

Elements of Physics

Matter: Atoms and Molecules

Teacher's Guide



Grade Level: 9–12

Curriculum Focus: Physical Science

Lesson Duration: Three class periods

Program Description

Investigate the common characteristics of atoms and how they combine to form elements. Students learn about electrons, neutrons, and protons, as well as how elements form molecules.

Onscreen Questions

- What is the difference between a compound and a mixture?
 - Why do some atoms form ions?
 - How do scientists locate black holes?
 - How does matter become a black hole?
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Lesson Plan

Student Objectives

- Explain scientists' ideas about the structure of the atom over the last century.
- Describe the scientific underpinnings of the different models that have been proposed.
- Communicate the progression of ideas about the structure of the atom through words and pictures.

Materials

- *Elements of Physics: Matter: Atoms and Molecules* video
- Computer with Internet access
- Print resources about the structure of the atom
- Sheets of poster board
- Markers and colored pencils

Procedures

1. Begin the lesson by asking students to draw a picture of what they think an atom looks like. Ask them to put their images away until the end of the lesson.
2. Tell students that the present-day model of the atom has evolved over many years. To give students some background into contemporary thinking, have them watch the segment “The Ties that Bind,” part of the program *Elements of Physics: Matter: Atoms and Molecules*.
3. Explain to students that the history behind our current thinking about the atom is an interesting example of how scientific ideas change as a result of experimentation. Tell students that they will work in small groups to develop a pictorial history of our changing ideas about the atom. They will draw each model proposed and write a caption describing what it shows and the scientific thinking behind the model. Tell students to make sure to show the relationship between the nucleus and the electrons in the drawings of each model.
4. Divide students into small groups of three or four. Give each group one or two sheets of poster board, and put out colored pencils and markers so that students have access to them. Give students time in class to research the topic. Suggest that they use any print resources available, or the Web sites below:
 - http://molaire1.club.fr/e_histoire.html
 - <http://everything2.com/index.pl?node=atom>
 - <http://www.lbl.gov/abc/wallchart/chapters/02/1.html>
 - <http://www.eurekalert.org/features/doe/2004-12/djna-emo122204.php>
 - <http://www.broadeducation.com/htmlDemos/AbsorbChem/HistoryAtom/page.htm>
 - <http://www.lbl.gov/abc/wallchart/chapters/02/4.html>

5. Here is a brief chronology summarizing the history of the atom.

“Plum-Pudding” Model

Based on the work of J.J. Thomson, who discovered that electrons have a negative charge (about 1897), this model presents the atom as a collection of negatively charged electrons mixed with positively charged particles.

Rutherford Atom

Based on the work of Ernest Rutherford in 1911, this model is the first to establish the nucleus in the center of the atom, with negatively charged electrons orbiting it, as planets orbit the sun.

Rutherford-Bohr Atom

In 1913, Niels Bohr improved upon the Rutherford model by stating that electrons travel the nucleus in a fixed orbit. At times, electrons can move from one energy level to another.

Charge-Cloud Model

With the emergence of Werner Heisenberg’s Uncertainty Principle, which states that it is impossible to know both the location and speed of an electron at the same time, scientists developed what is known as the charge-cloud model. According to this model, electrons move around the nucleus, but no attempt is made to show the orbital paths of the electrons. The electrons are depicted within a cloud to indicate that they are traveling at high speeds.

Quantum Model of the Nucleus

In 1930, James Chadwick discovered the neutron, which was found to have the same mass as the proton. With this discovery, it became clear that the mass of an atom came from the nucleus.

Nuclear Shell Model

This model is used to describe the behavior of electrons orbiting the nucleus of an atom. Electrons arrange themselves in shells around the atom, with the outermost shell called the valence shell. If this shell has eight electrons, it is considered stable. During chemical reactions, the valence shell will gain or lose electrons to increase its stability.

6. At the beginning of the next class, give students time to meet in groups and finish their drawings and captions. Then bring the class together for a discussion. Ask volunteers to share their ideas about the atom. Make sure that students understand the differences between each phase in the development of ideas about the structure of the atom.
7. Conclude the lesson by asking students to revisit the drawings they made before completing this activity. How have their ideas changed as a result of researching the atom? Do students think that ideas about the atom will continue to evolve? If so, what new ideas could emerge that might change thinking about the atom?

Assessment

Use the following three-point rubric to evaluate students' work during this lesson.

- **3 points:** Students showed a deep understanding of scientists' ideas about the atom; could describe in great detail the scientific underpinnings of each model of the atom; and were able to communicate their findings in words and pictures clearly and accurately.
- **2 points:** Students showed some understanding of scientists' ideas about the atom; could describe in some detail the scientific underpinnings of each model of the atom; and were able to communicate their findings in words and pictures satisfactorily.
- **1 point:** Students showed a weak understanding of scientists' ideas about the atom; had difficulty describing the scientific underpinnings of each model of the atom; and had difficulty communicating their findings in words and pictures.

Vocabulary

atom

Definition: The fundamental unit of matter made up of protons, neutrons, and electrons

Context: As scientists learn more about the relationship between electrons and the nucleus of an atom, their ideas about the atom and what it looks like change.

electron

Definition: A negatively charged part of an atom that moves in the space around the nucleus

Context: Electrons configure themselves around an atom in the most stable possible arrangement.

neutron

Definition: A particle found in the nucleus of an atom that does not have an electrical charge

Context: James Chadwick won the Nobel Prize in Physics for discovering the neutron.

proton

Definition: A particle found in the nucleus of an atom that has a positive electrical charge

Context: The protons of an atom stay bundled together in the nucleus because of the strong nuclear force found there.

quark

Definition: Tiny particles that are components of protons and neutrons

Context: The current thinking about protons and neutrons is that protons are made of three quarks that result in a positive charge, while neutrons are made of three quarks that result in no charge.

valence shell

Definition: The outermost shell of an atom that can gain or lose electrons during chemical reactions

Context: If there are eight electrons in the valence shell, then the atom is stable.

Academic Standards

National Academy of Sciences

The National Science Education Standards provide guidelines for teaching science as well as a coherent vision of what it means to be scientifically literate for students in grades K–12. To view the standards, visit <http://books.nap.edu/html/nses/html/overview.html#content>.

This lesson plan addresses the following national standards:

- Physical Science: Structure of atoms
- History and Nature of Science: Historical perspectives

Mid-continent Research for Education and Learning (McREL)

McREL's Content Knowledge: A Compendium of Standards and Benchmarks for K–12 Education addresses 14 content areas. To view the standards and benchmarks, visit <http://www.mcrel.org/compendium/browse.asp>.

This lesson plan addresses the following national standards:

- Science: Physical Sciences – Understands the structure and properties of matter
- Nature of Science – Understands the nature of scientific knowledge
- Language Arts: Viewing – Uses viewing skills and strategies to understand and interpret visual media; Writing: Uses the general skills and strategies of the writing process, Gathers and uses information for research purposes; Reading: Uses reading skills and strategies to understand and interpret a variety of informational texts

DVD Content

This program is available in an interactive DVD format. The following information and activities are specific to the DVD version.

How to Use the DVD

The DVD starting screen has the following options:

Play Video – This plays the video from start to finish. There are no programmed stops, except by using a remote control. With a computer, depending on the particular software player, a pause button is included with the other video controls.

Video Index – Here the video is divided into sections indicated by video thumbnail icons; brief descriptions are noted for each one. Watching all parts in sequence is similar to watching the video from start to finish. To play a particular segment, press Enter on the remote for TV playback; on a computer, click once to highlight a thumbnail and read the accompanying text description and click again to start the video.

Curriculum Units – These are specially edited video segments pulled from different sections of the video (see below). These nonlinear segments align with key ideas in the unit of instruction. They include onscreen pre- and post-viewing questions, reproduced below in this Teacher's Guide. Total running times for these segments are noted. To play a particular segment, press Enter on the TV remote or click once on the Curriculum Unit title on a computer.

Standards Link – Selecting this option displays a single screen that lists the national academic standards the video addresses.

Teacher Resources – This screen gives the technical support number and Web site address.

Video Index

I. Atoms: Nature's Building Blocks (4 min.)

Everything around us is comprised of matter and energy. But what makes up matter? Examine the parts of an atom and discover what makes matter.

II. The Ties That Bond (4 min.)

Most elements gain or lose electrons to increase their stability. Find out what is so important about stability and the difference between ionic and covalent chemical bonds.

III. Number of Neutrons (4 min.)

The number of protons in an element's atom stays the same, but the number of neutrons can vary. Learn about atomic mass and isotopes.

IV. Black Hole (38 min.)

Explore gravity and black hole theories to discover what happens when too much matter squeezes into one place.

Curriculum Units

1. Atoms and Matter

Pre-viewing question

Q: What is an atom?

A: An atom is the smallest whole unit of matter.

Post-viewing question

Q: Describe the parts of an atom.

A: Inside each atom is a nucleus made up of protons and neutrons surrounded by a cloud of particles called electrons. Protons have a positive charge, electrons have a negative charge, and neutrons have no charge. While the protons and neutrons remain in the nucleus, electrons fly around the nucleus in a cloud.

2. Valence Electrons and Atomic Bonds

Pre-viewing question

Q: What are some stable elements?

A: Answers will vary.

Post-viewing question

Q: What is the difference between an ionic and a covalent chemical bond?

A: In an ionic chemical bond, two ions bond because they are attracted to opposite electrical charges, as with sodium and chlorine. The ions stick together like magnets, giving away or taking electrons to create stable valence shells. In a covalent chemical bond, electrons are shared. An example is the bond between hydrogen and oxygen that forms water. When oxygen and hydrogen bond, the oxygen atom shares one electron with each of the two hydrogen atoms.

3. Atomic Mass, Isotopes, and Radiocarbon Dating

Pre-viewing question

Q: What information is displayed on a periodic chart?

A: Answers should include a list of known elements, atomic numbers of elements, atomic mass of elements, and atomic symbols of elements.

Post-viewing question

Q: What is an isotope?

A: An isotope is an atom with a different number of neutrons. The number of protons in an atom of an element remains the same, but the number of its neutrons can change. Isotopes usually share many of the same physical properties, but they can have unique properties such as radioactivity.

4. Searching for Black Holes

Pre-viewing question

Q: What do you know about black holes?

A: Answers will vary.

Post-viewing question

Q: What are the two kinds of black holes?

A: The two kinds of black holes are the stellar-mass black hole and the less common supermassive heavyweight. According to scientific theory, a stellar-mass black hole should weigh 10 times as much as a star like the sun, but it measures only the diameter of central London.

5. Newton, Michell, and Gravity

Pre-viewing question

Q: What was Isaac Newton's most important discovery?

A: Answers will vary.

Post-viewing question

Q: What did John Michell add to the Newtonian understanding of gravity?

A: Newton reasoned that all matter in the universe has gravity; it is a force that reaches from one body to another and pulls everything inward. The more mass an object has, the more gravity it has, and the stronger its inward pull. John Michell was the first person to combine Newton's idea of the inward pull of gravity with the knowledge that the speed of light is finite. Michell's giant leap was to imagine the ray of light leaving a star in the same way we view a rocket leaving the planet. For a rocket to escape the Earth's gravitational pull, it must push itself upward at 11 kilometers a second, faster than gravity pulls. Michell knew nothing of rockets, but he knew that in theory a massive star could have so much gravity that it could pull in rays of light traveling at 300,000 kilometers per second.

6. From White Dwarves to Black Holes

Pre-viewing question

Q: What kinds of objects have you observed in the night sky?

A: Answers will vary.

Post-viewing question

Q: What will happen to the sun when it runs out of nuclear fuel?

A: When the sun runs out of nuclear fuel, its own gravity will crush it into a ball the size of the Earth, but 100,000 times more dense. However, it has too little mass and too little gravity to become a black hole. Scientists refer to this type of star as a white dwarf.

7. Space-Time and the Singularity Concept

Pre-viewing question

Q: Is it necessary to see something to believe it?

A: Answers will vary.

Post-viewing question

Q: Describe the singularity concept and the event horizon.

A: The most terrifying concept in astrophysics lies at the bottom of a black hole, the singularity. Everything that has ever fallen into a black hole is destroyed at the singularity, crushed into a pinpoint of infinite density and smallness. All that remains in the outside universe is a perfect sphere of absolute darkness, a gravitational ghost of the star that died. This sphere is the event horizon, and it marks the edge of the abyss. It is only a few kilometers in diameter, but the immense gravity of the singularity would suck a hole inside it that is too deep to measure.

8. Speculations in Black Hole Theory

Pre-viewing question

Q: Do you think it will ever be possible to travel at or faster than the speed of light?

A: Answers will vary.

Post-viewing question

Q: What do scientists think happens when an object approaches the event horizon?

A: Scientists theorize that both space and time are stretched as an object approaches the event horizon. The closer an object gets to the event horizon, the harder light from it struggles to escape. Time doesn't change for the object, because gravity stretches its existence. But the object appears frozen in time. It is both destroyed in an instant and hovering for eternity, depending on one's point of view.