		Location	Charge in C	Relative charge	Mass	Relative Mass
Proton	p	nucleus	$+1.6\times10^{-19}$	+1	$1.67\times10^{-2?}$	1
Neutron	n	nucleus	0	0	1.68×10^{-27}	1
Electron	e	orbit nucleus	-1.6×10^{-19}	-1	9.1×10^{-31}	1/2000

$^{4}_{2}He$ (atomic mass → 4, atomic no. → 2)

Atomic mass = No. of protons + neutrons

Atomic no = No of protons (diff atomic no => different element)

ISOTOPES: Same atomic no. different mass no
same no. of protons, different no. neutrons

C^{6}_{14}, C^{6}_{12}

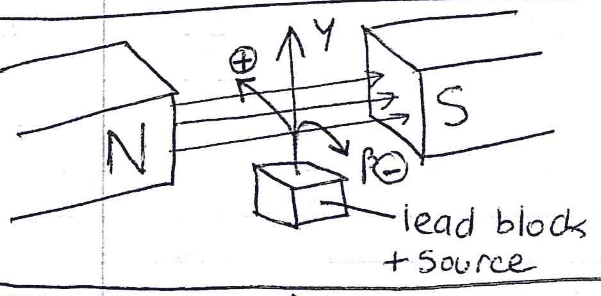
RADIO ACTIVITY: Discovered by Becquerel by accident - a uranium salt made a photographic plate go black even though plate was in dark wrapper.

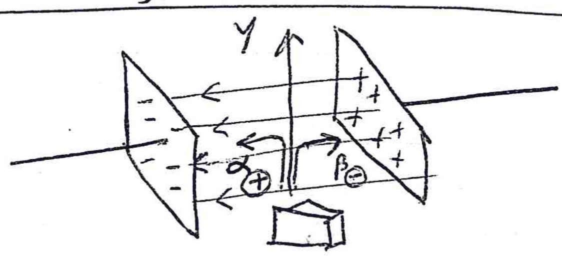
due to unstable isotopes getting rid of energy

α-radiation - Alpha radiation = fast moving Helium Nuclei (2P, 2N) (+)

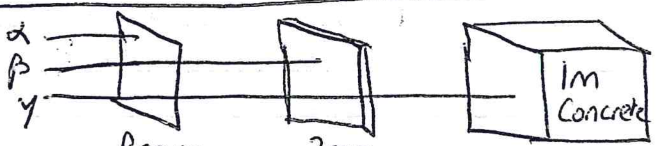
β-radiation - Hi speed electrons (−) or positrons (+)

γ-radiation - V. High frequency Electromagnetic radiation (0)



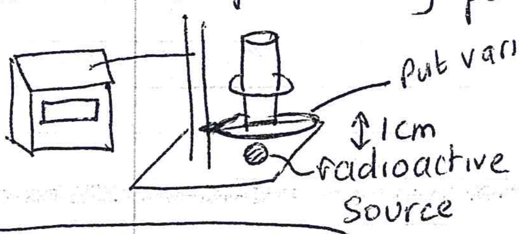


Penetration



Ionization α = MOST
β = less than α
γ = least (use electroscope de...)

Demonstrate penetrating power



Put various materials paper, aluminium, lead between GM tube and source
vary source (α,β,γ)

- charge E.S ⊕ or ⊖
- leaf diverge
- bring source near
- radiation ionizes the charge (+ve or −ve) so leaf collapses

α: W^{x}_{y} (mass, atomic no.) → Z^{x-4}_{y-2} + α^{4}_{2}

β^-: W^{x}_{y} → V^{x}_{y+1} + β^-

1 neutron → 1 proton + $\bar{e}$ + $\bar{\nu}$

$^{1}_{0}n \rightarrow {}^{1}_{1}p + {}^{0}_{-1}e$

β^+: W^{x}_{y} → U^{x}_{y-1} + β^+

1 proton → 1 neutron + e^+ + ν = $^{1}_{1}p \rightarrow {}^{1}_{0}n + e^{0}_{+1}$

p 352 Q 7, 8, 9, 13

Ex p350

ACTIVITY of radioactive substance = no. of nucleii decaying per sec.

$(A = dN/dt)$

Law of radioactive decay : No of nuclei decaying per sec $\propto$ no. of nuclei undecayed : $\frac{dN}{dt} = -\lambda N$ or $A = -\lambda N$

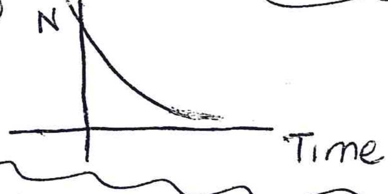
$\lambda = \frac{dN/dt}{N}$ or $\lambda = \frac{A}{N}$; Unit of Activity $= \frac{dN}{dt}$ 1 Bq = 1 deca

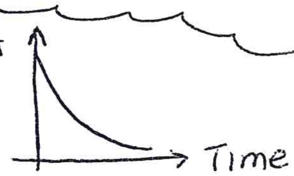
Half life = time for half of the undecayed atoms to decay

Half life = time for $A \to \frac{A}{2}$ also since $A = \lambda N$ if $N \to \frac{N}{2}$

$A \to \frac{\lambda N}{2} = \frac{A}{2}$

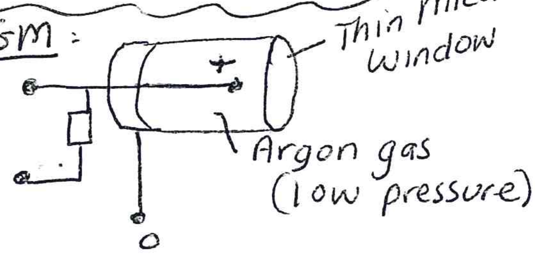
$T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$





G.M. tube : Detects radiation
Solid State Detector : Detects radiation

GM :



- Radiation goes thro mica window into gas
- Radiation ionises some argon atoms freeing up $\bar{e}$
- $\bar{e}$ pick up high speed in strong E field near anode.
- they collide with more atoms creating more $\bar{e}$
- an avalanche of $\bar{e}$ is created
- reaches anode a λ a 'pulse' of current flows in circuit
- no of pulses is counted on a ratemeter (electronic counter)

Most non radioactive isotopes can be made radioactive by bombarding them with neutrons → Artificial radioactive isotopes used in medicine/industry :

Uses of radioisotopes : Medical Imaging, Medical therapy (radiation kills cancer cells)

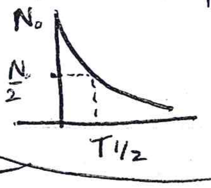
Food irradiation to sterilise it, Radioactive tracers, Carbon dating thickness, smoke detectors : small amount of radioactive source ionizes air near it. This causes a current to flow. Smoke particles interfere with current by sticking to ionised molecules → current drop. Drop in current triggers alarm.

look at Examples pg 355

Activity (A) = no of Nuclei decaying / sec. Becquerel (Bq)

Law of Radioactive decay: $A = \lambda N$
λ = decay Constant, N = No of undecayed nuclei

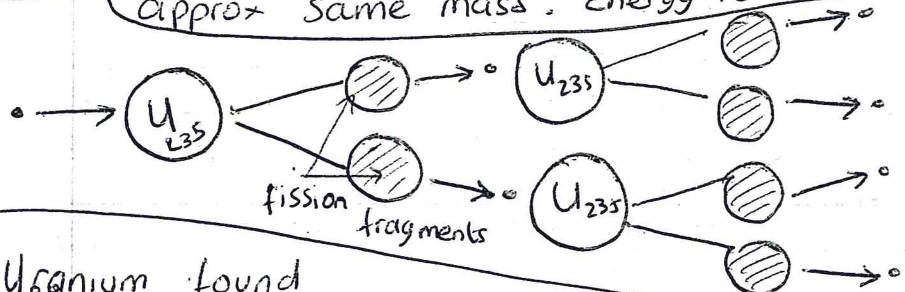
Half life = time taken for half of the undecayed atoms to undergo decay.



After n halflives $1/2^n$ of sample remains

Do Q1, 2, 4, 12, 15

Fission: Bombard large nucleus with neutrons (eg U^{235}). Don't always get same daughter nuclei but they are always approx same mass. Energy released.



fission chain reaction } fission fragment HIGHLY Radioactive

1.) Uranium found naturally is about 0.7% U_{235} and 99.3% U_{238}

2.) U_{235} is much more likely to undergo fission if bombarded with <u>slow</u> neutrons

3.) Most of energy released goes to KE of fragments + fast moving neutron

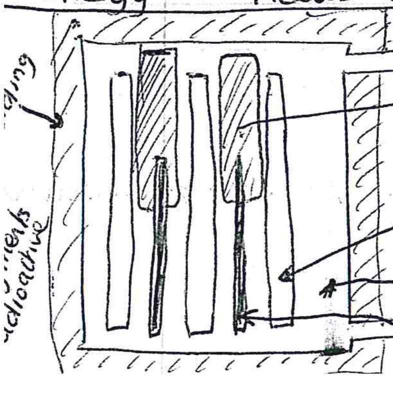
4.) If U_{235} is $\geq$ Critical Size then a chain reaction will occur (~ tennis ball)

5.) Pu_{239} Plutonium also undergoes fission with fast & slow neutrons

Pu_{239} and Ur_{235} are fissile (undergo fission with fast/slow moving neutrons

Atomic bomb (fission bomb) 2 pieces of fissile material below critical mass are brought together suddenly → chain reaction with enormous release of energy.

Nuclear Reactor (Fission reactor) Energy is released in controlled rate
Energy → heats water → steam → turn turbine

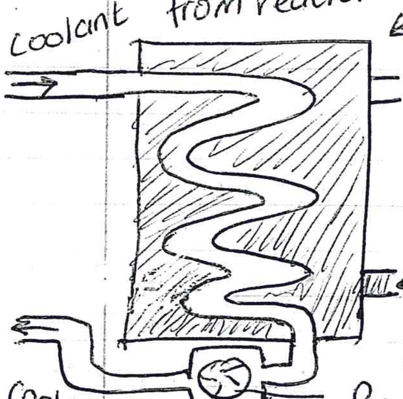


Control rods (steel with Cadium or Boron) absorb neutrons – slows reaction. In fully they stop reaction (lowered to reduce rate, lifted to increase)

moderator (Graphite or heavy water) Slows neutrons to produce fission rather than be absorbed by U_{238}

coolant absorbs heat and carries to heat exchanger

Fuel = Uranium slightly enriched with U_{235}



Environmental Impacts:
- mining Uranium ore releases gas (lung cancer)
- area around mine can be radioactive
- Can be serious Consequences if there are accidents in reactors (Chernobyl 1986, Fukushima 2011
- Removal & treatment of used fuel rods → they are reprocessed but transport is difficult/dangerous
- Radioactive waste - waste products have to be stored for 1000's years - problem for future generations

(Fusion) Two small nuclei join together to form a larger nucleus and energy is given out in the process

$$^{2}_{1}H + ^{2}_{1}H \rightarrow ^{3}_{2}He + ^{1}_{0}n$$

Deuterium; Helium + neutron

$$^{2}_{1}H + ^{3}_{1}H \rightarrow ^{4}_{2}He + ^{1}_{0}n$$

Tritium

(Fusion)
- need a lot of energy to overcome the Coulomb repulsion between atoms (then strong force will hold them together)
- This energy is created by heating the atoms to V.V.V Hi temps (10^{8} K
- Once fusion starts though, the energy that is released can keep the reaction going.
- no one has, to date achieved a sustained controlled reaction
- Hydrogen bomb is an uncontrolled fusion reaction. A small fission bomb produces the hi temps needed for the atoms to fuse causing energy release.
- Nuclear fusion in interior of Sun is main source of Sun's energy In a series of reactions Hydrogen fuses to form Helium + energy

(FUSION ADVANTAGES)
- much less radioactive waste produced
- no possibility of an uncontrolled runaway reaction occurring
- fuel (deuterium) is readily available in oceans - cheap to extract.

α, β, γ are ionizing radiation.

- All Ionizing radiation is harmful to human body. Damage depends on
  - type of radiation,
  - activity of source,
  - length of exposure,
  - type of tissue irradiated

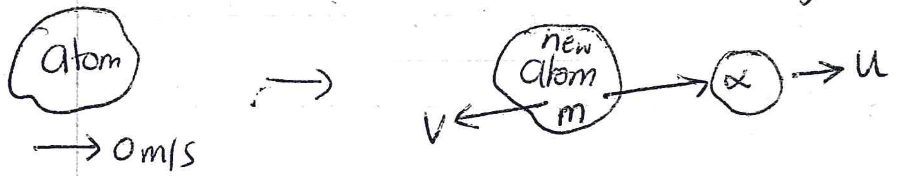
Causes: skin burns, cataracts, leukaemia, other cancers, genetic defects in children of parents exposed, death

ions / radicals produced disrupt normal operation of cell.

- must minimize exposure – there is background radiation due to cosmic rays from outer space, rocks in Earths crust contain traces of Uranium & decay product Radon gas. In Ireland regions of granite rock release Radon gas which can cause lung cancer.
Also there are manmade radioactive materials.

Pg 363 P4; 4, 6.

* Rem in nuclear reactions: mass/energy, momentum, charge are conserved.

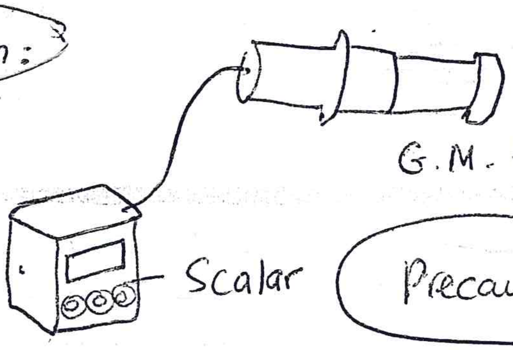


$$m_{new\,atom} V = -m_\alpha u$$

because Mom before = 0, Mom after = mv + mu

$$0 = mv + mu$$
$$mv = -mu$$

To measure background radiation:



- Set up as shown
- Switch on ratemeter/scaler
- Set high voltage supply to lowest value & allow tube to warm up
- set tube to operating voltage
- measure background rate (no of counts/100s)
-

Precautions

- Minimise time spent using sources
- use proper protective clothing
- Shield sources from you
- Don't eat/drink - use tongs

Mass ≡ Energy (Mass equivalent to energy) $E = mc^2$

1905 Einstein's Special Theory of relativity, proposed that mass is a form of energy. Mass can be converted into energy and energy can be converted into mass. Petrol + O_2 in container (sealed) react to give out energy ⇒ mass container before > mass after (tiny diff)

$E = mc^2$, $E = m(3 \times 10^8)^2$ $\quad m = \frac{E}{(3\times10^8)^2} = \frac{E}{9\times10^{16}}$

So, unless Energy given out is <u>massive</u> the change in mass is <u>tiny</u>.

1g of matter was converted into enereg in atomic bomb Hiroshima

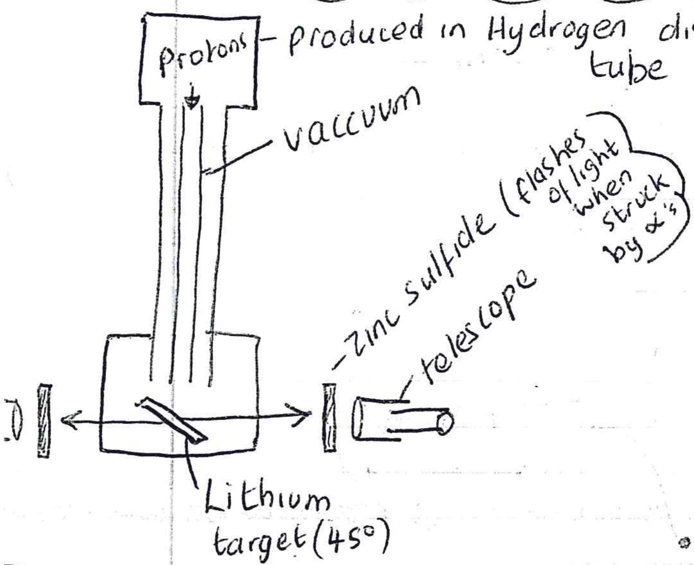
Fusion : mass of individual atoms > mass of combination so combining them means energy is given out (mass is 'lost' as energy)

Fission: mass of combination < mass of individual so splitting atoms means energy is given out (mass is 'lost' as energy)

Examples p363 | Cockcroft & Walton ← Irish | 1932

1st splitting of a nucleus by <u>artificially</u> accelerated particles (protons H^1_1)

$$^7_3Li + ^1_1H \rightarrow ^4_2He + ^4_2He + \text{energy}$$



- transformers, rectifiers, Capacitors to produce VH D.C. Voltage to accelerate protons
- protons struck Lithium target
- α particles emitted @ right angles & caused Zinc sulfide screen to flash - seen with μscope.
- For conservation of momentum the α particles had to be emitted in opp direction with same speed.

- Proton had energy of 1MeV, KE's of Helium nucleii = 17.3MeV ∴ <u>gain</u> in energy in exp - So it was calculated and found to be **1st experimental verification of $E=mc^2$**

NOBEL PRIZE 1951