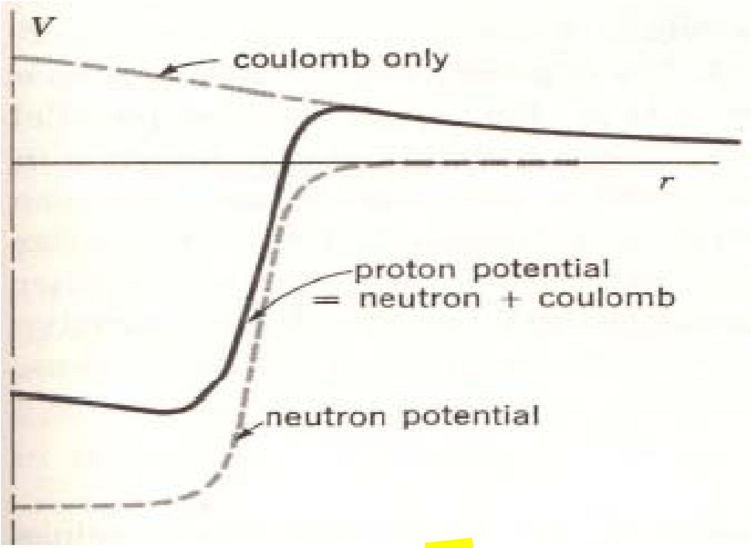
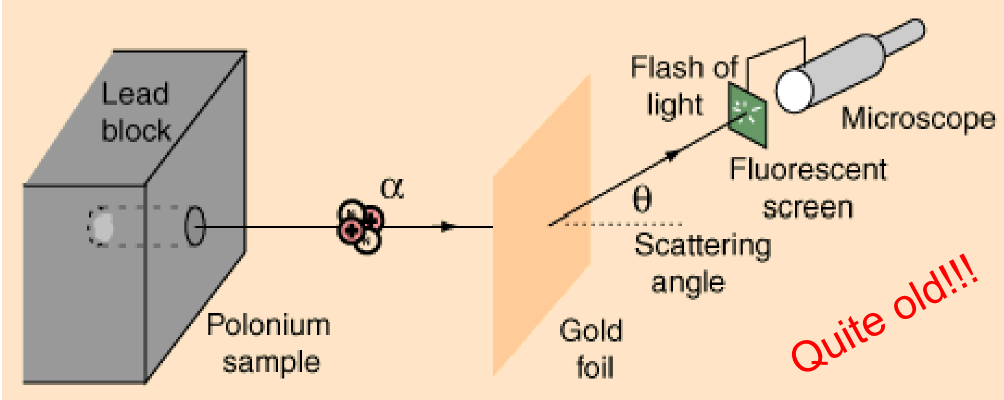
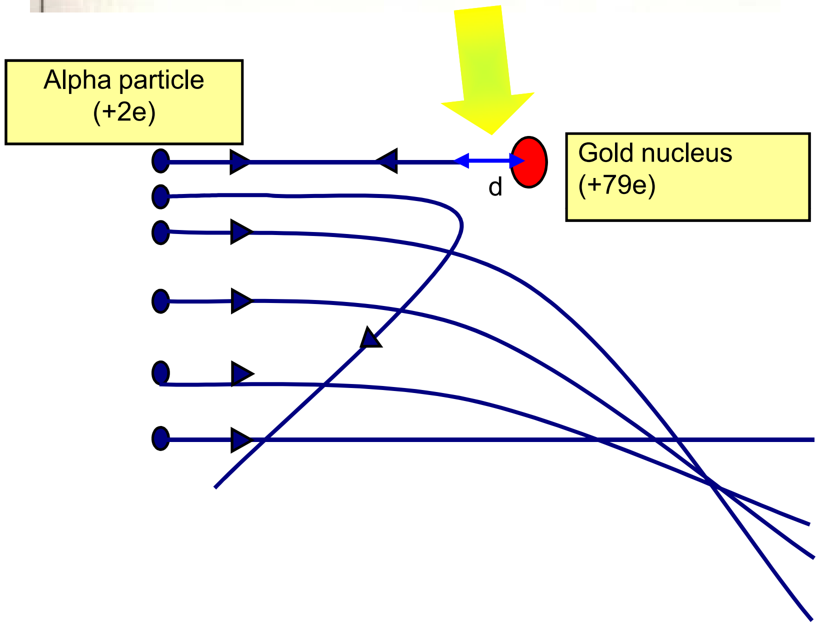
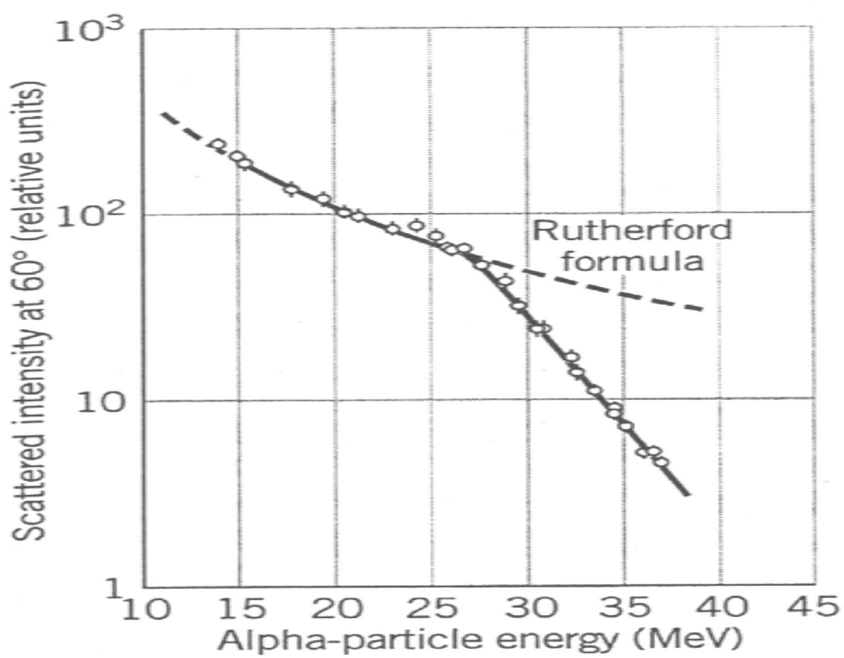
# Nuclear Size



# Nuclear Size

- Closest approach "d".
- $E_\alpha = E_{Coulomb}$ ▶ $d = 2kZe^2/E_\alpha$
- What about the recoil nucleus?
- Show that

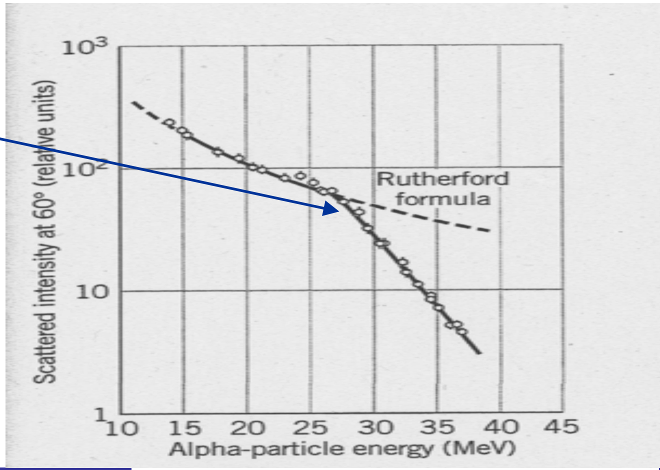
$$d = \frac{2kZe^2 m_N}{E_\alpha (m_N - m_\alpha)}$$

where $m_N$ : mass of the nucleus

$m_\alpha$ : mass of alpha

*What are the values of d for 10, 20, 30 and 40 MeV $\alpha$ on Au?*

*How does this explain … ?*



# Nuclear Shape

- Crude Nucleons in the nucleus are confined to an ***approximately*** spherically symmetric structure ▶ Nuclear ***radius.***
- ***Deformations…! Consequences….!! Advanced models.***
- HW 5

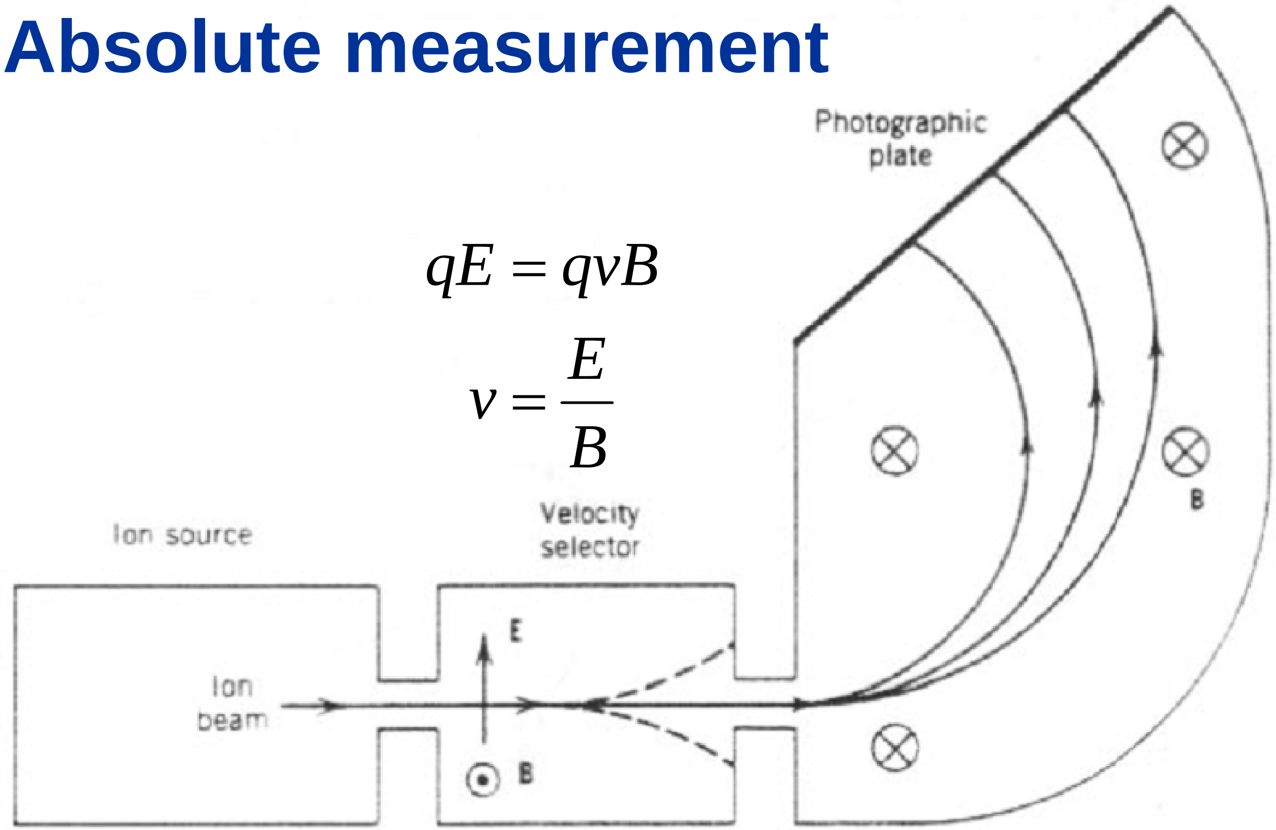
If it is assumed that the charge is uniformly **spherically** distributed in a nucleus, show that the electric potential energy of a proton is given by:

$$E = \frac{3}{5} K \frac{Z(Z-1)e^2}{R}$$

# Nuclear Mass

- Nuclear masses measured to high accuracy:
    - mass spectrograph.
    - energy measurement in nuclear reactions.

## Absolute measurement




$$qE = qvB$$

$$v = \frac{E}{B}$$

$$m\frac{v^2}{r} = qvB$$

$$mv = qrB$$

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

$$m = \frac{qBr}{v} = \frac{qB^2 r}{E}$$

If same *B*.

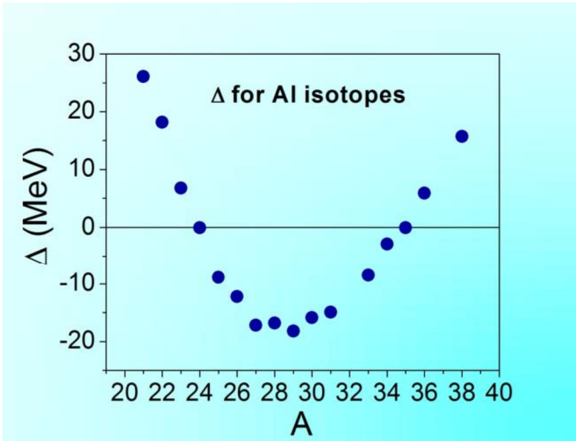
# Nuclear Mass

- $m(^{12}C)$ = 12 u. $m(^{1}H)$ with high precision?
- **Relative measurement. Mass Doublet method.**
- Mass ≅ 128. Difference in mass between $C_9H_{20}$ and $C_{10}H_8$ = 0.09390032±0.00000012 u = $12m(^{1}H) - m(^{12}C)$
- $m(^{1}H)$ = 1.00782503 ± 0.00000001 u.

- Usually atomic masses are tabulated.

http://physics.nist.gov/cgi-bin/Compositions/stand_alone.pl?ele=&all=all&ascii=ascii&isotype=all

- Mass of the atom < $Zm_H + Nm_n$. Why?
- Mass decrement = difference between actual mass and mass number: $\Delta = m - A$
- $\Delta$ could be positive or negative.



# Nuclear Binding Energy

$B_{tot}(A,Z) = [\, Zm_H + Nm_n - m(A,Z)\, ]\, c^2$ $\quad B\uparrow m\downarrow$

$B_{ave}(A,Z) = B_{tot}(A,Z) \,/\, A$

## Separation Energy

Neutron separation energy: (BE of *last neutron*)

$S_n = [\, m(A-1,Z) + m_n - m(A,Z)\, ]\, c^2$

$\quad = B_{tot}(A,Z) - B_{tot}(A-1,Z)$ ⬅ Prove that

$S_p = [\, m(A-1,Z-1) + m(^1H) - m(A,Z)\, ]\, c^2$

$\quad = B_{tot}(A,Z) - B_{tot}(A-1,Z-1)$ ⬅ Prove that

$S_\alpha = ??$

Magic numbers

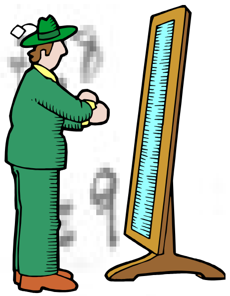
HW 6 Krane 3.9, 3.12, 3.13 and 3.14.

# Nuclear Binding Energy

Magic numbers

**Table 3.1** Some Mass Defects and Separation Energies

| Nuclide | Δ (MeV) | $S_n$ (MeV) | $S_p$ (MeV) |
|---|---|---|---|
| $^{16}O$ | −4.737 | 15.66 | 12.13 |
| $^{17}O$ | −0.810 | 4.14 | 13.78 |
| $^{17}F$ | +1.952 | 16.81 | 0.60 |



# Nuclear Binding Energy

In general

X ➔ Y + a

$S_a(X) = (m_a + m_Y - m_X)\, c^2$

$\quad = B_X - B_Y - B_a$

The energy needed to remove a nucleon from a nucleus ~ 8 MeV ≅ average binding energy per nucleon (Exceptions???).

**Nuclear Reactions**

**a + X > Y + b  or  X(a,b)Y**

Q-value = [m(a) + m(X) – m(Y) –m(b)] $c^2$

**Solve problem 11.6 in Krane.**

# Nuclear Binding Energy