# Rutherford Simulation
## Modeling the Structure of the Atom

### OBJECTIVE
This activity simulates Rutherford's gold foil experiment. While Rutherford's experiment used alpha particles and gold foil, students will use marbles to strike a cardboard shape hidden under a board. They will use the responses of the marble to hypothesize the shape of the object.

### LEVEL
Middle Grades: Chemistry

### NATIONAL STANDARDS
UCP.2, B.1, G.1, G.3

### CONNECTIONS TO AP
AP Chemistry:
I. Structure of Matter A. Atomic theory and atomic structure 1. Evidence for the atomic theory
AP Physics:

### TIME FRAME
45 minutes

### MATERIALS
(for a class of 28 working in teams of 4)

- 28 marbles
- 7 cardboard squares (approx 40 cm × 40 cm)
- 7 cardboard shapes
- utility knife, razor blade, or scissors*
- hot glue gun and glue sticks*
- tape*
- marker*
- resealable plastic bags, cups, or other small containers for dispensing marbles

* indicates items used in preparation by the teacher, and not used by students

## TEACHER NOTES

**Safety Alert**
1. Handle the razor blades with care.
2. Wear thick gloves and secure cardboard tightly before cutting.
3. Use caution with the hot glue gun. Avoid touching the hot tip or the melted glue.
4. Caution students not to throw the marbles or put them in their mouth.

This lesson can be used to supplement a lesson on atomic structure. The simulation provides some experience with drawing conclusions and the conclusion questions provide calculations to explore the size of atoms and nuclei. Students may need to review the dimensional analysis portion of *Foundation Lesson II: Numbers in Science* before attempting the calculations.

Prior to the day of the activity:

1. Cut 7 cardboard squares to approximately 40 cm × 40 cm. Use a marker to number the squares 1-7 in the upper left corner.

2. Cut 7 strips of cardboard approximately 2 cm wide and 60 cm long. Cutting along a ruler will help generate smooth edges that will stand up straighter.

3. Bend the strips of cardboard into simple geometric shapes such as a square, rectangle, right triangle, equilateral triangle, pentagon, diamond, rhombus, and circle. If less then 60 cm of length is needed, cut off any extra from the cardboard strip. Use generous amounts of hot glue to secure the cardboard ends together to make a closed figure. The figure should be large enough to take up much of the underside of the board.

4. Use generous amounts of hot glue to attach the figure to the non-numbered side of the cardboard square. You can center the shapes to make an easy target or place them off-center to make the simulation more challenging, but this may make the board difficult to stand up. For added difficulty, you can put 2 small shapes on the same board leaving a gap between them for a marble to roll through (See Figure 1). Allow the glue to dry thoroughly.

5. Another extension for this simulation is to use 2 cm cross sections of toilet paper rolls to make a more realistic cross section of the gold foil. The cross sections can act as “nuclei” and be spaced out and glued to the underside of the board. Students can be instructed to figure out how many “nuclei” are present in their sample. Be sure that you place them in such a way that each one could be hit directly by a marble or students may not be able to accurately count how many are present.

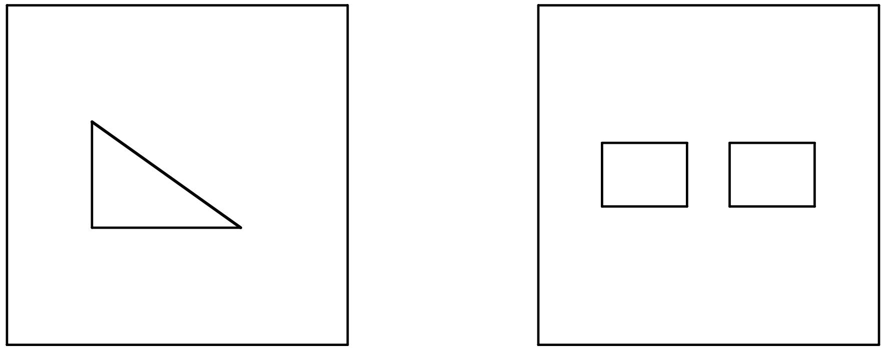


*Fig. 1*

On the day of the activity:

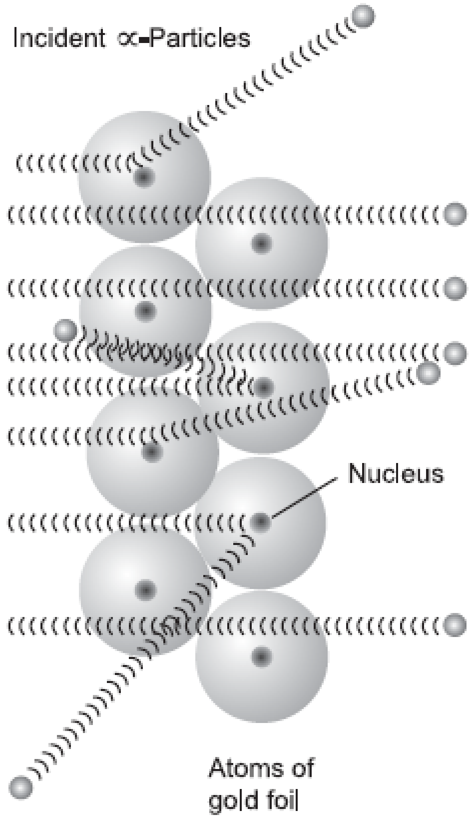
- If possible, set up the boards on the floor before students come into the classroom.
- Instruct students not to look at the underside of the boards.
- Distribute a set of 4 marbles to each team and discuss safe handling of the marbles for this simulation.
- As students complete their drawings they will ask that you evaluate their results.
- Before turning over the square, look at the students' picture and ask them questions about how they arrived at their conclusion, such as:
  - Is this picture to scale?
  - How do you know how big the shape is?
  - How do you know how many sides the shape has?
  - How do you know if the shape is in the center (or off-center)?
- Turn over the cardboard square and reveal the shape. Use the suggested scoring rubric or one of your own to assign a grade for this portion of the activity.
- If time permits you may have students rotate stations and try another board.

## POSSIBLE ANSWERS TO THE CONCLUSION QUESTIONS AND SAMPLE DATA

***Suggested scoring rubric*** (10 point scale, adjust weighting as needed)

| | Exactly correct | Right Idea | Not even close |
|---|---|---|---|
| Scale of object | 2 | 1 | 0 |
| Orientation of object relative to reference number | 2 | 1 | 0 |
| Number of sides | 2 | 1 | 0 |
| Angles | 2 | 1 | 0 |
| Thoroughness of justification statement | 2 | 1 | 0 |

1. Study the pictures below.



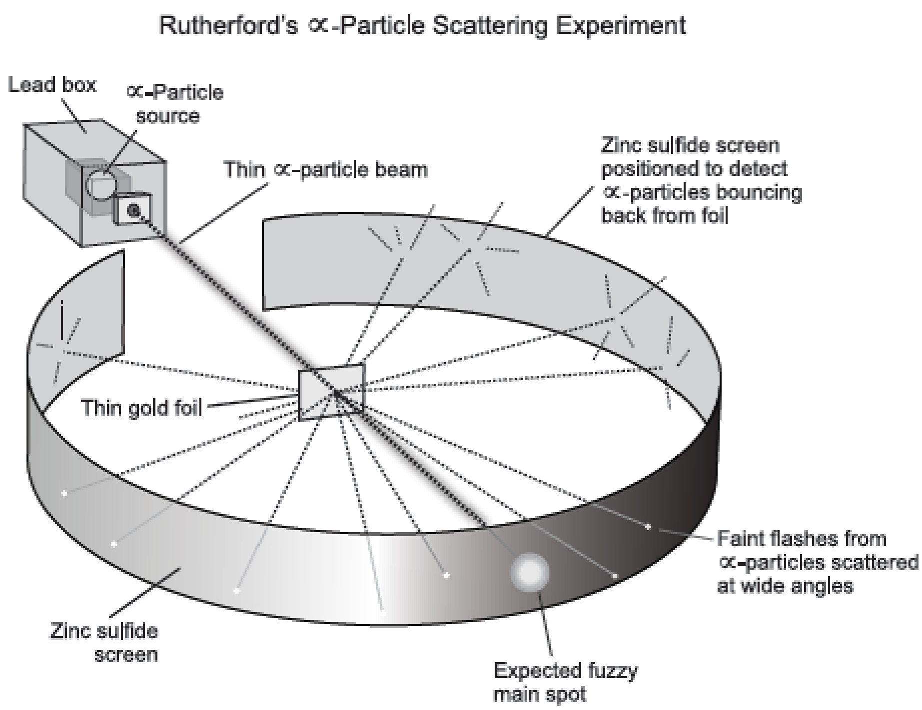



*Fig. 2*

i) Which component of the experiment did your marbles simulate? Why?

- The alpha particles.
- They were the particles used to bombard the atom in Rutherford's experiment in an attempt to learn about its features.

ii) Which component of the experiment did your hidden shape simulate? Why?

- The nucleus.
- The shape caused the marbles to be reflected back just as the nucleus did with the alpha particles.
- Partial credit for answers that mention only the gold foil but do not specifically mention the nucleus.

iii) How could your cardboard have been designed to better simulate the amount of empty space in the atom?

- Answers will vary but may include using more or smaller objects under the board.

2. The head of a pin is approximately 1 mm in diameter. The diameter of an atom is on the order of $2.5 \times 10^{-10}$ meters. Calculate how many atoms it would take to line up across the head of a pin. Show work.

- $1000\,\text{mm} = 1\,\text{m}$
  $1\text{ atom} = 2.5 \times 10^{-10}\text{ m}$
  $$1\,\cancel{\text{mm}} \times \frac{1\,\cancel{\text{m}}}{1000\,\cancel{\text{mm}}} \times \frac{1\text{atom}}{2.5 \times 10^{-10}\,\cancel{\text{m}}} = 4{,}000{,}000\text{ atoms}$$

3. The Angstrom (Å) is a unit commonly used to measure atomic particles. 1 cm = $1 \times 10^{8}$ Å. The nucleus of an atom is approximately $1 \times 10^{-4}$ Å in diameter. Calculate the diameter of a nucleus in meters. Show work.

- $1\text{cm} = 1 \times 10^{8}\,\text{Å}$
  $100\,\text{cm} = 1\,\text{m}$
  $$1 \times 10^{-4}\,\cancel{\text{Å}} \times \frac{1\,\cancel{\text{cm}}}{1 \times 10^{8}\,\cancel{\text{Å}}} \times \frac{1\text{m}}{100\,\cancel{\text{cm}}} = 1 \times 10^{-14}\text{ m}$$

4. Recall from question 2 that the diameter of an atom is approximately $2.5 \times 10^{-10}$ m. Using your answer from question 3, calculate the percentage of the atom's diameter that is nucleus. Show work.

- $$\text{Percent} = \frac{\text{part}}{\text{whole}} \times 100$$
  $$\text{Percent nucleus} = \frac{1 \times 10^{-14}\,\cancel{\text{m}}}{2.5 \times 10^{-10}\,\cancel{\text{m}}} \times 100 = 0.004\%\text{ nucleus}$$

5. If the nucleus occupies only a small percentage of the overall space in an atom, what occupies the rest of the atom?

- Empty space or the electron cloud

6. In this activity you had to observe indirect evidence and use it to draw conclusions about an object that you could not see. Describe some other instances in everyday life where indirect observation is used to draw conclusions.
   - Answers will vary, but might include:
     - Guessing the contents of a wrapped present
     - Identifying what is cooking in the oven by the smells in the house.
     - Physicians use anecdotal evidence from patients about their symptoms to diagnose an illness.

# Rutherford Simulation
## Modeling the Structure of the Atom

How can you investigate something you cannot see? Even with a microscope, atoms are too small to be seen. Many times in science we are faced with the challenge of learning about something that is too small, too big, or too far away to be studied with close examination. For these studies scientists must make observations about objects at a macroscopic level to explain what is happening at a microscopic level.

In this activity you will be simulating work done by Ernest Rutherford in 1910. His experiment was designed to bombard a thin piece of gold foil with a stream of alpha particles and to detect their movement through the gold foil. A radioactive film encircled the gold foil to pinpoint where the alpha particles came out. Rutherford was quite surprised by his results. In fact, his results were so surprising that it forced the adoption of an entirely new model of the atom!

### PURPOSE
The purpose of this experiment is to simulate Rutherford's work with alpha particles and gold foil. Through this experiment you will practice using indirect evidence to draw conclusions.

### MATERIALS
4 marbles per group

cardboard square with hidden shape

> **Safety Alert**
> Handle marbles with care. Do not throw the marbles or put them in your mouth.

### PROCEDURE
1. Write an if-then hypothesis as to how you will use marbles to deduce the shape of the object beneath your cardboard.

2. Without looking at the bottom side of the cardboard, place the cardboard square on the floor and sit around it.

3. Within your group, take turns rolling your marbles under the board and observing their behavior. If your marble becomes stuck, call your teacher over to retrieve it. **Do not disturb the board in any way**. You might find it helpful to place a piece of paper on top of the board and use it to track the movements of your marble. When observing your marbles, consider questions such as: Do they bounce back in a straight line? At an angle? Pass right through?

4. Continue making observations with your marbles until you have a good hypothesis as to the size, shape, and orientation of the hidden shape.

5. Using the square provided on your student answer page, draw what you believe to be the shape hidden under the cardboard. Be sure to orient your drawing so that the top of the shape is toward the numbered corner. This will provide a point of reference and allow you to show the approximate size of the shape. Record the observations that led to this conclusion.

6. When your group is in agreement on the drawing, call your teacher over to check your results. While you are waiting for your teacher, begin answering the conclusion questions.

Name_______________________________________

Period ______________________________________

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### HYPOTHESIS

### DATA AND OBSERVATIONS

#

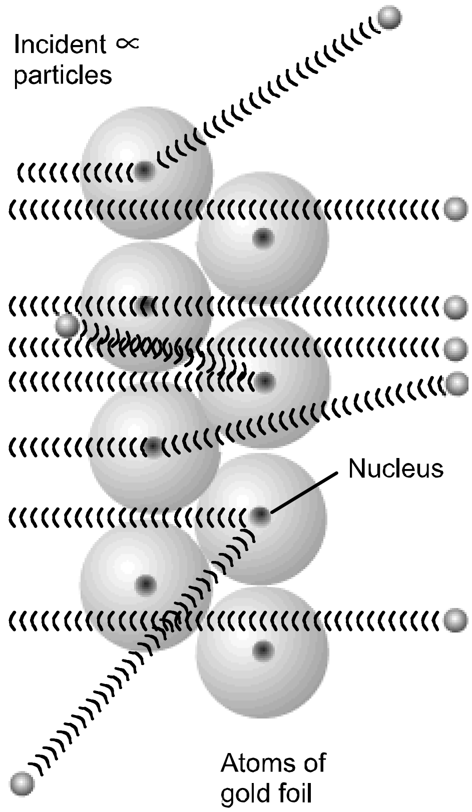
Justification:

#

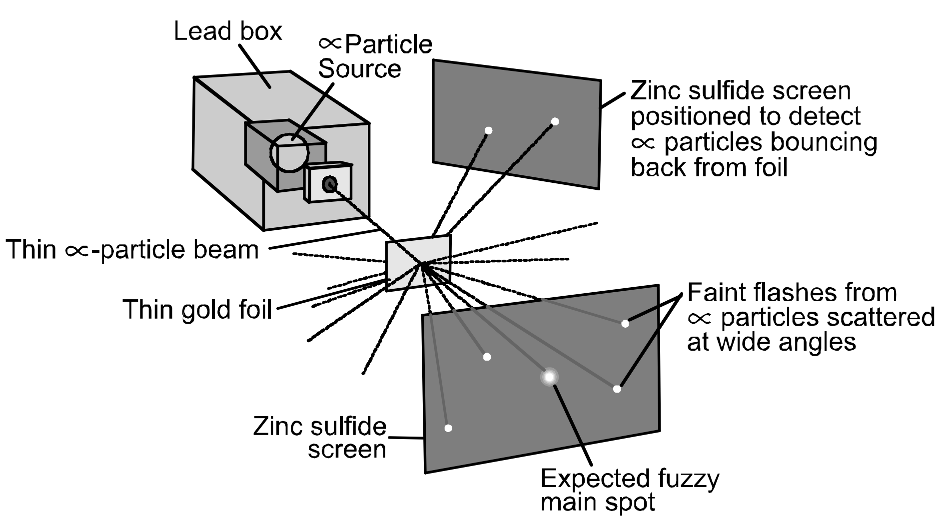
Justification:

## CONCLUSION QUESTIONS

1. Study the pictures below.




Rutherfordís ∝-Particle Scattering Experiment



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