# Modeling Rutherford's Experiment

***A Teacher's Guide***

**Cornell Laboratory for Accelerator-based Sciences and Education**
**Author: Lora K. Hine**

**Lesson: http://www.lepp.cornell.edu/Education/TeacherResources.html**
**Extension/Reading Activities: CMS Times for Kids! http://cms.cern.ch/**

***NYC K-8 Science Scope and Sequence:***

- **PS Standard 4 - Properties of Matter: 3.1a, 3.3a-d**
- **MST Standard 1 – Inquiry Skills**
- **MST Standard 4 – Process Skills**

*Engage:*

On January 1st, 1994 scientists at the National Research Council in Canada created the world's smallest ruler – each division measures the width of 18 atoms! The device was created in order to measure features designed on a computer chip that can be one-60th of a human hair wide. The calibrations are so minuscule that the ruler gained entry in the Guinness Book of World Records.

In 1911, nearly 80 years before the creation of the NRC's miniature ruler, Ernest Rutherford and his colleagues Hans Geiger and Ernest Marsden accurately measured the size of the nucleus of a single gold atom. How do you think they were able to do this?

To help students answer this question, hold up a cardboard box that contains a "mystery object". Ask the students how they can determine what is inside of the box without opening the box and looking inside. Students should offer up suggestions such as shaking the box, weighing the box, maybe sticking a pencil inside of the box to poke around. Encourage any idea that allows the student to determine some sort of characteristic about the object inside the box.

*Explore:*

Ahead of time, create 5-10 Mystery Boxes that contain a common classroom object. Number each box and record its contents. Create a display table with objects that are the same as those sealed inside of the boxes. Have an electronic scale or balance available for student use.

Ask students how they might be able to determine what is inside of the box without being able to view the object directly. What questions could they ask? What tests could they design? Pass out a cardboard box with a different mystery object sealed inside to each small group of students. Have the students use the Mystery Box handout to record their observations and results. After they complete the activity, facilitate a discussion with the group about how indirect measurements and observations helped them infer the identity of their mystery object.

*Explain:*
Often we can look at or touch an object to learn about it. Sometimes, objects are too small or too large for us to learn about them this way. When this happens, we need to use indirect measurement techniques, such as those used above.

Ernest Rutherford realized that atoms and the building blocks that make up an atom are much too small to be measured directly (say, by using a ruler or other measurement device). Rutherford and his colleagues designed an experiment to measure the characteristics of atoms indirectly. The scientists used a thin piece of gold foil at which they directed alpha particles, which were like very small bullets. Though they could not see the atoms in the gold foil, they knew that if they watched where the alpha particles went after hitting the gold foil, they could draw conclusions about what was inside of the gold atoms. Alpha particles are very small, but they are heavy. They also travel quickly, and they have a positive electrical charge. When the alpha particles exited the foil after colliding with the gold atoms in the foil, they were detected with a specially designed screen that Rutherford placed around the experiment. The screen would light up at the point of the collision where the alpha particles stuck it.

At the time of Rutherford’s experiment, the physicist thought the composition of an atom resembled plum pudding; electrons positioned throughout the atom surrounded by a soup of positive charges that would balance out the negative. Rutherford believed that each fired alpha particle would travel through the “pudding” of positive and negative charges in the gold foil, deflect only slightly as they encountered other positive charges, hit the special screen, and light up.

Most of the alpha particles went through the foil with no change in direction as expected. But he was surprised to see that once in awhile one of the alpha particles would deflect right back at the source! Upon this discovery, Rutherford exclaimed: “It was almost as incredible as if you fired a fifteen-inch shell at a piece of tissue paper and it came back and hit you!" This experiment led Rutherford to conclude that an atom is actually mostly empty space with a small, dense, positively charged nucleus in its center.

*Elaborate:* Your team will receive a large wooden board, under which your teacher will place a flat shape. Your team's job is to identify the shape without ever seeing it. You can only roll marbles against the hidden object and observe the deflected paths that the marbles take. Use arrows to indicate the direction of motion. Your team will have five minutes to "observe" a shape.

Use this piece of paper for sketching the paths of the marbles as they are rolled under the board and bounce off of the object. You can use different colored pencils to help you keep track of the various paths the marbles take. Analyze this information to determine the object's actual shape. Draw a small picture of each shape you studied in the boxes below, and answer the questions below.

***Trial One***

*Evaluate:*

1. Your prediction of the shape based upon above data and observations:

2. Based on your experience, how would your team be able to improve their ability to determine the shape of the unknown object?

3. Can you tell the size of the object as well as its shape?

4. What information gave your team the best indication of the shape of the object?

5. Without looking, how can you be sure of your conclusions?

Many of the observations we make in science are indirect measurement such as you have just made! The approach we have been using is very similar in many ways to that used by scientists in studying the size, shape, and nature of elementary particles, atoms and molecules.

6. As a group, think about the above statement and decide on a definition for the term "indirect observation". Write it here:

7. Actual Shape (following class discussion!): ____________

Teacher Resources:

*Materials Needed:*

- Small cardboard boxes
- An assortment of Mystery objects (same one per box and one for display)
- Electronic balance or scale
- Wood (approximately 6 inches across) cut into a triangular, circular or rectangular shape. Or, use Styrofoam insulation (1" thick) cut in shapes.
- Large piece of plywood (which is much larger than the block and can be placed over the block). Or, use a plastic cafeteria tray to the cover shape.
- Marble or steel ball bearing
- Colored pencils (optional)

*References:*

University of Virginia Physics Department. "Indirect Measurement II". http://www.phys.virginia.edu/Education/outreach/8thgradesol/IndirectMeasure2.htm

The Particle Adventure www.particleadventure.org

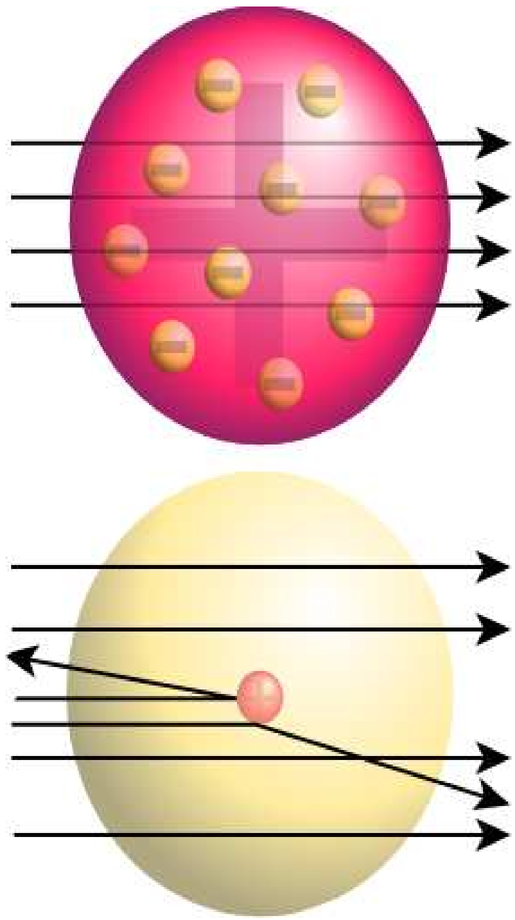
University of Colorado Boulder http://www.colorado.edu/cu4k12/

Wikipedia - http://en.wikipedia.org/wiki/Geiger-Marsden_experiment

Therese Arsenault, Lansing Middle School Science Teachers

# Image: Rutherford gold foil experiment results

*- Wikimedia Commons*



*Top:* Expected results: alpha particles passing through the plum pudding model of the atom undisturbed.

*Bottom:* Observed results: a small portion of the particles were deflected, indicating a small, concentrated positive charge.

# Mystery Box Handout

Box Number: ________

## Challenge:

Hidden inside the box is an object. Your job is to find out as much as you can about the mystery object. What do you think the object is? How do you know?

Working with your partner or group,

1. Brainstorm the questions you might ask to find out more about the object. Write them here.

2. What kinds of tests can you design to help you answer these questions? Write them here.

3. Create a way to organize your data. Include the test, reason for the test, and observations.

4. From your data, what do you think the object in the box is? Use evidence to tell how you know.