# The nuclear atom

(1909) Rutherford and students probed the atom.

① α particles (5 MeV) on thin gold foil

(1919) ② α on N atoms → protons ⇒ Nuclear Splitting (Nuclear Substructure)

③ Rutherford proposes the neutron – a second nuclear particle

④ Rutherford and J. Chadwick search for the neutron

(1932) "Miracle Year" ① Chadwick discovers the neutron

② Chemist H.C. Urey identifies the deuterium atom.

③ Deuterium, the deuteron provide the simplest proton-neutron system in nature.

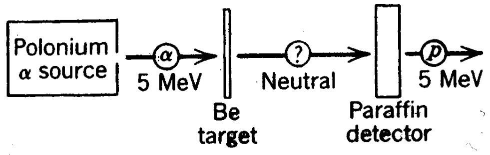
⇒ Study the force between nuclear particles.

④ Accelerators were built to accelerate protons → disintegrate the nucleus.

⇒ Probe the nucleus at controlled energies > KE (radioactive sources)

(1920) ~~19~~ (Mass, charge, size) of the nucleus $R < 10^{-14}$ fm

**Figure 14-1**
Chadwick's neutron-detection experiment.



Nuclear β decay had been observed – $\beta^{\pm}$ from the core of the atom.

① proton-electron model (in the nucleus) had several flaws.

$$\text{Bohr magneton} \quad \mu_B = \frac{e\hbar}{2m_e} = 5.788 \times 10^{-5} \text{ eV/T}$$

$$\text{Nuclear magneton} \quad \mu_N = \frac{e\hbar}{2m_p} = 3.152 \times 10^{-8} \text{ eV/T}$$

Magnetic moment of the nucleus ~ $\mu_N$ not $\mu_B + \mu_N$

② Spin properties of the nucleus → Nitrogen

N - integer $\overset{\text{nuclear}}{\text{spin}}$ $A=14$ $Z=7$ $\Rightarrow \underbrace{(14 \text{ protons} + 7 \text{ electrons})}_{\text{odd-spin}}$ in the nucleu

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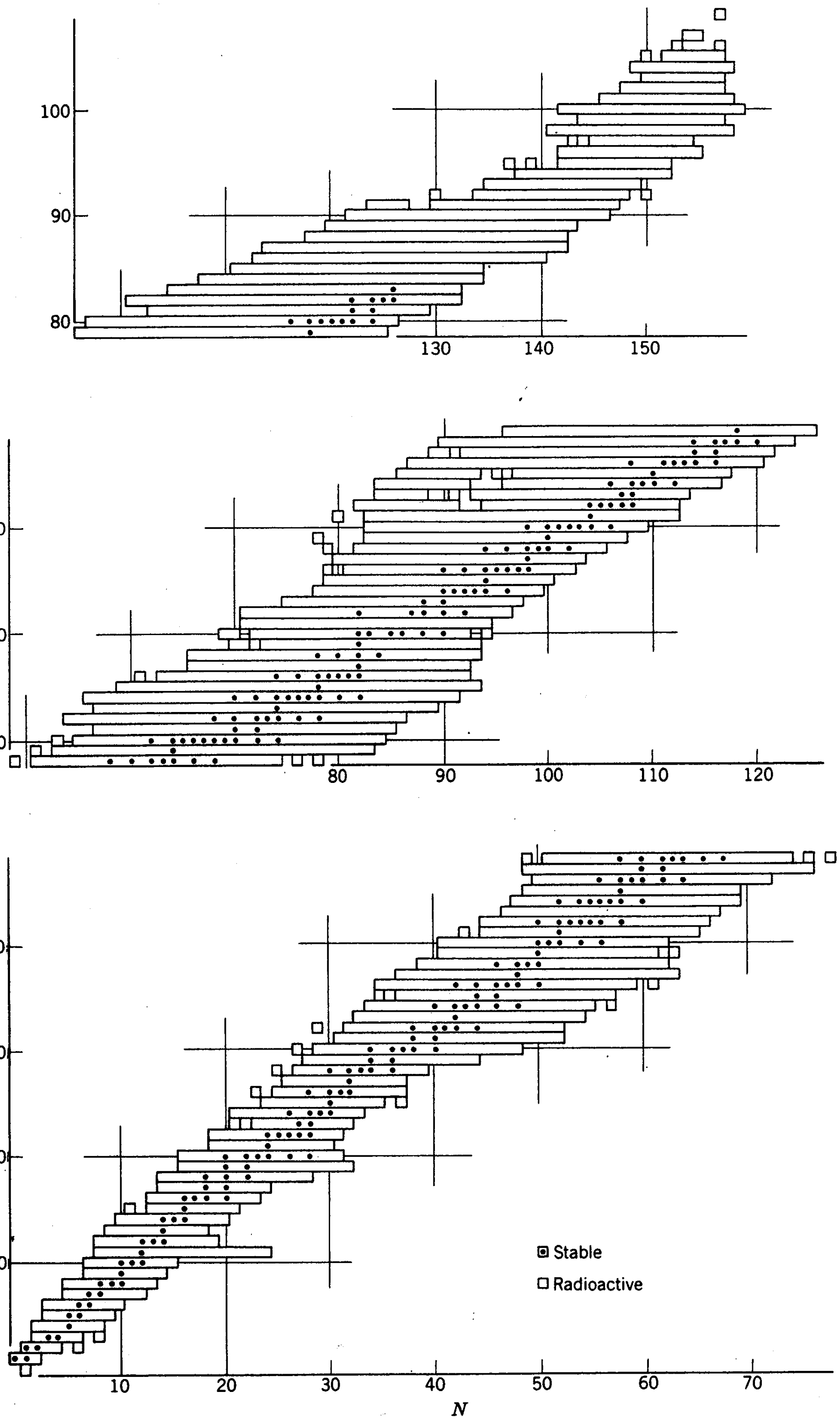
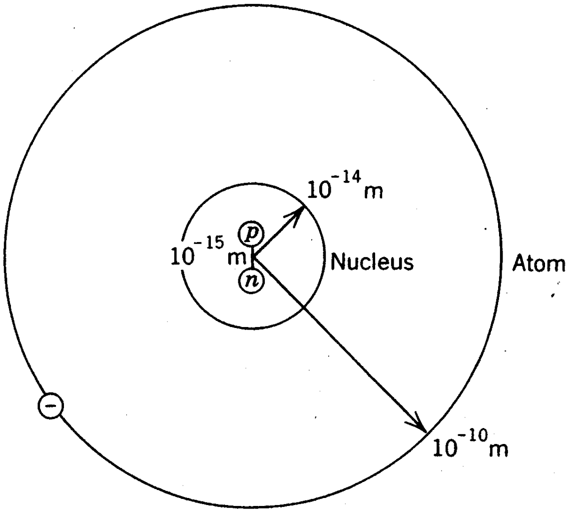
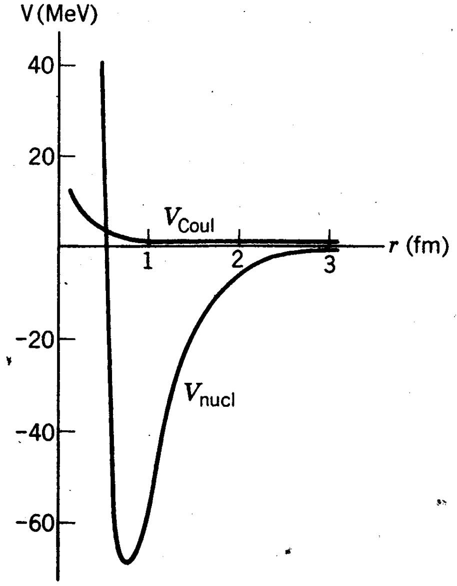


**Figure 14-2**
Qualitative scales of atomic and nuclear size.



pairs of constituent particles. It is known that the nuclear forces between proton and proton, proton and neutron, and neutron and neutron are essentially *identical.* Evidence for this important simplifying property of the nuclear force has been gathered from proton–proton and neutron–proton scattering experiments and from many other sources. The small size of the nucleus is a qualitative indication that this two-body force has a *very short range.* Figure 14-2 shows a highly schematic (and disproportionate) comparison of the orders of magnitude for the atomic radius, the nuclear radius, and the internucleon range.

**Figure 14-3**
Potential energy for a system of two nucleons.



$M_p = 938.27$ MeV $\quad M_n = 939.57$ MeV

$\mu_p = 2.7928\,\mu_N \quad \mu_n = -1.9130\,\mu_N$

$$\vec{\mu}_I = g_I\,\mu_N\,\frac{\vec{I}}{\hbar}$$

$\frac{g_p}{2} = 2.7928 \quad \frac{g_n}{2} = -1.9130$

$$\boxed{\frac{g_p}{2} = 1 \quad \text{and} \quad \frac{g_n}{2} = 0}$$

Dirac Theory
spin $\frac{1}{2}$ particles.

Recall: $\frac{g_s}{2}$ (electron) $= 1.001....$