Introducing the Atom

Context

Elements are substances that cannot be broken down into simpler forms of matter, and they are the primary constituents of all matter. The elements are the basis of all chemical interactions, and the implications of the ways in which atoms interact are relevant to every aspect of our lives, from health to technology, energy, and the environment.

Essential Questions

- What is an element?
- What is an atom?
- What happens to an atom when its structure is changed?
- How do knowledge and understanding of elements impact different aspects of our lives?

Enduring Understandings

- All matter is made of atoms.
- Atoms consist of protons, neutrons, and electrons; the nucleus consists of protons and neutrons, with electrons orbiting in shells.
- Protons have a positive charge, electrons have a negative charge, and neutrons have no charge.
- Changing the numbers of protons, electrons, or neutrons changes an atom and can create different elements and isotopes; isotopes are atoms of a single element that differ in number of neutrons, and can be stable or unstable.
- Elements each have different properties that are useful to people in different ways.
- Some elements go through a process of radioactive decay. People utilize radioactivity in many ways, but it can also be dangerous.

Time

This activity can be completed in 1–2 class periods of approximately 50 minutes.

Grade Level

Grades 6–12

Differentiation

Activities can be completed as a class guided by the teacher, in groups, pairs, or individually based on students' abilities.

Materials

- Core Concepts: Periodic Table
- Index cards
- Paper/pencils
- Supplement chart "Changing the Properties of an Atom"

Student Learning Objectives

- Students will be able to define *atom* and *element* in their own words, and demonstrate an understanding of the structure of atoms by creating a physical model or illustrated depiction of an element when provided with number or protons, neutrons, electrons.
- Students will understand that the periodic table is a graphic representation of all known elements and that it contains information about the properties of each element.

Next Generation Science Standards Addressed	
MS-PS1-1.	**Develop models to describe the atomic composition of simple molecules and extended structures.** [Clarification Statement: Emphasis is on developing models of molecules that vary in complexity. Examples of simple molecules could include ammonia and methanol. Examples of extended structures could include sodium chloride or diamonds. Examples of molecular-level models could include drawings, 3D ball and stick structures, or computer representations showing different molecules with different types of atoms.] [*Assessment Boundary: Assessment does not include valence electrons and bonding energy, discussing the ionic nature of subunits of complex structures, or a complete description of all individual atoms in a complex molecule or extended structure is not required.*]
HS-PS1-1.	**Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.** [Clarification Statement: Examples of properties that could be predicted from patterns could include reactivity of metals, types of bonds formed, numbers of bonds formed, and reactions with oxygen.] [*Assessment Boundary: Assessment is limited to main group elements. Assessment does not include quantitative understanding of ionization energy beyond relative trends.*]
HS-PS1-8.	**Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.** [Clarification Statement: Emphasis is on simple qualitative models, such as pictures or diagrams, and on the scale of energy released in nuclear processes relative to other kinds of transformations.] [*Assessment Boundary: Assessment does not include quantitative calculation of energy released. Assessment is limited to alpha, beta, and gamma radioactive decays.*]
HS-PS2-6.	**Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.** [Clarification Statement: Emphasis is on the attractive and repulsive forces that determine the functioning of the material. Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, and pharmaceuticals are designed to interact with specific receptors.] [*Assessment Boundary: Assessment is limited to provided molecular structures of specific designed materials.*]

NGSS Science and Engineering Practices Addressed

- o Asking questions (for science) and defining problems (for engineering)
- o Developing and using models
- o Constructing explanations (for science) and designing solutions (for engineering)
- o Obtaining, evaluating, and communicating information

NGSS Crosscutting Concepts Addressed

- Patterns. Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.
- Scale, proportion, and quantity. In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.
- Systems and system models. Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.
- Energy and matter: Flows, cycles, and conservation. Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.
- Stability and change. For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.

Common Core ELA Standards Addressed

CCSS.ELA-Literacy.RST.6-8.1, 9-10.1, 11-12.1

Cite specific textual evidence to support analysis of science and technical texts.

CCSS.ELA-Literacy.RST.6-8.2, 9-10.2, 11-12.2

Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.

CCSS.ELA-Literacy.RST.6-8.4, 9-10.4, 11.12.4

Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6–8, grades 9-10 texts and topics.

CCSS.ELA-Literacy.RST.6-8.7, 9-10.7, 11-12.7

Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

Observation

1. Introduce the lesson by cutting an apple (or another item) in two, cutting a resulting half in two, and repeating. Ask students how many times they think you could continue cutting the apple. Is there a point at which the pieces are no longer *apple*? In other words, what are the smallestor most fundamental building blocks of matter? Note that *atom* is the Greek word for *uncuttable*.
2. As a class, define *element*. Note that the defining features of elements are that they cannot be broken down into simpler substances, and that elements are the primary constituents of matter.

Hypotheses

1. Create an Exploration Chart for documenting students' exploration into atomic structure like the one below. (Note that this is an advanced version of the classic KWL [Know, Want To Know, Learned] chart.)

Prior Knowledge/ Preconceptions	Questions/ Hypotheses	Research	Conclusions/ Further Questions

Through guided class discussion, fill in the first two columns of the chart; generate a list of things students know, or think they know about atoms, and a list of questions or hypotheses students have about atoms/atomic structure.

Suggested Prompts

- Have you heard or read about elements or atoms before? In what context?
- Do you know the names of any of the elements?
- Do you know the names of any of the constituents of an atom?
- Have a student or students attempt to draw a model of an atom based on prior knowledge.

Research or Experimentation

Lesson

1. Introduce the Core Concepts: Periodic Table homepage. Review or explain that the periodic table is a graphic representation of all known elements and provides information about the properties, or unique characteristics, of each element.
   a. Hover over carbon's square on the table and review the information about the properties of carbon. Note that the number in the corner of the element square corresponds to the number of protons (and also the number of electrons) in that element.
   b. Briefly examine the table to familiarize students with its layout.
2. Open the Element Builder and select "Start Tutorial." Complete the tutorial and bonus quiz as a class to examine the structure of an atom.

Lab

1. Have students work in teams to complete the first three "challenges" in the Element Builder: Complete Tutorial (which was completed above as a class), Unlock the Period 2 Elements, and Master the Noble Gases. Be sure that teams document their progress through the activities as they complete them. (For more advanced students, complete the fourth and fifth challenges—Help Uranium Decay into Lead and Turn Lead into Gold—as well.)
2. Working in teams and using the information from the Element Builder, students fill out the attached supplement "Changing the Properties of an Atom."
3. Play the Element Card Game either as a class or in small groups.

Element Card Game

Materials:

- Index cards
- Paper/pencils

Method:

1. Divide class into groups and give each group of students 20 index cards. Have each student take 4–5 cards and label each card with one of the following particles: proton, neutron, electron. If there are cards remaining, have students label them as electrons.

2. Label index cards with the following (if playing as a class, only one set of the following cards is needed; if playing in groups, have each group create a set of the following cards):
   - **a.** Add proton
   - **b.** Add neutron
   - **c.** Add electron
   - **d.** Subtract proton
   - **e.** Subtract neutron
   - **f.** Subtract electron
3. Lay all particle cards face up on desks and have groups work together to select the particle cards necessary for a carbon atom. Have each individual draw a representation of a carbon atom on their papers.
4. Shuffle the command cards, and draw one. If playing as a class the teacher or a student volunteer may do this. Students follow the command on the card using particle cards to alter their atom, draw a model of the resulting atom, and explain the consequence of the change (e.g., created a different element, created a new isotope of the original element, created an ion, etc.).
5. If a new element is created the first group to recognize and name the element wins a point (or reward of the teacher's choice). Beginners may require a periodic table for reference. Advanced students may try playing without reference.
6. If an ion is created, the first group to correctly identify the charge and call out "positively charged ion" or "negatively charged ion" wins a point (or reward of teacher's choice).
7. Continue multiple rounds to reinforce understanding of atomic structure.

Analysis

As a class return to the Exploration Chart. Through guided class discussion document the facts students learned in their research in the **Research** section. Document students' observations and further questions about their research in the **Conclusions/Further Questions** section.

Suggested Prompts

Are any of the entries in the **Prior Knowledge/Preconceptions** column of the Exploration Chart supported by the research? If so, which ones? How are they supported?

What do we think might be some of the roles of atoms and elements in nature?

What do we think might be some of the roles of atoms and elements in our lives?

Report

Have students write several paragraphs in response to the following prompts:

1. In your own words, define "element." Give one or more examples of different elements.
2. In Greek, the word *atom* means "uncuttable." Why do you think we use this word?
3. Draw a representation of each of the following:
   - **a.** A carbon atom.
   - **b.** Another isotope of carbon.
   - **c.** A carbon ion.

Assessment Evidence

Ongoing Assessment

- Guided Discussions and Exploration Chart

Summative Assessment

- Element Builder progress documentation and Changing the Properties of an Element Chart
- Element Card Game notes
- Report
- Lesson rubric:

	Absent 0	Insufficient 1	Sufficient 2	Exceeds Expectations 3	Total Points
Changing the Properties of an Atom	Student did not complete the task	Incomplete or inaccurate information	Accurate information included	Student has gone above and beyond the required task	
Element Builder Progress	Student recorded no information or notes	Incomplete sections, or incomplete information in all sections	All basic information in all sections	Student has gone above and beyond the required task	
Report	Student did not hand in a report	Report consists of fewer than three paragraphs, and includes incomplete or inaccurate information	Report consists of three or more paragraphs and includes complete and accurate information	Student has gone above and beyond the required task	

Extension: Exploring Radioactive Decay

Introduction

1. Create a new Exploration chart and introduce the term *radioactive*. Begin a guided conversation by asking students what they think of when they hear the term. In the **Prior Knowledge/Preconceptions** column of the Exploration Chart, list the students' responses. **Suggested prompts:**

   a. Where have you heard the term *radioactive* before?

   b. Do you think *radioactivity* is a good thing or a bad thing?

   c. Do you know of any ways in which people use radioactivity to our benefit? (carbon dating, medical tests, etc.)

2. Continuing the guided conversation, note any questions or hypotheses students have about radioactivity.
   Suggested questions:

   a. What exactly is radioactivity?
   b. What causes radioactivity?
   c. What does radioactivity have to do with the elements?
3. As a class, complete the "Help Uranium Decay Into Lead" challenge in the Interactive Periodic Table.
4. Return to the Exploration Chart and in the Research column note what was learned during the activity.

Modeling Decay

1. Explain that radioactive decay is a random process, like flipping a coin. Ask students:

   a. What does *random* mean?
   b. What are the odds of getting heads on any flip of a coin?
2. Explain that radioactive decay is measured by *half-life*. Explain that radioactive isotopes decay by losing half of their radioactive nuclei per each half-life. Ask students: If we begin with 60 radioactive nuclei, how many will remain after one half-life? (30) How many after another half-life? (15)
3. Divide students into groups and give each student approximately 80 objects with recognizable tops and bottoms (e.g., coins or M&Ms), explain that these will represent radioactive nuclei. Have students count their objects and note the total.
4. Have students put their objects in a paper cup, shake it up, and pour it out onto the desk. Separate the objects into "face up" and "face down" groups. Record the number of radioactive nuclei (face down objects), and begin the process until no nuclei are left.
5. Pool the class' data and review (questions may be discussed as a class, or answered individually):

   a. Judging the data, how accurate is the assumption that half of our radioactive nuclei will decay in each half-life?
   b. Is there any way to predict whether an individual nucleus (one specific object in our model) will decay?
   c. Why did we pool the class data rather than using individual groups' data separately?
6. Return to the Exploration chart and use a guided conversation to complete the **Conclusions/Further Questions** column.