SNC1D/1P Atoms, Elements, and Compounds/Exploring Matter

Teacher Demo/Student Activity: Finding the electron

Topics	Timing
atomic structure scientific method electrostatic attraction and repulsion	preparation: 30-45 min (first time only) demonstration: 5 min

Specific Expectations

SNC1D

A1.5 conduct inquiries, controlling some variables, adapting or extending procedures as required, and using standard equipment and materials safely, accurately, and effectively, to collect observations and data

A1.6 gather data from laboratory and other sources, and organize and record the data using appropriate formats, including tables, flow charts, graphs, and/or diagrams

A1.10 draw conclusions based on inquiry results and research findings, and justify their conclusions

C3.1 explain how different atomic models evolved as a result of experimental evidence (e.g., how the Thomson model of the atom changed as a result of the Rutherford gold-foil experiment)

C3.2 describe the characteristics of neutrons, protons, and electrons, including charge, location and relative mass

SNC1P

A1.5 conduct inquiries, controlling some variables, adapting or extending procedures as required, and using standard equipment and materials safely, accurately, and effectively, to collect observations and data

A1.6 gather data from laboratory and other sources, and organize and record the data using appropriate formats, including tables, flow charts, graphs, and/or diagrams

A1.10 draw conclusions based on inquiry results and research findings, and justify their conclusions

C3.1 identify the characteristics of neutrons, protons, and electrons, including charge, location, and relative mass

Introduction

Prior to Thomson's work it was thought that the atoms of each element were unique, invisible particles (as proposed by Dalton), or that atoms were made of subatomic particles that had significant mass compared to the atom as a whole. Thomson used Crookes tubes (see below) to disprove both of these ideas with his discovery of the electron, a negatively charged entity with a miniscule mass compared to that of the atom. Thomson applied a magnetic field to a discharge passing through a Crookes tube. He then used the data from this experiment to determine the mass-to-charge ratio of the particles emitted at the cathode. To his surprise, Thomson found that this ratio was constant regardless of the applied voltage. This implied that the particles emitted at the cathode were identical. Thomson predicted that these particles, which he called electrons, were a fundamental part of all elements of matter.

This demonstration allows students to simulate the results that Thomson would have observed for a variety of different atomic models.

Crookes Tubes

Crookes tubes emit electrons through the application of high voltage. These electrons then flow through a partial vacuum from the cathode (negative electrode) to the anode (positive electrode) in straight lines. The glow observed in these tubes results from electrons interacting with the residual gas in the tube or with a screen placed inside the tube. The path of a beam of electrons, like that of any charged particle, can be influenced by the application of a magnetic field.

Materials

- safety goggles
- a ramp and horizontal track, about 3 times the width of the marbles, made from any materials available (e.g., Hot Wheels track, cardboard, Plexiglas, wood)
- rare metal earth magnets or other very strong magnets
- tape
- glass marbles
- stainless steel ball bearings of a similar size to the marbles
- stainless steel ball bearing of a very small diameter

Safety Considerations

- Provide MSDS sheets for all chemicals used.
- Rare-earth magnets can shatter if they are allowed to snap together quickly. Handle them with caution.
- Handle strong magnets with care: two together can painfully pinch skin.
- Do not place magnets close to electronic equipment as they can damage it permanently.
- Do not try to modify rare-earth magnets because the powder created during machining is highly flammable.

Procedure

Wear appropriate PPE: safety goggles.
Construct the following apparatus before class:

1. Make a curved ramp (shown blue in Fig.1) using cardboard, Hot Wheels track, or any other stable flat material. If the horizontal portion can be constructed of Plexiglas this will allow students to observe the path of the balls when the apparatus is placed on an overhead projector.
2. Use cardboard or Plexiglas (depending on the availability of materials) to create the walls (shown in grey in Fig.2). The walls should be sturdy enough to support the magnets.
3. Tape the magnets (shown as large dark grey circles) to the side walls, midway along the horizontal portion of the track.
4. Attach a barrier to the end of the track to stop the marbles and ball bearings from flying across the room.

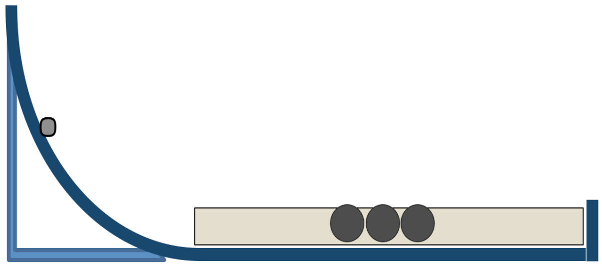

Fig.1 Side view

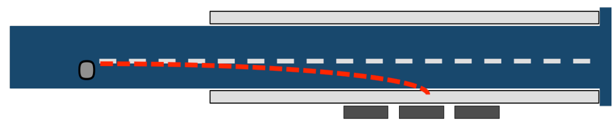

Fig.2 Top view

5. Once the apparatus is set up, conduct some trials runs to optimize the demonstration and get the desired results. The top of the ramp represents the cathode. The barrier at the end represents the anode.
    a. Check that all the ball bearings are actually magnetic.
    b. The marbles (representing unique atoms according to Dalton's theory) and large ball bearings (representing cations according to the Rutherford theory) should run completely straight down the ramp and along the horizontal track (white dashed line in Fig.2). The speed of the marble or ball bearing will be controlled by how far up the ramp it is released. The large ball bearings should track straight, because the protons have too great a mass to be easily deflected by the magnetic field. Adjust the speed of the ball bearing as well as the distance from the ball bearing to the magnets to achieve this.
    c. The small ball bearings (representing electrons) should be deflected by the magnet (red dashed line in Fig.2). To increase the accuracy of the model, the small and large ball bearings should be released from the same height with the desired results.

For the demonstration, the students should wear safety glasses in case the magnets shatter or the marbles chip.

6. Show the video of how the cathode ray tube works (#2 in Additional Resources).
7. Explain the set up of the simulated cathode ray tube.
8. Show the students the marble and ball bearings, explaining that these are the subatomic particles in an atom.
9. **Predict/Explain**
   Ask the students to predict which of the three balls would represent the electron. Have the students justify their choice.
10. **Observe**
    Let each of the different "sub-atomic particles" roll through the "cathode ray tube". The students should record the deflection/impact point of each.
11. **Explain**
    Have the students explain their observations and make connections to the particles found in the atom.

Disposal

Store the apparatus for future use to save preparation time.

What happens?

The marbles will roll straight down the track, from the "cathode" to the "anode". The large ball bearings will also roll straight down the track, but the small ball bearings will be pulled off to one side.

How does it work?

The marbles cannot be deflected from their path by the magnets, because they do not contain magnetic metals. If the apparatus is calibrated properly the greater momentum of the large ball bearings will prevent them from being deflected significantly by the magnets, but their magnetic nature represents the fact that they have a charge. The small ball bearings will have less momentum and will therefore be much more easily deflected by the magnets.

Teaching Suggestions/Hints

1. Make sure that you use paramagnetic ball bearings (slightly attracted to a magnetic field) for this activity.
2. Since operating the activity requires practice to find the right place from which to release the "particles," it works more smoothly as a teacher demonstration than as a student activity.
3. The marbles will give the result that would have been expected for Dalton's atomic model. Different colours and sizes of marbles can be used to emphasize this point. The paramagnetic ball bearings represent charged subatomic particles with different masses. Releasing equal numbers of large and small ball bearings simultaneously is the best representation of Thomson's actual experiment, where both electrons and cations are present in the Crookes tube.

Next Steps

Continue to progress through the development of the atomic model, by moving onto a discussion, and a demonstration, of "Rutherford's Black Box".

Additional Resources

1. A short narrative of J. J. Thomson's work at Cambridge University and his discovery of the electron: http://www.youtube.com/watch?v=IdTxGJjA4Jw -
2. A demonstration of Crooke's tube is provided with an explanation of how it works: http://www.youtube.com/watch?v=XU8nMKkzbT8 –