The Size of the Nucleus

By Closest Approach of an Alpha Particle

Rutherford's scattering experiment proved that the nucleus is very small. It also enabled the size of the nucleus to be estimated.

Point P is the closest point that the α-particle can get to the nucleus before being repelled. At point P the KE of the α-particle is zero as it stops momentarily. All of its energy has now been converted into PE.

We can use Coulomb's Law to estimate the size of the nucleus:

$PE = Vq$ (where q is the charge on the α-particle)

$$PE = \frac{qQ}{4\pi\varepsilon.r}$$

If the α-particle has been accelerated through a pd of 7.68MeV it has gained a KE of

1.23×10^{-12} J

$$r = \frac{qQ}{4\pi\varepsilon.PE}$$

$$r = \frac{(79 \times 1.6 \times 10^{-19})(2 \times 1.6 \times 10^{-19})}{4\pi\varepsilon. \times 1.23 \times 10^{-12}}$$

$$= 3 \times 10^{-14} m$$

This is the maximum value for the radius of a gold nucleus.

Points to note:

- The nucleus is treated as a point charge
- The α-particle is stopped some distance away from the nucleus
- It takes higher energy α-particles to penetrate the nucleus
- If the same calculation was made for other particles such as protons, neutrons or electrons the result would be slightly different

By Electron Scattering

This method gives a more accurate estimate of the nuclear radius.

The scattering of electrons is treated like the diffraction of waves around a spherical object.

It can be shown that:

$$\sin\theta = \frac{0.61\lambda}{R}$$

Where λ is the de Broglie wavelength of the electrons

Θ is the angle of diffraction

R is the nuclear radius

This estimates R = $\mathbf{2.65 \times 10^{-15} m}$

Points to note:

- The de Broglie wavelength of the electrons needs to be of the order of the nuclear diameter to get an appreciable scattering effect
- The electron diffraction minima are not zero, indicating that the boundary of the nucleus is fuzzy, not sharp
- Since the boundary is not sharp, various methods of estimating the nuclear radius give rather variable results from 1.2fm to 1.5fm.

The radius depends on the nucleon number by the relationship:

$$R = r_o A^{1/3}$$

Where A is the nucleon number and r_o is a constant with the value 1.4×10^{-15} m