Activity worksheet: Thomson's and Rutherford's atomic models

Name	Group	Date

What you will learn

With the atomic models simulation you will repeat the experiment in which Rutherford discovered the nucleus of the atom. You will fire α particles at atoms and see why an experiment can force scientists to change a model.

How to work. Each activity has three steps:

1. **Predict.** Before looking at the simulation, write down what you think will happen and why.
2. **Observe.** Set up the simulation, watch what happens and note down the data.
3. **Explain.** Compare what happened with your prediction and explain why.

If your prediction turns out to be wrong, don't rub it out: getting it wrong and understanding why is the best way to learn.

Each activity has a link that opens the simulation already set up. If you have the worksheet on paper, go to **simulaciencia.es/en/simulations/modelos** and set it up as described under “Set up the simulation”.

α particles have two protons and two neutrons: their charge is positive. With the “One at a time (click)” firing mode, each click in the blue strip next to the source fires an α particle at that height. The “Angle graph” counts how much each particle is deflected, from 0° (it carries straight on) to 180° (it comes back).

Before you start

What do you think now? Write T (true) or F (false). You will come back to this table at the end.

Statement	T or F
a) The atom is a small solid ball, full of matter.	
b) An α particle bounces off the nucleus because it hits it, like a billiard ball.	
c) The nucleus takes up a large part of the atom.	
d) If scientists change their model, it is because the previous one was nonsense.	
e) α particles are deflected in the same way whatever the atom.	

Activity 1. Thomson's model

Set up the simulation: Thomson model, **Atom** view, Z = 79 (gold), firing one at a time. Open the simulation ready to use

Predict. In Thomson's model, the positive charge is spread over the whole atom and the electrons are embedded in it. If you fire α particles at this atom, what will happen to them?

My prediction

Observe. Fire at least eight particles at different heights.

How many go through the atom?	What is the largest deflection?	Do any come back?

Explain. According to Thomson's model, why are the α particles hardly deflected?

My explanation

Activity 2. The gold foil experiment

Set up the simulation: Thomson model, **Foil** view, Z = 79, continuous stream with emission switched on and the angle graph open. Open the simulation ready to use

Predict. Next you will switch to Rutherford's model, with a small nucleus where all the positive charge is concentrated. What difference do you expect in the graph?

My prediction

Observe. Wait for about 500 particles (n = 500) with each model. Hover over the bars to read their percentage. Change the model in the “Model” drop-down list.

Model	% in the first bar (0–10°)	Are there any red bars (more than 90°)?	Approximate % in the red bars
Thomson			
Rutherford			

Explain. Rutherford and his co-workers saw that some α particles bounced back. Why did that result force them to abandon Thomson's model?

My explanation

Activity 3. A tiny nucleus

Set up the simulation: Rutherford model, **Atom** view, Z = 79, firing one at a time. Open the simulation ready to use

Predict. What do you think will happen if you fire an α particle exactly at the height of the nucleus? And if you fire it far from the nucleus?

My prediction

Observe. Fire particles at different distances from the nucleus and draw their paths.

Height of the shot	What does the particle do?
At the height of the nucleus	
Just above the nucleus	
Far from the nucleus	

Explain.

1. Does the particle touch the nucleus before it is deflected? What force deflects it?
2. Why do most particles go through the atom without being deflected? What does that tell us about the atom?

My answers

Activity 4. More charge in the nucleus

Set up the simulation: Rutherford model, **Atom** view, Z = 1 (hydrogen). Open the simulation ready to use

Predict. Will an α particle be deflected more when it passes close to a hydrogen nucleus or a gold nucleus? Why?

My prediction

Observe. Always fire at the height of the nucleus and change the atomic number with the slider.

Atomic number Z	Element	What does the particle do?
1	Hydrogen	
14	Silicon	
79	Gold	

Explain. How is the number of protons in the nucleus related to the deflection of the α particle?

My explanation

Activity 5. Faster means less deflected

Set up the simulation: Rutherford model, **Atom** view, Z = 79 and speed 4. Open the simulation ready to use

Predict. If the α particle goes faster, will it be deflected more or less when it passes close to the nucleus?

My prediction

Observe. Always fire at the same height, just above the nucleus, with three different speeds.

Speed (“Energy”)	Approximate deflection (large, medium, small)
4	
10	
16	

Explain. Why is a faster particle deflected less?

My explanation

Activity 6. Challenge: what is missing from Rutherford's model?

Set up the simulation: Rutherford model, **Atom** view, Z = 14. Open the simulation ready to use

Observe. Describe the silicon atom: which particles are in the nucleus, how many there are and how the electrons are arranged.

Nucleus	Electron shells

Explain. The simulation draws the electrons in shells of 2, 8, 18... Rutherford did not know this. Which scientist later proposed that electrons are in energy levels? Which problem with Rutherford's model did it solve?

My explanation

Apply what you have learnt

Answer without the simulation.

1. Draw an atom according to Thomson's model and another according to Rutherford's. Mark where the positive charge is and where the electrons are.
2. The radius of an atom is about 100,000 times bigger than that of its nucleus. If the nucleus were a 1 cm marble, how big would the atom be? Compare it with something you know.
3. A classmate says: “Rutherford proved that Thomson was stupid”. Explain what is wrong with this sentence.
4. What would have happened in the experiment if the α particles had a negative charge?

Question	Answer
1	
2	
3	
4	

Review your ideas

Go back to the “Before you start” table. Would you change any of your answers? Write which one and explain why, using something you saw in the simulation.

What has changed in my ideas

Going further (Year 13 Physics)

1. In a head-on collision, the α particle stops at a minimum distance from the nucleus $r_{min} = k \cdot q \cdot Q / E_k$. If the energy of the particle is multiplied by four, what happens to r_{min}? Check it in the simulation with speeds 8 and 16.
2. Calculate the distance of closest approach of a 5 MeV α particle to a gold nucleus (Z = 79). Data: $k = 9 \cdot 10^9$ N·m²/C², $e = 1.6 \cdot 10^{-19}$ C.

My answers

Self-assessment

Put an X to show how confident you feel at the end.

I can...	Yes	Nearly	Not yet
Describe Thomson's and Rutherford's atomic models			
Explain the gold foil experiment and its result			
Explain why the atom is almost empty and the nucleus is tiny			
Explain why an experiment can make scientists change a model			
Use a prediction and an observation to change an idea I had			

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