Dinner with Democritus

Introduction

This is an opportunity of a lifetime—travel back in time to meet the Greek philosopher Democritus and fill him in on the history of the atom. How far has the atom evolved since he defined it over 2400 years ago?

Science Concepts

- Atomic models
- Subatomic particles (protons, electrons, neutrons)

Background

Democritus (circa 460–370 BC) gave birth to the concept of the atom. Democritus was a Greek philosopher who built on the ideas of other philosophers including Leucippus, his teacher. He produced a more elaborate view of the atom by saying that it is impossible to divide the atom into infinitely smaller and smaller pieces. He proposed that all material was made of small, indivisible, incompressible, eternal (imperishable) elements he called "atomos." It took almost 2200 years before anyone accepted this atomic model.

In 1803, John Dalton (1766–1844), a British chemist and physicist, developed the atomic theory of matter. The theory states that each element is composed of small, indestructible particles, called atoms, which are alike and have the same size, mass, and chemical characteristics. Furthermore, Dalton said atoms of one element differ from those of another element in terms of their mass. Atoms cannot be created, divided, or destroyed, and they must therefore combine in whole number ratios to form compounds. Essentially, Dalton thought that atoms were tiny, hard spheres. He developed his theory after observing and measuring the properties of gases, a result of his interest in meteorology. It was not long before Dalton's "modern" atomic theory was modified further.

In 1897, an English scientist, Joseph John "J. J." Thomson (1856–1940), proposed what became known as the "plum pudding" model of the atom. He too was interested in gases and conducted experiments in which he passed an electric current through a gas in an evacuated tube called a Crookes tube, which is now referred to as a cathode ray tube. As a result, the gas gave off negative particles which Thomson detected based on deflection by a magnet between charged plates. He called these particles corpuscles, which later became known as electrons. Since the overall atoms were neutral, or uncharged, the negative particles had to come form inside the atom, which meant that an atom was not indivisible—it was made of smaller particles! Thomson was not able to find a positively charged counterpart for the corpuscle, so he concluded that the negative corpuscles were suspended in a positive pudding-like material. In 1910 Robert Millikan (1868–1953), through his famous oil drop experiment, determined the size of the charge of an electron. However, Thomson's model still did not provide all the answers.

The British physicist Ernest Rutherford (1871–1937), in 1911, devised an experiment to test Thomson's model. Rutherford set up a sheet of gold that was hammered very thin (2000 atoms thick) and fired a stream of positively charged particles at it. He surrounded the sheet with a screen that was coated with a material that would glow when struck with positively charged particles. He had to use a telescope to see the light produced by the particles hitting the screen. If Thomson's solid sphere model were correct, the large positively charged particles would shoot straight through the thin foil. Rutherford was surprised to find that, although most of the particles did pass straight through the foil, some of the particles were deflected greatly, as if they had hit something solid. Since like charges repel, Rutherford concluded that atoms must be mostly empty space with a tiny, dense, positive nucleus at the core and lighter negative electrons scattered at the atom's edge. He concluded that the majority of the atom's mass was confined to the nucleus. Although this nuclear model of the atom was getting closer, Rutherford still did not have the entire picture.

In 1913, the Danish physicist, Niels Bohr (1885–1962) improved the atomic model by proposing that electrons reside in specific energy levels. He believed that, like the planets orbit the sun, electrons orbit the nucleus in fixed orbits located at definite distances from the nucleus. He also stated that the chemical properties of the element were dependent on the number of electrons in the outer orbits and that photons were emitted when electrons drop from a higher energy orbit to a lower energy orbit, otherwise it did not emit energy. Although the Bohr model explains the hydrogen atom, it does not work for more complex atoms.

In 1926, the Austrian physicist Erwin Schrödinger (1887–1961), proposed an atomic model based on the principles of wave mechanics, which involve complex mathematical equations. Electrons are treated as three-dimensional waves. This wave model is also called the electron cloud model or the quantum mechanics model. In this model, electrons do not

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move like planets orbiting the sun, rather their exact location is impossible to predict and is represented as a cloud. Based on how much energy the electrons have, a probable location can be determined. There was still one major problem with the overall model—the atoms were missing mass.

The number of protons (the atomic number) only accounted for about half of the mass in the nucleus of an atom. In 1932, English physicist James Chadwick (1891–1974) identified the third subatomic particle, the neutron. Neutrons have no electrical charge and a mass approximately equal to that of a proton. Isotopes are formed by atoms of the same element when they have a different number of neutrons. The discovery of the neutron solved a major problem, but was this everything there was to know about the atom?

The three subatomic particles, the proton, neutron, and electron were discovered but are these fundamental particles? Over 2200 years ago it was believed that the atom was a fundamental particle. This is, of course, not true since the atom can be divided into protons, neutrons, and electrons. Can protons, neutrons, and electrons be divided into smaller particles? The answer is "yes," at least in the case of protons and neutrons. Scientists have discovered that protons and neutrons can be divided into particles called quarks. Are quarks fundamental particles? Yes, in fact there are six flavors of quarks, antiquarks, leptons, and antileptons that make up all the known fundamental particles. The electron is one flavor of lepton so it is a fundamental particle. What holds all these particles together?

There are four fundamental forces or interactions between these particles. The strong force, the weak force, gravity, and the electromagnetic force are the four fundamental forces. The electromagnetic force is the force that causes like things to repel and opposite things to attract. The strong force is the force responsible for keeping the protons tightly packed in the nucleus instead of being blown apart by the electromagnetic force. Weak interactions result in the decay of massive quarks and leptons into lighter quarks and leptons. Gravity actually has the least effect on the fundamental particles.

Is there still more to learn? Does the Standard Model of the atom hold all the answers? Scientists are still trying to solve the mystery of the atom, its component particles and even antiparticles, and their associated masses, charges, and forces.

Materials

Composition book

Map pencils or crayons

Safety Precautions

Although the materials in this activity are considered nonhazardous, please follow all normal laboratory safety precautions.

Preparation

Research the history of the atom using the Internet, textbooks, encyclopedias, other reference volumes, and the local library.

Procedure

1. Using the composition book and research notes, create a diary entry for each discovery or advancement as it relates to the atom. The entries should be written from the atom's perspective as if it were a "live" person.
2. Each entry should include the date, the names of the scientists involved, a summary of the discovery or advancement, and any appropriate diagrams.

Tips

- The diary should be written from the atom's perspective and should chronicle the "life" of the atom from the first proposal by Democritus through the modern concept of the atom. Each entry should describe the atom's experiences.
- Instead of a diary, students could provide one of the following products to prepare them for their meeting with Democritus and the class presentation:
    1. Prepare a brochure for each advancement in the concept of the atom. The illustrated brochures should include the date, scientists involved, and the impact on the accepted atomic theory.
    2. Develop a comic strip in which each major advancement in the theory of the atom is discussed in three to five

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panels.

3. Write a fable, similar to a children's book, using illustrations and text to chronicle the "life" and "adventures" of the atom through time.
4. Write a movie script with the atom as the main character. The movie will be a documentary about the history of the atom and should include drawings or sketches for each scene.
5. Prepare a pamphlet that outlines the history of the atom. The pamphlet should be illustrated and in chronological order.
6. Write a play in which the atom is the main character. Draw sketches to show the stage hands how to set up each scene.

- Set length limits and specify the minimum number of entries for each product. Should there be at least 8 or 10 advances or discoveries listed; should there be a separate listing for each subatomic particle, etc.?
- Composition books may be purchased at many super stores. As an alternative, provide 15–20 sheets of typing paper, place them in a stack, fold them in half, and staple them to make a small book.

Extensions

The student is invited to travel back in time to have dinner with Democritus and should use the diary and its contents to deliver a presentation in front of the class just as the student would to Democritus.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Systems, order, and organization
Evidence, models, and explanation
Constancy, change, and measurement
Evolution and equilibrium
Form and function

Content Standards: Grades 5–8
Content Standard B: Physical Science, properties and changes of properties in matter
Content Standard E: Science and Technology
Content Standard G: History and Nature of Science

Content Standards: Grades 9–12
Content Standard B: Physical Science, structure of atoms, structure and properties of matter
Content Standard E: Science and Technology
Content Standard G: History and Nature of Science

Materials for *Dinner with Democritus* are available from Flinn Scientific, Inc.

Catalog No.	Description
FB0643	Assorted Color Pencils, 12

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