

Atomic Target Practice

Rutherford Scattering and the Nuclear Atom

Introduction

It is one of the most famous experiments of all time. More than 25 years after conducting the experiments, Ernest Rutherford described the results this way:

"It was about as credible as if you had fired a 15-inch shell at a piece of tissue paper and it came back and hit you."

The experiment itself was actually the culmination of a series of experiments carried out over a five-year period, dealing with the scattering of high-energy alpha particles by various substances. What is "Rutherford scattering," and why was it so important?

Concepts

- Atomic structure
- Atomic mass
- Nucleus
- Nuclear charge

Background

Ernest Rutherford received the Nobel Prize in Chemistry in 1908 for his investigations into the disintegrations of the elements as a result of radioactive decay. Among the products of the radioactive decay of elements are alpha particles—small, positively charged, high-energy particles. In trying to learn more about the nature of alpha particles, Rutherford and his co-workers, Hans Geiger and Ernest Marsden, began studying what happened when a narrow beam of alpha particles was directed at a thin piece of metal foil. Alpha particles are a type of nuclear radiation, traveling at about 1/10 the speed of light. As expected for such high-energy particles, most of the particles penetrated the thin metal foil and were detected on the other side. What was unexpected was that a few—a very few, to be sure—of the alpha particles were actually reflected back toward the source, having been "scattered" or bent. Due to their encounters with the metal atoms in the foil target, The number of alpha particles that were reflected back depended on the atomic mass of the metal. Gold atoms, having the highest atomic mass of the metals studied, gave the largest amount of so-called "back scattering."

Rutherford's scattering experiments have been described as a "black box" experiment. The properties of the alpha particles, their mass, charge, speed, etc., were at least partially understood. The atoms making up the target, however, presented Rutherford with a kind of black box—the structure of the atom was not known at the time. In order to explain the

results of the scattering experiments, Rutherford had to unlock the black box, that is, he had to solve the structure of the atom. In 1911 Rutherford proposed the following model for the structure of the atom:

- Most of the mass of the atom is concentrated in a very small, dense central area, later called the nucleus, which is about 1/100,000 the diameter of the atom.
- The rest of the atom is apparently "empty space." (Most of the alpha particles traveled straight through the metal foil, as if nothing were in their path.)
- The central, dense core of the atom is positively charged, with the nuclear charge equal to about one-half the atomic mass. (As alpha particles randomly struck the gold target, a few approached the nucleus of an atom head-on. The positively charged alpha particles were strongly repelled by the nuclear charge and "recoiled," or bounced back to the source.)

It is not practical to recreate Rutherford's original scattering experiments in the general laboratory. Some idea of the challenge that faced Rutherford and his co-workers can be gained from the following "black box" activity using marbles and an unseen, unknown target.

Experiment Overview

The purpose of this activity is to discover by indirect means the size and shape of an unknown object, which is hidden underneath the middle of a large board. The board is raised about 2 cm, leaving just enough space to roll or shoot a marble at the object. By observing and tracing the path the marble takes after striking the unknown target from a variety of angles, it should be possible to estimate the general size and shape of the unknown target.

Pre-Lab Questions

1. This activity is a simulation of Rutherford's scattering experiments. Read the entire Procedure and compare the components used in this simulation (the marbles, the board, the unseen object and the traced paths of the marbles) to Rutherford's original experiments. What role is played by each component?
2. It is important to trace the apparent path of each marble roll, even when the marble rolls straight through without striking the unknown target. What general information about the target can be inferred based on where the marble rolls in one end and out the other?

Atomic Target Practice Lab Answers

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