LESSON PLAN:
Exploring Periodic Trends

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 are periodic trends?
- How are periodic trends related to the structure of atoms?
- How does understanding periodic trends allow us to predict properties of different elements? What properties can be predicted by understanding trends?

Enduring Understandings
- Each element has properties that affect its behavior and interaction with its environment. These properties can be predicted using the periodic table as a model.
- Periodic trends include Atomic Number and Atomic Weight, which increase as one moves down and to the right on the periodic table; Atomic Radius and Metallic Properties, which increase as one moves down and to the left on the periodic table; and Electron Affinity, Electronegativity, and Ionization Energy, which increase as one moves up and to the right of the periodic table.
- Understanding the periodic trends allows us to make predictions about the properties of individual elements based on their position on the periodic table.
- There are some exceptions to the rules of periodic trends.

Time
This activity can be completed in 2–3 class periods of approximately 50 minutes.

Grade Level
Grades 9–12

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
- Periodic Trends Scavenger Hunt (Supplement 1) (if applicable)
- Printed Exploration Charts (Supplement 2) for each student or group

Lesson Objectives
- Students will be able to explain why periodic trends occur.
- Students will be able to make predictions about the relative properties of elements using the periodic table as a model.

Next Generation Science Standards Addressed	
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.*]

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, grades 11–12 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).

NGSS Science and Engineering Practices Addressed

- Asking questions (for science) and defining problems (for engineering)
- Developing and using models
- Constructing explanations (for science) and designing solutions (for engineering)
- Engaging in argument from evidence
- 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.
- 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.
- Structure and function. The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.
- 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.

Observation

The following activity may be done together as a class or in small groups depending upon needs of students. For students who need more guidance, print out the Periodic Trends Scavenger Hunt worksheet (Supplement 1).

Divide students into groups and explain that they will have ten minutes to explore the interactive Core Concepts: Periodic Table homepage and note as many patterns as they can find. Remind them to think of what they already know about the organization of the table.

When ten minutes are up, display the Core Concepts: Periodic Table interactive homepage for the class and have students share their observations. Ensure that all the following patterns are noted, and if any are missed, guide the class in discovering them:

- Atomic Number increases as one moves down and to the right.
- In general, Atomic Weight increases as one moves down and to the right.
- In general, Atomic Radius increases as one moves down and to the left.
- In general, metals are located to the left, and metallic properties increase as one moves down and to the left.
- In general, Electron Affinity, Electronegativity, and Ionization Energy all increase as one moves up and to the right.

Teaching Tip

Print out the Periodic Table Trends reference sheet for students to consult as the class explores the trends. This reference sheet is found on the Core Concepts: Periodic Table Reference Guides page.

Hypotheses

1. Provide each student with a printed Exploration Chart (Supplement 2) so that they may document their progress through the lesson. (Note that this is an advanced version of the classic KWL [Know, Want To Know, Learned] chart.) Have students note the class's observations about periodic trends in the Prior Knowledge/Preconceptions column of their Exploration Charts.

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

2. As a class, record the following questions in the **Questions/Hypotheses** column of the Exploration Charts:

   a. Why do atomic radii decrease as atomic number increases across a period? That is, why do atoms become smaller in size as you move to the right across a period?

   b. Why do atomic radii increase as atomic number increases down a column or group?

   c. Considering the answers to the previous two questions, why do ionization energy, electronegativity, and electron affinity increase moving up and to the right on the table?

Research or Experimentation

VISUALIZING PERIODIC TRENDS: ATOMIC TUG OF WAR

MATERIALS

- 2 pieces of string or rope at least two yards in length
- Papers labeled "proton," "electron," and "neutron"
- Element Builder activity

METHOD

1. Explain that atomic structure causes the periodic trends. Display the Element Builder activity and click on "Free Build." Alternatively, draw a model of a Hydrogen atom on the board. Ask two students to come to the front of the room and act as a human model of the atom. Give one student a paper with "proton" written on it and the other a paper with "electron" written on it. Give each student one end of a string or rope. Explain that protons are positively charged and massive and they exert a pull on electrons, which are negatively charged and comparatively tiny. Discuss with the class that the two model students are evenly matched, and ask what would happen if another "proton" were added to the nucleus and allowed to pull on the rope?

2. Add another proton in the Element Builder. What element has been created? (An unstable Helium isotope.) Have a third student model the second "proton," and allow the two "protons" to pull the "electron" closer to them. Explain that this is why atomic radius decreases as atomic number increases across a period: the nucleus is able to exert more force on the electrons and pull them closer to it. When electrons orbit closer to the nucleus, the width of the atom decreases. Add student volunteers to the model: one more electron and two neutrons to stabilize the element, giving the new electron the second string.

3. Next, place another "electron" in the atom model, further along one of the strings. Ask students which "electron" will feel less of the pull of the nucleus—the electron closer to the nucleus or the electron farther from it? (The farther electron will feel less of the pull.) Explain that this is why atomic radius increases as one moves down a column of the table: there is greater distance over which the nucleus must exert its force, and there is some shielding provided by the electrons closer to the nucleus. As electron "shells" are added, the width of the atom increases.

4. Explore the atomic structures of several elements in the Element Builder and discuss how the structures affect atomic radius. Discuss Ionization Energy, Electronegativity, and Electron Affinity in the same context. Explain that increased ability to attract electrons explains why these trends increase as atomic number increases across a period, but that greater distance and shielding explain why these trends decrease moving down columns.

Analysis

As a class, answer the questions in the **Questions/Hypotheses** column of the Exploration Charts, placing answers in the **Conclusions/Further Questions** column.

PERIODIC TRENDS GAME

MATERIALS

- Printed periodic tables
- Dice
- Notebook paper
- Pencils

METHOD

1. Divide class into groups or have students play individually. Give each group or student a periodic table and a die. Printable periodic tables in color and in black & white are available on the Core Concepts: Periodic Table Reference Guides page under Resources for Teachers/Librarians.
2. Have each group or student number a piece of notebook paper 1 through 10.
3. Have students roll their dice onto the table. For whatever elements a die lands on, have students note the atomic number and the element symbol (and the element name, if they know it without reference), and note how the trends might apply to that element in relation to other elements on the table. (For example, if a student rolled Barium, she might note, "Lower electronegativity and ionization energy, greater atomic radius, higher metallic properties," etc.).

Report

Have students answer the following questions:

1. Within a period, why are more massive atoms smaller?
2. Why are more metallic elements more reactive?
3. Describe how the location of an element on the periodic table allows us to predict its relative properties.

Assessment Evidence

ONGOING ASSESSMENT

- Guided conversation
- Exploration Charts

SUMMATIVE ASSESSMENT

- Periodic Trends Game notes
- Reports

- Lesson rubric:

	Absent 0	Insufficient 1	Sufficient 2	Exceeds Expectations 3	Total Points
Periodic Trends Game Notes	Student did not complete the task	Incomplete or inaccurate information, fewer than ten elements represented	Accurate information included for all ten elements	Student has gone above and beyond the required task (more than 10 elements covered thoroughly and accurately)	
Exploration Chart	No information in the individual Exploration Chart	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	Only one or two questions answered. Report consists of fewer than three paragraphs, and includes incomplete or inaccurate information	All three questions answered. Report consists of three or more paragraphs and includes complete and accurate information	Student has gone above and beyond the required task	

Extensions

3D PERIODIC TREND MODEL

Have students research different ways of visualizing periodic trends. A useful place to start is the interactive Core Concepts: Periodic Table homepage. Another excellent resource is http://www.rsc.org/periodic-table/trends.

Working individually or in groups, have students create 3D models of one or more of the periodic trends. 3D models can be constructed using the provided periodic table BLMs, and gluing paper, straws, Lego bricks, or other color-coded or size-coded items to the table.

Because of time or material constraints, this activity can be limited to the main group (or “representative”) elements. That is, students can omit the Transition Elements that are found in the middle of periodic table and the Lanthanides and Actinides that are commonly found at the bottom of the periodic table. The main group elements are found in groups 1–2 and 13–18 on the table.