Rutherford’s Gold Foil Experiment
Teacher Guide

Purpose:

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 students will see likely paths of the alpha particles which were deflected. The undeflected particles are not shown.

Rutherford's Gold Foil Experiment
Teacher Answer Key

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

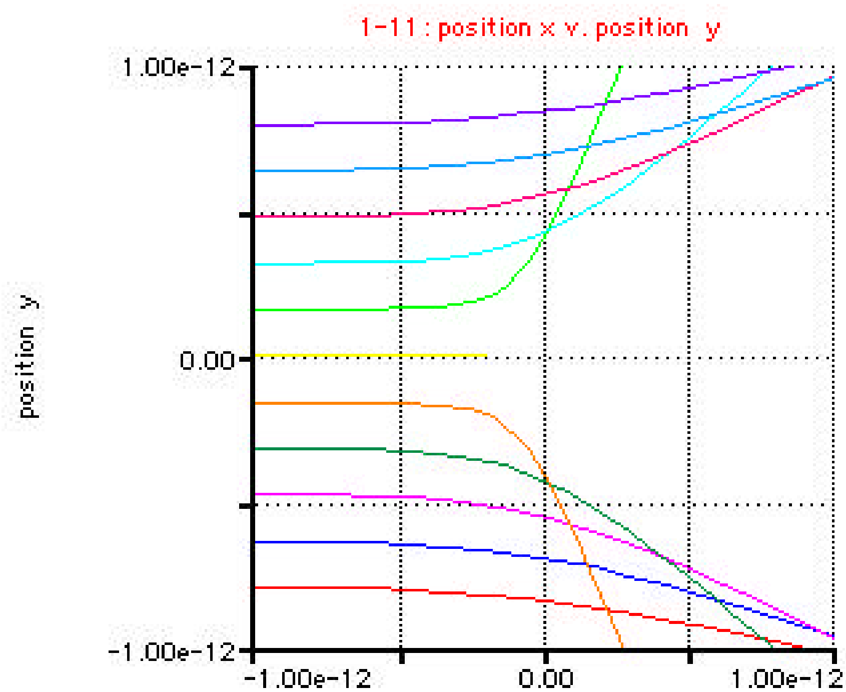
Z_alpha_particle = **2**

Z_nucleus = **79**

initial_position_x = **-1×10^{-12}**

Q2. What does Z stand for? **The atomic number of the nucleus**

Q3. Sketch the resulting graph on the axes provided. Indicate the probable position of the gold nucleus. **Hint: Students may enjoy using colored pencils to draw the graph.**



Q4. How did you decide where the gold nucleus was?

The gold nucleus would appear to be at (0,0) since the particles all veer away from that point.

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

Those that come closer to the gold nucleus will have greater changes in their paths than those that start at positions farther away. The closer they come, the greater the repulsion, the more the paths veer off.

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.) Describe what the graph is telling you about the paths of the particles in relationship to the nucleus.

> **The particles travel closer to the nucleus before veering off. The degree of curvature of their paths is not as steep. See Appendix for the graph.**

Q7. Describe any changes in page 3 of the graph compared to the other two pages. Describe what the graph is telling you about the paths of the particles in relationship to the nucleus.

> **Now the particles curve off much sooner and much sharper. See Appendix for the graph.**

Q8. Now that you have seen the paths of particles at three different kinetic energy levels, what can you conclude about the effect of the initial kinetic energy of the alpha particles on their paths? Justify your conclusions.

> **If the particles have more kinetic energy, it takes more force (or longer) to change their path and the change is not as great. If they have less, they are easily turned by the gold nucleus.**

Q9. What is the atomic number for aluminum?

> **13**

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.

> **The paths have much less curvature with aluminum foil than with the gold foil. See Appendix for the graph.**

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

> **The smaller charge of the nucleus means that the effect on the alpha particles is much less.**

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

> **The smaller charge of the nucleus results in a smaller effect on the alpha particles which results in less curvature in the paths. This might make it more difficult to detect the position of the nucleus.**

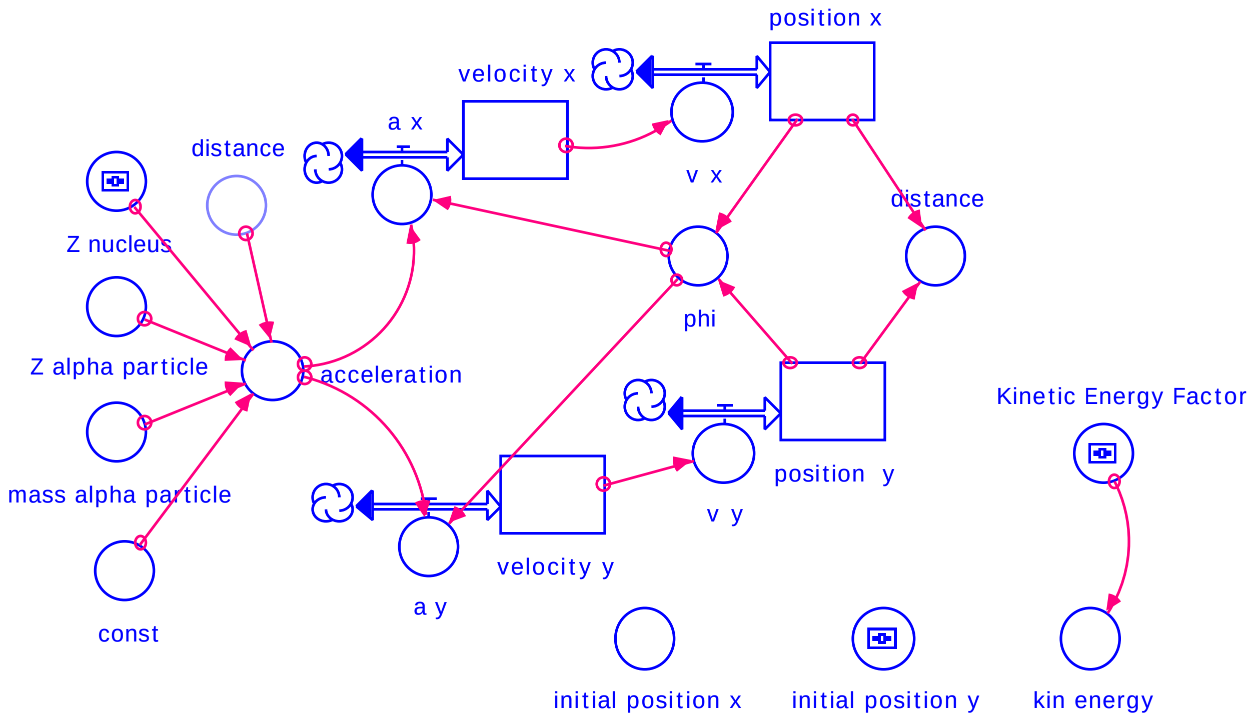
Q13. In this simulation, you have tested the effect of two different variables on the paths of alpha particles. List those variables.

> **a. initial kinetic energy of the alpha particle**
> **b. atomic number of the nucleus**

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?

> **The initial kinetic energy of the alpha particle should be small so that the particles are deflected more easily. The nucleus should have a large atomic number so that the alpha particles are deflected easily. This makes the detection of the nucleus easier.**

Rutherford's Gold Foil Experiment
Appendix



position_x(t) = position_x(t - dt) + (v_x) * dt
INIT position_x = initial_position_x
v_x = velocity_x

position__y(t) = position__y(t - dt) + (v_y) * dt
INIT position__y = initial_position_y
v_y = velocity_y

velocity_x(t) = velocity_x(t - dt) + (a_x) * dt
INIT velocity_x = SQRT(2*kin_energy/mass_alpha_particle)
a_x = acceleration*COS(phi)

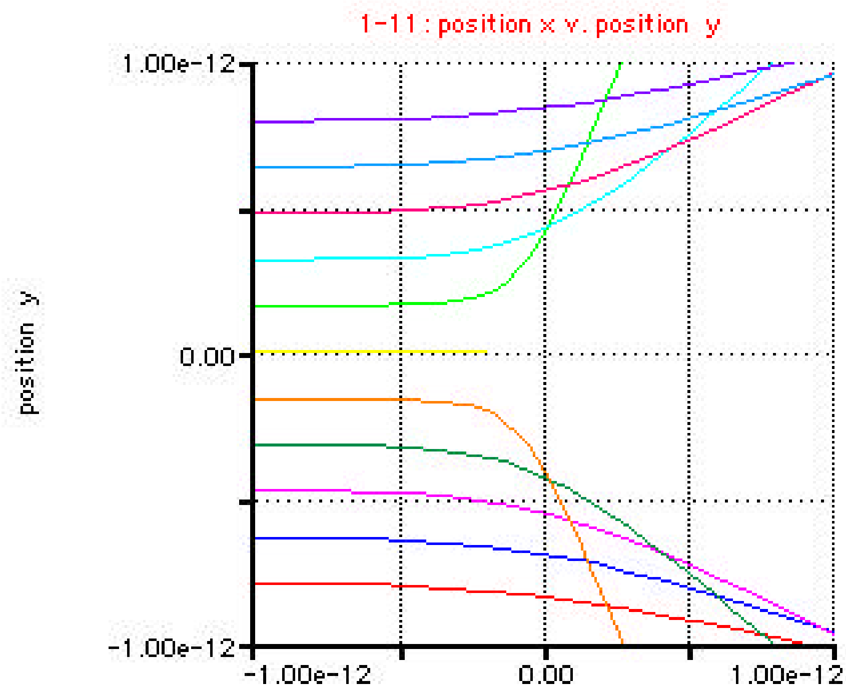
velocity_y(t) = velocity_y(t - dt) + (a_y) * dt
INIT velocity_y = 0
a_y = -acceleration*SIN(phi)

acceleration =
-const*Z_alpha_particle*Z_nucleus_gold*(1.6e19)^2/distance^2/mass_alpha_particle
const = 1/(4*PI*8.85E-12)
distance = SQRT(position_x^2+position__y^2)
initial_position_x = -1e-12
initial_position_y = .01e-12
Kinetic_Energy_Factor = 1
kin_energy = Kinetic_Energy_Factor*1e6 {eV} * 1.6e-19 {As}

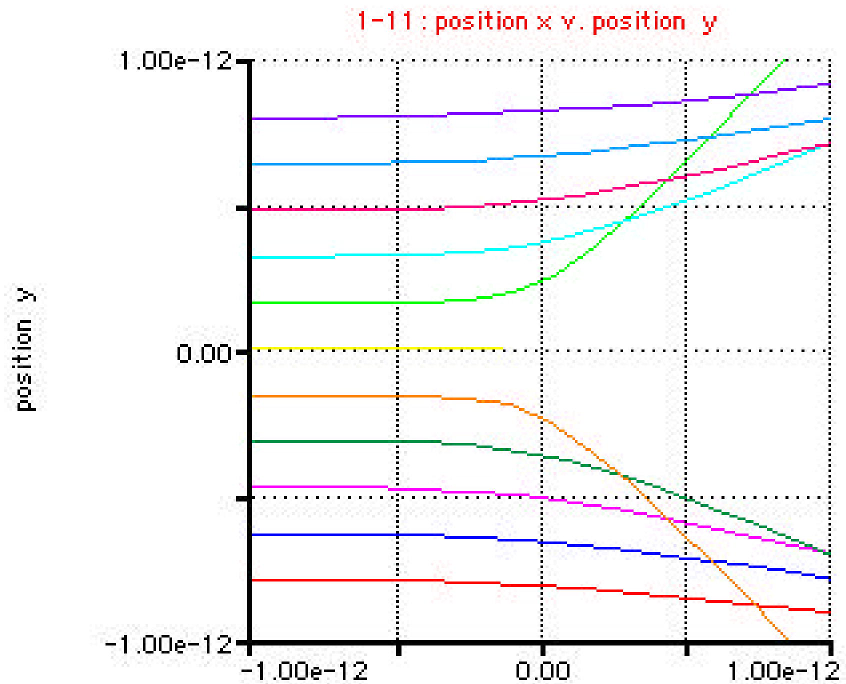
mass_alpha_particle = 4*1.66e-27 {kg}

phi = If position__y>=0 then SQRT((ARCTAN(position__y/position_x))^2) ELSE
- SQRT((ARCTAN(position__y/position_x))^2)
Z_alpha_particle = 2
Z_nucleus = 79

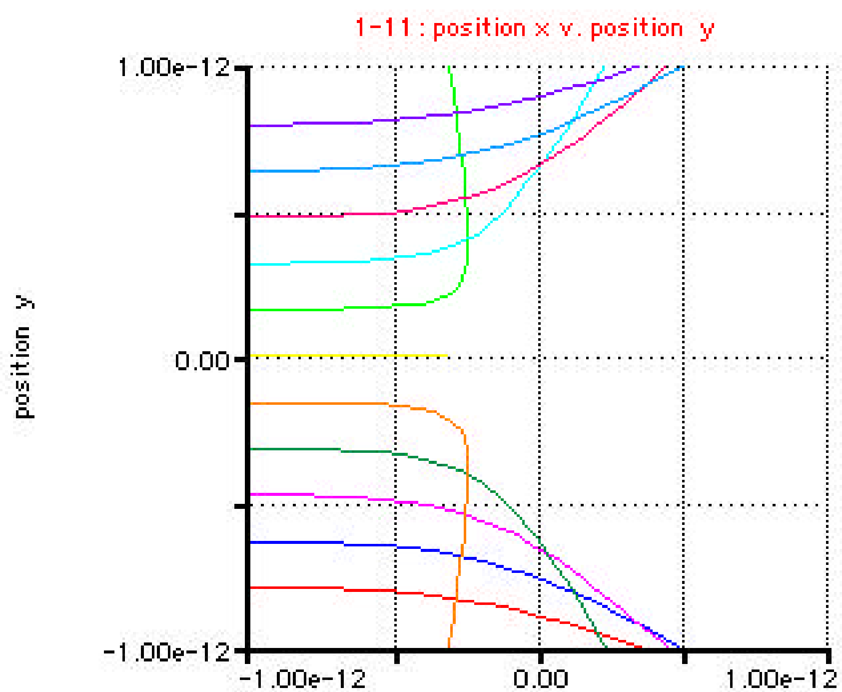
Gold Foil, Kinetic Energy Factor = 1
Graph 1:Page 1



Gold Foil, Kinetic Energy Factor = 2
Graph 1:Page 2



Gold Foil, Kinetic Energy Factor = 0.5
Graph 1:Page 3



Aluminum Foil, Kinetic Energy Factor = 1
Graph 1:Page 4