$ is left after 70 years.

A source has decayed to $1/128^{th}$ of its initial activity after 50 days. Find half-life.

$\dfrac{1}{128} A_0 = A_0 e^{-\lambda \times 50 \times 24 \times 3600}$ $\quad t_{1/2} = \dfrac{0.693}{\lambda} = 7.1$ days //

$\therefore \lambda = 1.12 \times 10^{-6}\ s^{-1}$

Carbon Dating

→ C-14, with a half life of 5730 yrs, is constantly being formed in upper atmosphere

→ When cosmic rays enter atmosphere, they can produce neutron. The nuclear reaction shown takes place:

$^{14}_{7}N + ^{1}_{0}n \rightarrow ^{14}_{6}C + ^{1}_{1}H$

→ This is a natural transmutation.

→ C-14 reacts with oxygen and forms $^{14}_{6}CO_2$, which is absorbed by plants during photosynthesis.

→ The plants are eaten by animals which is eaten by other animals. However, once the being dies, no more radioactive C-14 is taken in. and the percentage in the remains start to decrease due to radioactive decay.

this means, if ratio of C-14 to C-12 is known, the age of the specimen can be determined.

The activity of C-14 in living materials is about 15 counts per minute for each grain of specimen.

An old wooden tool is found to contain 6% of $^{14}_{6}C$ than that of an equal mass of fresh wood. How old is the tool!

$t_{1/2} = 5730$ yrs.

$m = m_0 e^{-\lambda t}$

or, $0.06\, m_0 = m_0 e^{\cancel{5730 \times 24 \times 365 \times 24 \times 3600 \times t}\ \frac{-0.693}{5730 \times 24 \times 365 \times 3600} \times t}$

∴ $t = 23262$ yrs.