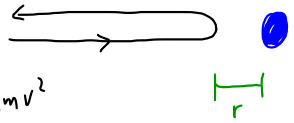
B2 - Nuclear Physics

1. Radius of nucleus to be estimated via particle scattering (i.e. Gold Foil → Geiger-Marsden Exp)
   - use conservation of energy for determining closest-approach distances.

$E_K = 0 \qquad E_p = \dfrac{k2eZe}{r}$

α particle   nucleus

alpha particle



$E_K = \frac{1}{2}mv^2$

$E_p = 0$

This gives an upper limit for the radius of the nucleus

2. Bainbridge mass spectrometer (see Topic 6)
   - charged particles deflected in a magnetic field
   - a way to sort isotopes.

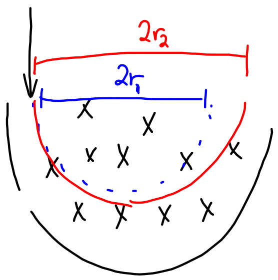
atom → ionized (ionization chamber) → velocity selector $\left(v = \frac{E}{B}\right)$ ← electric field strength → detection chamber

$F_c = F_{mag}$

$\frac{mv^2}{r} = qvB$

$r = \frac{mv^2}{qvB}$

$r = \frac{mv}{qB}$



$\frac{r_1}{r_2} = \frac{m_1}{m_2}$

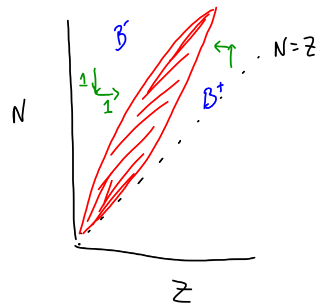
$2(r_2 - r_1) = \frac{2\overbrace{(m_2 - m_1)}^{\Delta m}v}{qB}$

Difference in r indicate diff. in isotope masses.

3. Evidence for existence of nuclear energy levels.
   - α particles + γ rays have discrete energies.
   - β^- particles have a continuous range of energies.
   - $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mE}}$ => discrete values of λ for discrete energies.

deBroglie wavelength

4. β^+ decay. => recall your stability curve (TOPIC 7)



<u>β- minus decay</u>

$$n_0^1 \rightarrow p_1^1 + e_{-1}^0 + \bar{\nu}$$

$$C_6^{14} \rightarrow N_7^{14} + e_{-1}^0 + \bar{\nu}$$

one less neutron
one more proton
(converts a neutron to a proton)
(brings it closer to stability band)

<u>β- positive Decay</u>

proton decays into a positron (β^+) and a neutrino

positron (β^+) AKA antielectron

$$P_1^1 \rightarrow n_0^1 + e_1^0 + \nu$$

← neutrino

$$F_9^{18} \rightarrow O_8^{18} + e_1^0 + \nu$$

← discrete energy together

has one more neutron and one less proton bringing it closer to the stability band

What happens when an electron + positron come together?

$$e_{-1}^0 + e_1^0 \rightarrow ??$$

The electron (β^-) and the positron (β^+) annihilate each other.

producing two γ-ray photons going in opposite directions.

$\beta^- + \bar{\nu}$ => have discrete energies <u>together</u>
each has a continuous energy

$\beta^+ + \nu$ => have discrete energies together
each has a continuous energy.

5. Radioactive Decay Law + decay constant

↓ probability of decay of a nucleus per unit time.

$$\frac{\Delta N}{\Delta t} \propto -N$$

$$\frac{\Delta N}{\Delta t} = -\lambda N$$ where λ is the decay constant.

* $N = N_0 e^{-\lambda t}$ — number of nuclei

$A = A_0 e^{-\lambda t}$ — activity (rate at which it decays)

* $A = -\frac{\Delta N}{\Delta t}$

* $A = \lambda N$ — activity

where $A_0 = \lambda N_0$

* $A = \underbrace{\lambda N_0}_{A_0} e^{-\lambda t}$ * data booklet.

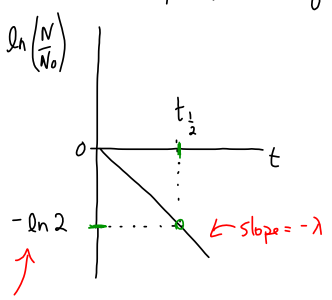
$$N = N_0 e^{-\lambda t}$$

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

$$\ln\left(\frac{N}{N_0}\right) = -\lambda t$$

$$y = mx + b$$

A plot of $\ln\left(\frac{N}{N_0}\right)$ vs t is linear with a slope of $-\lambda$ and a y-intercept of zero.



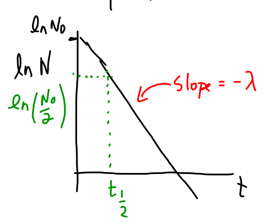
$t_{\frac{1}{2}}$ is when $\frac{N}{N_0} = \frac{1}{2}$ so $\ln\left(\frac{1}{2}\right) = \ln 2^{-1} = -\ln 2$

Alternatively: $N = N_0 e^{-\lambda t}$ $\quad \ln\left(e^{-\lambda t}\right)$

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

$$y = b + mx$$

A graph of $\ln N$ $(\ln A)$ vs t will be linear with a slope of $-\lambda$ and a y-intercept of $\ln N_0$ $(\ln A_0)$.



6. Derive the relationship between the decay constant and half-life.

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

at $t_{\frac{1}{2}}$, $N = \frac{N_0}{2}$

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

$$\frac{1}{2} = e^{-\lambda t_{\frac{1}{2}}}$$

$$\ln\left(\frac{1}{2}\right) = -\lambda t_{\frac{1}{2}}$$

$$\ln(2^{-1}) = -\lambda t_{\frac{1}{2}}$$

$$-\ln 2 = -\lambda t_{\frac{1}{2}}$$

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

7. Methods for measuring half-lives

8. Problems involving half-life.