

NUCLEI

SIZE OF THE NUCLEUS

INTRODUCTION

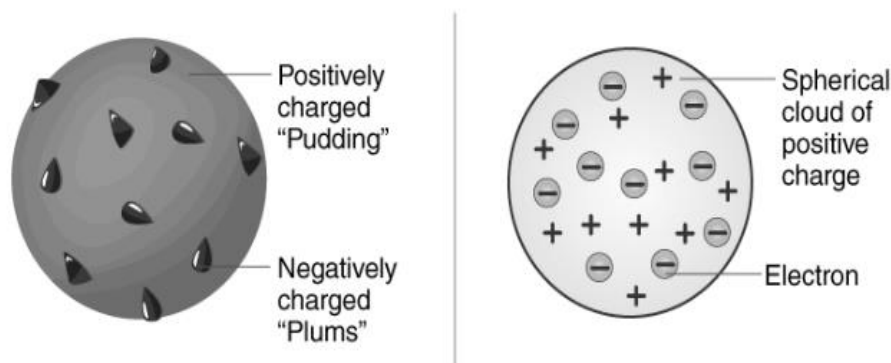
Comprehending the fundamental makeup of matter plays a crucial role in the field of Physics. Delving into the dimensions of the nucleus, a focal point of this discussion, owes much to the Rutherford gold foil experiment. The Rutherford model of the atom stands as the initial accurate understanding of the atom, forming the foundation upon which Bohr constructed his own interpretation.

RUTHERFORD GOLD FOIL EXPERIMENT

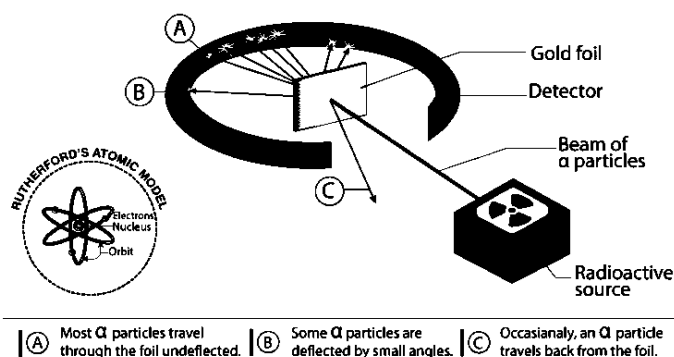
Preceding Rutherford's experiment, the prevailing model of the atom was the Thomson or "plum pudding" model. According to this model, the atom was conceptualized as a positive material "pudding" with negatively charged "plums" dispersed within it. However, Rutherford's alpha-particle scattering experiment marked a pivotal shift in our understanding of atomic structure. Rutherford conducted this experiment by directing beams of alpha particles at a thin gold foil to scrutinize the scattering patterns of these particles and assess the validity of the existing model.

JJ THOMPSON PLUM PUDDING MODEL

In Rutherford's groundbreaking experiment, he demonstrated that the atom predominantly comprised empty space, featuring a nucleus at its core with electrons orbiting around it. As alpha particles were directed towards a gold foil, Rutherford observed a remarkable phenomenon: approximately 1 in 20,000 particles experienced a change in their motion direction by more than 90 degrees. Meanwhile, the remaining 19,999 particles deviated only slightly from their original paths. This observation led to the inference that the atom's structure involved a vast emptiness with the majority of its mass concentrated in minuscule volumes at the nucleus's core. This central volume was subsequently termed 'the nucleus,' deriving from the Latin word for 'little nut.'



RUTHERFORDS GOLD FOIL EXPERIMENT



In the course of this experiment, Rutherford derived three significant observations:

- 1. Straight-Through Trajectory of Alpha Particles:** The majority of highly charged alpha particles passed directly through the gold foil without any significant deflection. This outcome aligned with expectations if the Thomson "plum pudding" model, where positive and negative charges are uniformly distributed, were accurate.
- 2. Large Angle Deflection of Some Alpha Particles:** Surprisingly, a portion of alpha particles experienced considerable deflection, deviating from their initial paths at substantial angles. This observation was inconsistent with the anticipated behavior under the plum pudding model and indicated the presence of concentrated positive charge within the atom.
- 3. Backward Deflection of a Few Alpha Particles:** Perhaps the most astonishing revelation was that a very small fraction of alpha particles were not only deflected but actually reflected backward, akin to shooting a large projectile at tissue paper and having it rebound toward the source. This unexpected phenomenon underscored the existence of a highly dense and positively charged nucleus at the atom's core.

In order to account for the unexpected outcomes observed during the experiment, a radical rethinking of the atomic model became imperative. The proposed model aimed to reconcile these observations and introduced significant modifications to the existing understanding of the atom.

According to this innovative model, the positive material constituting the atom was no longer thought of as uniformly distributed throughout the atom in a pudding-like manner. Instead, it was conceptualized as being concentrated in a small yet immensely dense region known as the nucleus. This nucleus served as the central core housing the majority of the atom's mass.

In this updated model, electrons were envisioned as orbiting around the nucleus, analogous to celestial bodies orbiting a central gravitational force. This new configuration of the atom addressed the experimental findings, especially the occurrences of alpha particles being deflected at large angles and even rebounding backward. The concentrated positive charge in the nucleus explained why most particles passed through undeflected, while the rare collisions with the nucleus accounted for the unexpected deflections and reflections.

This model paved the way for a more accurate understanding of the atom's structure, laying the foundation for subsequent advancements in atomic theory.

Size of the Nucleus

The determination of the nucleus size became achievable through Rutherford's experiment. The approach involved calculating the point of closest approach of an alpha particle. By propelling alpha particles with a kinetic energy of 5.5 MeV, the experiment yielded an estimated point of closest approach at approximately $4 \times 10^{-14}\text{m}$. In this scenario, the prevailing force was identified as Coulomb repulsion, and the absence of contact signified that the actual nucleus size was smaller than $4 \times 10^{-14}\text{m}$.

The meticulous measurement of the sizes of various nuclei ensued through numerous iterations of the experiment. This extensive data collection enabled the derivation of a formula for systematically determining the size of a nucleus, expressed as

$$R = R_0 A^{\frac{1}{3}},$$

Where R_0 equals $1.2 \times 10^{-15}\text{m}$.

Analyzing the formula reveals that the volume of the nucleus, proportionate to R^3 , is directly proportional to the mass number (A). Additionally, it is noteworthy that the equation lacks a mention of density. This absence is justified by the fact that nuclear density remains constant across elements, approximately at $2.3 \times 10^{17}\text{kg. m}^{-3}$. This knowledge contributes significantly to our understanding of the intrinsic properties of atomic nuclei.