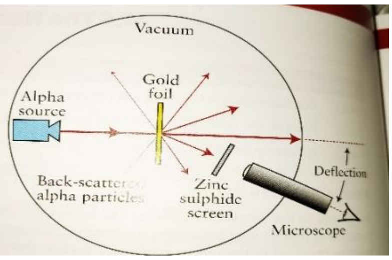
The Nucleus and Nuclear Decay

Atomic Structure: JJ Thompson developed Kelvin's idea into plum pudding model (+ charged sphere w/ electrons inside)

If this model was correct there would be no back scattering and a small no. deflected

Rutherford, Marsden & Geiger Experiment - α particles in vacuum to avoid deflection by collisions with air molecules, incident on gold foil, detected by scintillations produced on hitting fluorescent screen. Microscope moved to position, angle & no. flashes measures, microscope moved to new angle and repeat.



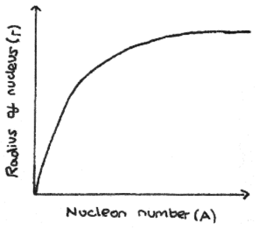
1. most particles passed though (didn't come close enough to any repulsive charge) therefore atom mostly empty space

2. Particles + charged & deflected therefore nucleus + charged

3. 1/8000 scattered back therefore nucleus much more massive than particle (factor 50)

Edge of nucleus doesn't have sharp edge

$r = r_0 A^{\frac{1}{3}}$,$r_0 = 1.2x10^{-15}$m, $V = \frac{4\pi r^3}{3} = \frac{4\pi {r_0}^3 A}{3}$, M=Am, $\rho = \frac{M}{V} = \frac{3Am}{4\pi {r_0}^3 A} = \frac{3m}{4\pi {r_0}^3}$, $r_0 =$ $radius\ of\ nucleon$



Ratio of 10^{15} between atomic and nuclear density as atomic diameter $\sim 10 -^{10}$ and volume $\sim 10 -^{30}$, whereas nucleus diameter $\sim 10 -^{15}$ and volume $\sim 10 -^{45}$

Nucleons (protons & neutrons) held together by strong interaction (stronger than repulsion between nucleons). Isotopes – nuclei w/ same no. protons but differing no. neutrons

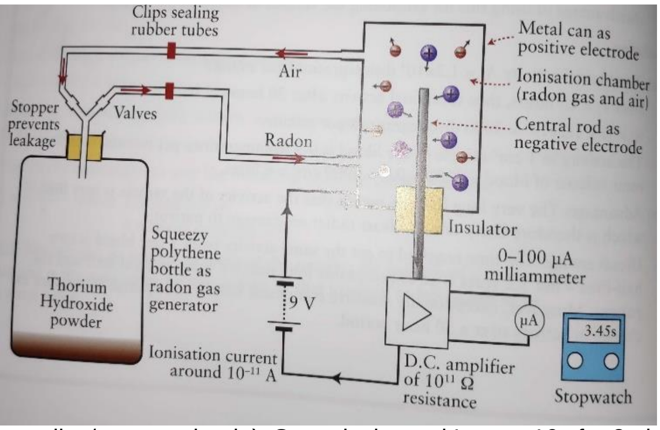
${}^A_Z X$, A: mass no. (no. nucleons), Z: atomic no. (no. protons)

Radioactive decay – unstable isotopes disintegrate spontaneously to a more stable nucleus with the release of α, β, or γ radiation. 1Bq = 1 disintegration/sec

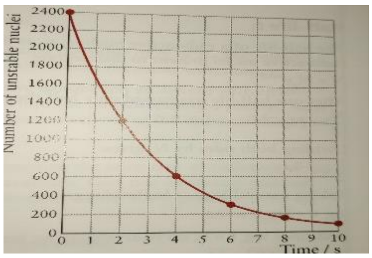
	Charge	Penetration	Ionization	${}^A_Z X$ →
α	+	Low (4cm air)	High	${}^{A-4}_{Z-2}Y + {}^4_2 He$
β	-	Medium (meters air)	Medium	${}_{Z+1}^{A}Y + {}^{0}_{-1}e$
γ	no	High	Low	${}^A_Z X + \gamma$

α is slow (5% c) He nucleus, E loss by ionization, stopped by paper

Ionization – electrically neutral atoms convert to ions as decay particle causes electron ejection from atom, **Ion-Pair**: +&- ion produced together. **Decay** unaffected by temp, chem reactions etc



$N = N_0 e^{-\lambda t}$, Rate of decay directly proportional to no. unstable nuclei, A = -λN, $decay\ const. =$ $fraction\ unstable\ nuclei\ that\ decay/sec$, $t_{\frac{1}{2}}$ = time for half nuclei to disintegrate/ activity to fall to half original = 0.693/λ from $\frac{N_0}{2} = N_0 e^{-\lambda t_{\frac{1}{2}}}$, Longer $t_{\frac{1}{2}}$ means low A so less radiation

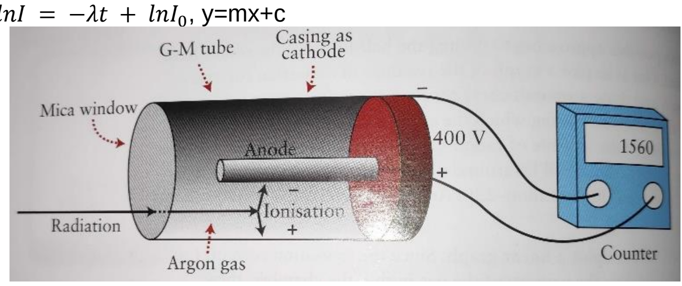


Why consider $t_{\frac{1}{2}}$ when source used for medical imaging: must be long enough to remain in bloodstream and be carries around body for detection. Must be short enough for minimal exposure

Finding $t_{\frac{1}{2}}$ w/ ionization chamber Adjust amplifier, fill chamber w/ gas (release clips/squeeze bottle), Start clock, read I every 10s for 3min

Ionization current directly proportional to no. & activity of gas atoms, $I = I_0 e^{-\lambda t}$, $lnI = -\lambda t + lnI_0$, y=mx+c

Finding $t_{\frac{1}{2}}$ w/ counter



Correct for background radiation (avg over 30min)

Protactinium-234 source from U-238 compound in bottle

Reading in counts/ min from GM tube and ratemeter

Characteristic of isotope that makes it suitable for exp: half life between 50s and 6 hrs (roughly), short half life

Plot count rate/ t, find t to half, repat+avg, or plot ln (corrected count rate) / t, grad = - λ, safety: shielding, distance, duration