Scope, Sequence & Coordination

A National Curriculum Development and Evaluation Project for High School Science Education

SS
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Scope, Sequence & Coordination

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Student Materials

Learning Sequence Item:

962

Evidence Revealing the Composition of the Atom

March 1996
Adapted by: John Laffan and Linda W. Crow

Contents

This micro-unit was adapted by **John Laffan** (Clinton High School, Clinton, N.Y.) and **Linda W. Crow** (Baylor College of Medicine, Houston, Texas)

Science as Inquiry

The Mystery Box

Overview:

Procedure:

Select a Mystery box. Without opening it, try to learn about its contents by using all the tools of observation available to you. Outline your plan to determine the contents of the box and record all observations you make.

Questions:

1. What evidence supports your conclusion about the type of item contained in the box.

3. What kinds of questions did you ask once you were given the opportunity to ask questions?

3. What kinds of things can you do to determine the contents of your box if you had access to other kinds of observational tools?

4. Since you can see what is inside, how can you be 100% sure of its contents?

Science as Inquiry

Hit the Penny

Overview:

Procedure:

Place a sheet of paper on the floor and put a penny somewhere on it. From a height of several feet above the floor, drop a pencil. If the pencil hits the penny, record it as a hit. If it hits the paper, record it as a miss. Ignore all trials where the pencil lands outside the area bounded by the paper. Do this for at least 100 trials.

Questions:

1. How did the number of penny hits compare to the total number of trials? Express this result as a ratio.

2. What would the ratio of the number of hits to trials be if all the data for your class were combined?

3. Now, combine the number of hits for all groups in your class. How does this number compare to the total number of trials performed? Express your answer as a ratio.

4. What is the area of the penny? How does it compare it to the area of the paper? Express your result as a ratio.

5. How would you find the area of a quarter if all you had was a piece of notebook paper, a quarter and a pencil?

6. What method could you use to find the size of an object which is suspended in the center of a cardboard box?

7. Why did we do so many trials?

8. What would we find if we did only 50 trials? How about 10,000 trials?

Science as Inquiry

Size by Some Chance

Overview:

Procedure:

Arrange the pennies on the sheet of paper in a random fashion. Try to distribute them evenly across the whole paper. Drop the pencil onto the paper from a height of four or five feet 40 to 50 times. Record the number of times the pencil strikes the sheet and the number of times it strikes a penny. All drops which miss the paper are to be neglected.

Questions:

1. Using just the data you have collected, what is the area of a single penny?

2. How did you arrive at your result?

3. What other measurements can you make by using this method?

Science as Inquiry

My Ruler isn't This Good

Overview:

Procedure:

Place six to nine marbles in an area which is 60 cm wide. Roll additional marbles randomly toward the entire target area. Release the marbles from a point which is about a meter from the target area. If the rolling marble hits two nuclear marbles, count just one hit. If the rolling marble goes outside the 60-cm-wide area, do not count that trial. At least 200 trials need to be completed. Be sure to record the total number of trials and the total number of hits for all trials.

Questions:

1. Using your data, what is the probability of hitting a target marble?

2. Without using a measuring device such as a ruler, what is the diameter of the marble?

3. How does this activity simulate what Rutherford did with alpha particles and gold foil?

Student Sheet

Science as Inquiry

Just Past That Hill

Overview:

Procedure:

Mold a volcano-shaped hill, of base diameter 2 to 4 cm, out of plastic modeling clay and wrap it with one layer of plastic wrap. Place the hill in the center of a long flat desk or lab table—or on a space on the floor. At one end of this area place a border made from modeling clay. This will serve to catch the marbles that are rolled past the hill. It may also be helpful to create a sort of bowling alley by constructing a rectangular area which is surrounded by books. Gently roll the marbles, one at a time and at random from one end of the alley past or into the hill. Observe the paths the marbles take as they pass by the hill or interact with it.

Questions:

1. Hod do the shapes of each of these paths compare?

2. How do your observations of these paths help you to create a mental picture of an atom?

3. When Rutherford fired alpha particles (which have a positive charge) at gold foil what did he find?

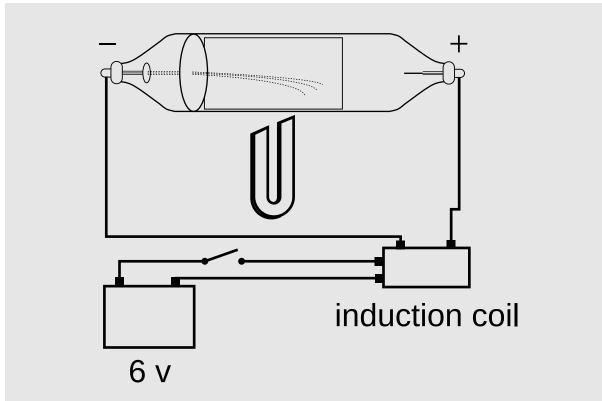
4. Describe a model of the atom which would be consistent with your observations of rolling marbles. Pretend the marbles and the hill are both charged positively?

5. Could you determine the size of the hill by rolling marbles past it? What kinds of problems are there with this method of determining size?

Science as Inquiry

How Do We Know that Atoms Exist?

Many students in the United States have been told about the atomic nature of matter. Their teachers have told them or they have read in their science books, that atoms are made up of a nucleus (containing neutrons. and protons) that is surrounded by electrons. It is easy to describe and explain this model of the atom. It is also easy to explain and describe the parts that make-up the atom. What is not so easy to b understand is how we know that there are atoms, electrons, protons, and neutrons. Nor. is it easy to understand how we know how atoms are put together.



How do we know that there are atoms?

Our belief in atoms came many years ago through chemistry. Scientists found that when iron and oxygen combined to form rust, the amounts involved followed an interesting pattern. The mass of iron and the mass of oxygen was always in the same ratio. For example, if 56 grams of iron reacted completely with 16 grams of oxygen, you would get 72 grams of rust, or iron oxide. If you used more iron and the same amount of oxygen. you still made 72 grams of rust. All the iron over the 56 grams would remain iron. This sort of thing happens in all chemical reactions .

Scientists wanted to explain these observations about chemical reactions. They imagined that iron was made up of tiny pieces. They called these pieces atoms of iron. Oxygen was also be made up of tiny pieces called atoms of oxygen. If each of these substances had very tiny masses, (iron-56 units and oxygen-16 units), then we could compare their masses in a mass ratio of 56 to 16 (56:16 iron to oxygen). If we imagine that they must combine one atom to one atom, sort of hooking on to each other, then when we have billions of pairs of these combinations, which we call molecules with combined masses of 72 units each. The mass ratio of iron to oxygen would still be the same, 56 units:16 units, iron to oxygen.

Over the years. the existence of atoms has been documented through many different kinds of experiments and in many ways. Now we have certain kinds of supermicroscopes through which we can see individual atoms.

What about electrons, protons, and neutrons? ❑

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Science as Inquiry

How Do We Know there are Electrons and Protons?

How do we know there are Electrons?

Most of our evidence for electrons originated from experiments with sparks which inside of glass tubes are called discharges. Some of the glass tubes are similar to your television tubes. These early experiments led to the development of the picture tube.

Certain phosphor coatings on metal plates can be made to light up when struck by electrically charged particles. Early experiments sent unknown radiations from radioactive elements along a path. The radiations struck the phosphor coated metal plates causing them to light up. By placing magnets and electrically charged plates nearby. scientists could study the unknown radiations to better understand what the radiations where.

A very famous scientist, Dr. J. J. Thomson studied a kind of unknown radiation called beta particles. He found out that they had a negative electric charge. He found this by studying a beam of these particles. As the particle beam passed a magnet, they bent. The bending of the particle path was what Thomson would see for a negatively charged particle.

Thomson could not tell by the bending how much negative charge was on the particles or how much mass the particles had. The bending as the beam passed the magnet did tell Thomson that the ratio of charge to mass had to be a certain amount. This would be like saying, “I don’t know how much you weigh or how tall you are. I do know that the numerical value of your weight is 30 times more then your height in meters. If I could measure one of these numbers. your weight or height, I could calculate the other measurement.” In 1897, Thomson called these negatively charged particles electrons.

In the early 1900s, Robert Millikan carried out some remarkable experiments. He moved drops of oil between two metal plates connected to a battery. What he saw was very exciting. The only way a drop of oil could move upward would be if it were electrically charged. Millikan had several charged drops that he could watch. Every now and then, he would change the charge on the drops using a radioactive source. What Millikan saw was that the charged drops of oil would move upward at a certain speed, or twice that speed, or three times that speed. The drops would not move upward at a speed in between one, two, or three times the beginning speed. This was exciting because it meant that the charges on the drops of oil could only be one chunk, two chunks, or three chunks of charge. Never anything smaller than the smallest chunk, or never a charge in between chunks. Millikan realized that the smallest chunk was a single extra electron riding on the oil drop. In this way, he was able to measure the charge on a single electron. one of the smallest bits of matter in the universe.

Not only did Millikan find the charge on the electron, because he knew the ratio of charge to mass, Millikan “weighed” the electron. For the first time, we knew the charge and the mass of this fundamental particle of nature.

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How do we know there are protons?

Early experiments in chemistry led to the idea that atoms existed. When the mass of the electron was found, it was much too small to account for the mass of atoms.

Atoms were known to be electrically neutral. After all, a piece of iron or aluminum does not shock you. We know that there are electrons in elements because we see them coming out in the form of beta rays. Electrons can easily be knocked out of atoms. Since the atom is electrically neutral, scientists argued that there must be a positive charge in atoms for every electron's negative charge. But no one knew what these plus charges were or how they were arranged inside the atoms. ❐

Science as Inquiry

How Do We Know there is a Nucleus for the Atom and that it Contains Neutrons??

How do we know there is a nucleus for the atom?

J. J. Thomson tried to imagine what the atom might look like. He suggested that the atom was like a plum-pudding. The atom was a ball of plus charge. It contained most of the mass of the atom. The electrons were like plums stuck at various places inside the ball. You might want to think of the atom as a chocolate chip cookie instead of a plum pudding. The cookie would be the plus charge. It would contain most of the mass of the atom. The chips would be the electrons having the negative charge of the atom but very little mass.

This model of the atom was studied all over the world by scientists. In England, a scientist named Ernst Rutherford studied the model by firing alpha particles into atoms of gold in a thin gold foil. If the Thomson model of the atom was valid, the particles should go straight through the gold foil. An alpha particle's mass is 4,000 times greater than the mass of an electron. If an alpha particle passed a electron, it would only be slightly deflected by the charge of the electron because the electron's mass is too small to the change the path of the massive alpha. The cookie part of the atom would not deflect the alpha either. The cookie's mass is great enough; however, the charge is spread out over a large area. No one area has a great enough charge to deflect the alpha.

You can imagine the shock and excitement when one of Rutherford's graduate students saw alpha particles hitting the gold foil and occasionally being bounced backward. This could only happen if they were hitting something very, very heavy and very, very small. From calculations of the number of such deflections and their direction, Rutherford was able to show that most of the mass of the atom was concentrated in a very small area. He called this area the nucleus.

This discovery would change the entire way we look at atoms. Now we could imagine atoms made up of a nucleus of plus charges surrounded by electrons.

How do we know there are Neutrons?

Not only were electron beams studied in the late 1800s and early 1900s, many experiments were done where beams of particles were fired into targets to see what would come out. One experiment gave very strange results.

When a beam of protons was fired into a certain metal target, the radiation coming out had certain peculiar properties. The radiation would not bend in a magnetic field: so it was not charged. It was not an intact atom, because it was highly penetrating going through metal shields. The only thing that could penetrate metal shields were x-rays or gamma-rays.

Scientists, measured how much penetrating power these strange rays had. Working backward, they figured out how much energy the beam of protons had to have to produce x-rays

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or gamma-rays. The energy did not add up correctly. When Chadwick, a scientist. examined the data, he assumed the strange radiation was a particle that had the same mass as a proton but was neutral in charge. He called the particle a neutron.

With the discovery of the neutron , scientists could describe atoms as a nucleus containing neutrons and protons, with electrons surrounding the nucleus. This is the basic model we use for the atom. In more modern theories, the way the electrons are arranged and move has been refined. ▲