

## Nuclear Physics: The Nucleus

Syllabus statements  
13.2.1-13.2.3

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### Measuring the Mass of a Nucleus: the Mass Spectrometer

- A stream of ionized gas is produced so that each atom in the gas has a net charge of  $-1e$
- The ions move through slits, then pass into a region of strong electric field and magnetic fields (perpendicular to each other) to move them in straight line and to force them into a focused beam of a known velocity (only one velocity will pass straight through both the electric field and magnetic field...)
- These ions pass into a second region of strong magnetic field
- The deflection pattern of these ions as a result of the magnetic field is measured and allows for interpretation of the mass of the atom. (the radius of an ion's path depends on its mass)
- These observations help demonstrate the existence of isotopes

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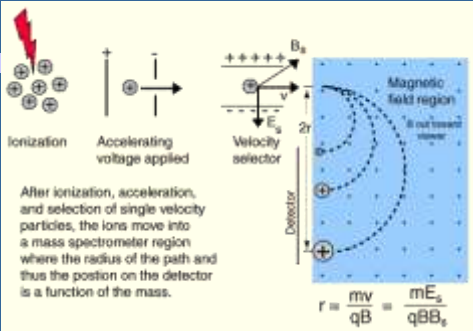
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### Mass Spectrometer



picture from: <http://hyperphysics.phy-astr.gsu.edu/Hbase/magnetic/maspec.html>

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## Do Nuclei have well-defined Radii?

- We can use the conservation of energy to determine the "distance of closest approach" between a nucleus and an incoming particle (i.e. alpha particle)
- If the particle is shot at a stationary nucleus, the total energy of the particle-nucleus system is completely due to the kinetic energy of the particle.
- When the particle gets as close as it possibly can get to the nucleus, it will stop briefly, then turn around. When it stops, all of its energy is now electric potential energy.

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## Do Nuclei have well-defined Radii?

- $Q$  = charge of the alpha particle ( $2e$ )
- $q$  = charge of the nucleus ( $Ze$ )
- $k$  = coulomb's constant
- $d$  = separation distance

$$E = k \frac{Qq}{d}$$

- Using conservation of energy, we can assume that the kinetic energy is equal to the electric potential energy, giving a stopping separation of... →

$$d = k \frac{2Ze^2}{E_k}$$

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## Example

- Assume an alpha particle was accelerated to a kinetic energy of 2.0 MeV, and is directed toward a gold nucleus (think Rutherford's gold foil experiment...). What is the minimum separation distance?

$$d = k \frac{2Ze^2}{E_k}$$

$$d = (8.99 \times 10^9) \frac{2 \cdot 79 \cdot (1.60 \times 10^{-19})^2}{(2.0 \times 10^6)(1.6 \times 10^{-19})}$$

$$d = 1.14 \times 10^{-13} \text{ m}$$

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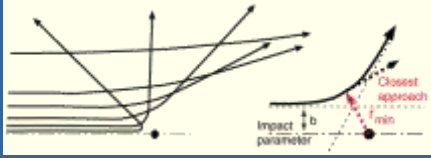
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## Scattering Experiments

- *Distance of closest approach:*



- Since most alpha particles do not hit head on, significant scattering can occur. Physicists have determined how to mathematically use the scattering angles to determine the radius of the nucleus (you won't have to do this, though ☺)

From: <http://hyperphysics.phy-astr.gsu.edu/hbase/nuclear/rutca2.html#c5>

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## Evidence for Nuclear Energy Levels

- **Gamma Decay:** a nucleus that is unstable as a result of excess internal energy emits gamma radiation when the nucleus returns to a more stable energy state.
- The spectra of the gamma rays emitted is discrete, indicating that there are specific energies released from the nucleus
- Much like electrons emitting photons when they drop from higher energy levels, these discrete energies indicate that there are specific levels in the nucleus that correspond to the energy of gamma radiation.

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