Rutherford's Gold Foil Experiment
Student Guide

Introduction:

The purpose of this activity is to investigate the results of the Rutherford Gold Foil Experiment via a computer simulation. Rutherford wanted to study the inner structure of of the atom. He hypothesized that a beam of alpha particles would pass through thin sections of matter largely undeflected. He believed that some alpha particles would be slightly scattered whenever they encountered electrons. Studying the scattering patterns would enable him to draw conclusions about the distribution of electrons in atoms.

When Rutherford's assistants bombarded very thin foils of gold with alpha particles, they observed something quite different. The majority of the alpha particles penetrated the foil undeflected, some experienced slight deflections, a few underwent serious deflections, and others bounced back in the direction from which they came.

Two years later, Rutherford had an explanation for this puzzling behavior. The atom's mass was not uniformly distributed as he had originally thought. Rather, he hypothesized that most of the mass and all of its positive charge are centered in a very small region called the nucleus. The rest of the atom is empty space. The units of positive charge are on the nucleus and the units of negative charge are outside the nucleus.

With the Rutherford model, the likely paths of the alpha particles which were deflected are seen. The undeflected particles are not shown.

The Simulation:

1. Open the Rutherford STELLA model (Rutherfd.stm). The model should open at the map page showing you a graph and three sliders.

2. In the upper left hand corner of the screen, you should see a down arrow $\bigtriangledown$. Click on the down arrow to go to the Model page and then click on the down arrow again to go to the Equations page.

   Q1. From the Equations page, record the values for the following:

   Z_alpha_particle =   _____
   Z_nucleus =   _____
   initial_position_x =   _____

   Q2. What does Z stand for? _____

3. In the upper left-hand corner of the screen, you should see an up arrow $\bigtriangleup$. Click on the up arrow to go to the Model page and then click on the up arrow again to return to the Map page.

4. For the first experiment, you are going to change the initial y-position that the alpha particle starts at as it approaches the gold nucleus. Each time you change the y-position slider, the alpha particle will start from a different position on the y-axis.

5. Begin by clicking on the y-position slider bar and dragging it all the way to the left (-8 x 10^{-13}). Run the model by clicking on Run on the menu bar and dragging down the menu to the Run option. You should see a curve form on your graph.

6. Then move the slider (or type in the box and press return or enter) until the initial y-position is set at -6.4 x 10^{-13} and run the model again. Note that you only have to type the -6.4 since the power of 10 is already printed on the slider. You should see a second curve appear.

7. Repeat for positions of -4.8, -3.2, -1.6, 0, 1.6, 3.2, 4.8, 6.4 and 8.0 x 10^{-13}.

Q3. Sketch the resulting graph on the axes provided. Indicate the probable position of the gold nucleus.

1 : position x v. position y
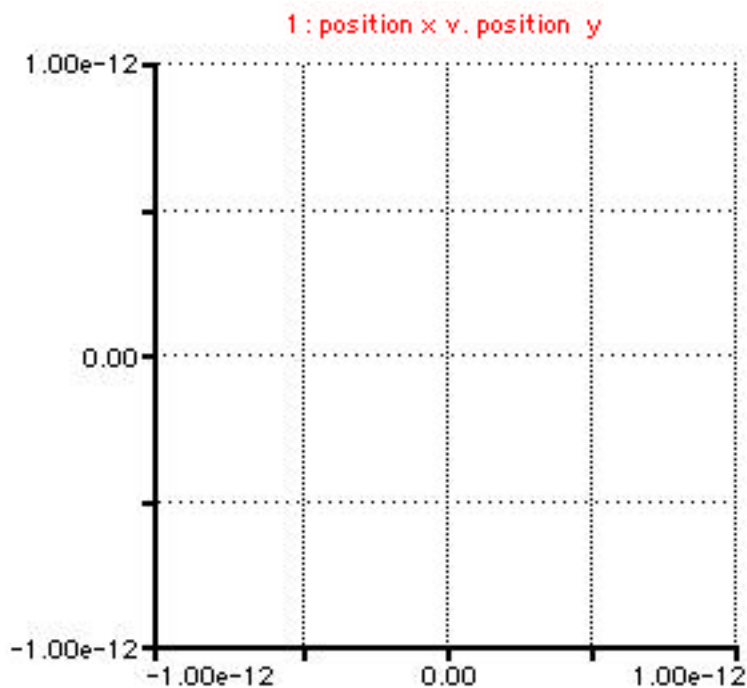
Q4. How did you decide where the gold nucleus was?

Q5. Why do particles starting at different y-positions follow different shaped paths?

8. Lock the graph by clicking on the padlock 🔓 in the lower left-hand corner. Locking the graph keeps it fixed when we do later runs using another graph.

Rutherford - Student Guide   2

9. Turn to the second page of the graph pad by clicking on the upturned page corner in the lower left-hand corner. Do not be surprised to see that it looks just like the first page. Look for the label Graph 1: p2 on the lower edge of the graph pad. If you are on the wrong page, continue clicking on the page corner until you see Graph 1: p2.
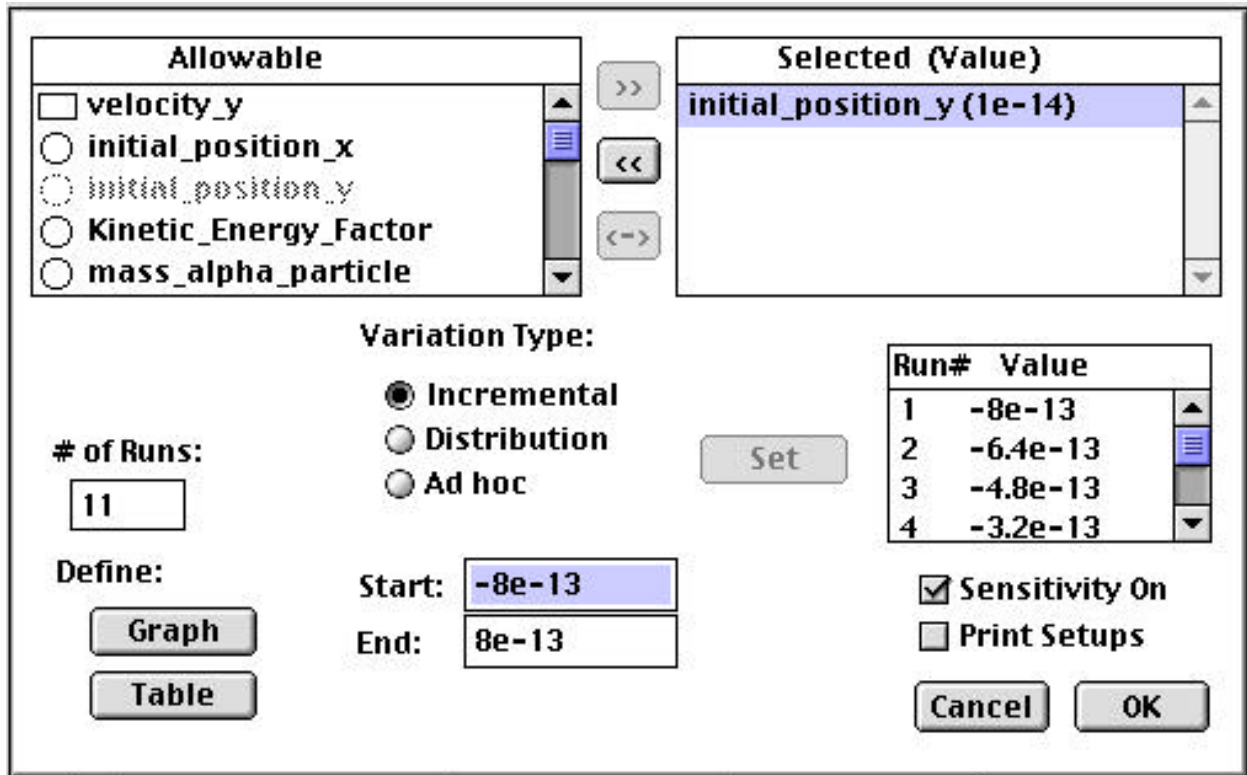
10. Clear this second graph by going to the Map menu and choosing Restore Graphs & Tables. (Don't worry, it won't clear the locked graph on page 1.)

11. Now that we have seen the deflection pattern of the paths of alpha particles bombarding gold foil with a Kinetic Energy Factor of 1.0, we will use the simulation to investigate the effect of changing the kinetic energy with which the beam of alpha particles is emitted.

12. Set the Kinetic Energy Factor slider to 2.0. This will double the initial kinetic energy.

13. At this point you could repeat the 11 runs you did in the first part using the y-position slider, or you could use a different function of STELLA (Sensi-Specs) to do the eleven runs automatically.

- Go to the Run menu and select Sensi-Specs.
- From the list of Allowable variables on the left, double-click on initial_position_y to move it to the Selected box.
- Change the # of Runs to 11 and click once on initial_position_y in the Selected box.
- Enter -8e-13 in the Start box and 8e-13 in the End box. Note that 8e-13 means 8×10^{-13}.
- Click on the Set button and you should see the numbers which you used for the first graph appear in the box at the bottom right.
- If your window looks like the one below, click OK.

14. Run the model (notice it is now an S-run).

> **Q6.** How does this graph compare to the first? (You can easily get to the first by clicking on the upturned page corner lower left-hand corner of the graph.)

15. Lock the second graph and click on the upturned page corner to see page 3 of the graph pad.

16. Clear this third graph by going to the Map menu and choosing Restore Graphs & Tables.

17. Set the Kinetic Energy Factor slider to 0.5 and run the model again.

> **Q7.** Describe any changes in page 3 of the graph compared to the other two pages.

> **Q8.** Why does changing the initial kinetic energy of the alpha particles change the shape of the curves?

18. Gold foil seems expensive. Why not aluminum foil? Lock the third graph and click on the upturned page corner to see page 4 of the graph pad. Clear this fourth graph by going to the Map menu and choosing Restore Graphs & Tables.

> **Q9**. What is the atomic number for aluminum?

19. Change the Z nucleus slider to 13 and return the kinetic energy slider to 1.00. Run the model one more time.

> **Q10.** How does this graph compare to the first one you made? Describe what the graph is telling you about the paths of the particles in relationship to the nucleus.

> **Q11.** Give a possible reason that aluminum foil caused less deflection in the paths than gold foil.

Q12. What is one possible reason why aluminum foil was not chosen by Rutherford for his experiment?

20. You have just completed an experiment in which you used a computer simulation to determine the optimal conditions under which the position of a nucleus may be easily determined when bombarded by a beam of alpha particles.

Q13. In this simulation, you have tested the effect of two different variables on the paths of alpha particles. List those variables.

Q14. Based on this simulation, describe how the two variables chosen in question 13 above should be changed so as to maximize the amount of deflection for an alpha particle fired from a specific location on the y-axis. Why should this combination maximize the deflection?