Khan Academy

High School Chemistry

Unit 2: Atomic models and periodicity

Overview

In this unit, students will deepen their understanding of atomic structure by **developing and using models** and analyzing patterns in the periodic table related to atomic structure and the properties of elements.

Lesson 1: Students will **develop an understanding of the Bohr model and use the model** to explain how atoms absorb energy and emit light to produce characteristic atomic emission spectra.

Lesson 2: Hands-on science activity (see below)

Lesson 3: Students will apply their understanding of valence electrons from the Bohr model and new knowledge of patterns in the periodic table in order to draw and interpret Lewis diagrams.

Lesson 4: Students will compare the quantum model to the Bohr model and use the concept of orbitals to write electron configurations for atoms based on an element's location in the periodic table.

Lesson 5: Students will continue exploring patterns in the periodic table and learn to predict certain properties of elements based on their locations in the table.

Lesson 6: Students will analyze and apply trends in atomic radius and ionization energy going down a group or across a period in the periodic table. They will use their understanding of atomic structure and attractive and repulsive forces to explain these trends.

Hands-on science activity

What makes a neon sign glow?

Students will **carry out an investigation** and **analyze and interpret data** from several different light sources. They will then **develop and use a model** to explain how atomic emission spectra are produced and why different elements produce different spectra. Click here for links to the activity.

Standards

Performance expectations: **HS-PS1-1 | HS-ESS1-2**

Disciplinary core ideas: **HS-PS1.A.1 | HS-PS1.A.2 | HS-PS4.B.4 | HS-ESS1.A.2**

Science and engineering practices:

- Developing and using models
- Planning and carrying out investigations
- Engaging in argument from evidence
- Analyzing and interpreting data

Crosscutting concepts:

- Systems and system models
- Energy and matter
- Structure and function
- Patterns

Click here to read the full standards.

Essential questions

- How can the Bohr model be used to explain the way atoms absorb and emit energy to produce characteristic line spectra?
- What makes different models of atomic structure useful for understanding and explaining the properties of atoms?
- How are patterns in the periodic table used to make predictions about atomic structure and properties of elements?

Lesson notes

Lesson 1: The Bohr model and atomic spectra PEs: HS-PS1-1, HS-ESS1-2 DCIs: HS-PS1.A.1, HS-PS4.B.4, HS-ESS1.A.2	Resources Video 1, Article 3, Exercise 4
Objectives	**Teaching tips**

• Identify an element based on its **Bohr model**.
• Draw the Bohr model for an element based on its location in the periodic table.
• Interpret a Bohr model to determine the relative energies of electrons in different **shells** and the number of **valence** and **core electrons** in the atom.
• Compare the **wavelength**, **frequency**, and **photon energy** of different bands in the **electromagnetic spectrum**.
• Describe how the **color** of **visible light** is related to its wavelength, frequency, and photon energy.
• Predict how the wavelength, frequency, or photon energy of electromagnetic radiation changes as one of these properties increases or decreases.
• Use the Bohr model to explain how atoms absorb energy and emit light to produce characteristic **atomic emission spectra**.
• Analyze atomic emission or **absorption spectra** to identify the elements present in a sample.
	• Begin with a simple "Black Box" activity to help students recognize the power and limitations of scientific models. Ask students to consider how we can draw pictures and describe the structure of something that we cannot see. Emphasize that we cannot see atoms, so all of our atomic models are based on inferences made from *indirect* observation of how matter behaves in different situations.
	  ○ Create your own "black boxes," by placing items with different properties inside sealed, opaque containers. Alternatively, glue pieces of cardboard inside the containers to create barriers with different patterns, and place a marble inside each box before sealing it. Various resources and kits for this type of activity are available online as well.
	  ○ Have students work in small groups to come up with models for the inside of their boxes without opening or damaging them.
	  ○ As an extension, provide materials for students to prototype and test their models. Have them adjust and improve their models as they gather more information.
	• Introduce the key relationships in Coulomb's law by allowing students to explore the interactions of bar magnets. Guide students to examine what happens as they change the distance between the magnets and as they point the same poles or opposite poles toward each other. If magnets of different strengths are available, students can investigate how a more powerful magnet affects the interactions. This will help students to understand forces of attraction and repulsion between charged subatomic particles in the Bohr model. There is no need to introduce the mathematical equation for Coulomb's law, but students must understand that:
	  ○ Particles with opposite charges attract, while particles with the same charge repel.
	  ○ The strength of the attractive or repulsive force depends on the distance between the charged particles and the magnitudes of their charges.

	• Have students work in small groups on whiteboards to practice using the periodic table to draw Bohr models for different elements. Ask students to annotate their diagrams to identify core and valence electrons, and have them explain to each other the steps they went through to create their models. Develop a class list of "tips and tricks" for drawing the Bohr model of any element based on its location in the periodic table. • Ask students to examine a diagram of the electromagnetic spectrum. Assign students to research everyday applications of different bands in the spectrum, including radio waves, microwaves, infrared, visible, ultraviolet, and x-rays, and share their findings with each other. Use this as an entry point for discussing what all parts of the spectrum have in common and how they differ in terms of speed, wavelength, frequency, and photon energy. • Implement the hands-on activity "*What makes a neon sign glow?*" to introduce the phenomenon of atomic emission spectra and allow students to discover how Bohr's model can be used to explain it (see Lesson 2). • Encourage students to explore the PhET Neon lights simulation for support visualizing the process that leads to atomic emission spectra. • Ask students to consider how fireworks produce a dazzling display of colored light. (*See the "Related phenomena" section below for more information.*)

Lesson 2: Hands-on science activity
What makes a neon sign glow?

PEs: HS-PS1-1
DCIs: HS-PS1.A.1, HS-PS4.B.1

Resources
Activity
1

Description	Links
Students will **carry out an investigation** and **analyze and interpret data** from several different light sources. They will then **develop and use a model** to explain how atomic emission spectra are produced and why different elements produce different spectra.	• Full activity overview (**Khan Academy article**) • Student activity guide (**Doc** | **PDF**) • Teacher guide (**Doc** | **PDF**)

Lesson 3: Lewis diagrams

PEs: HS-PS1-1
DCIs: HS-PS1.A.1, HS-PS1.A.2

Resources
Video 1
Exercise 2

Objectives	Teaching tips
• Draw a **Lewis diagram** for an atom or ion from its Bohr model. • Determine the number of valence electrons in a neutral atom of a main	• Have students create a T-chart comparing Lewis diagrams and Bohr models. Ask them to consider what information is included and excluded in each representation of an atom and what might be advantages and disadvantages to using each kind of model.

group element based on its **group number** in the periodic table. • Draw a Lewis diagram for an atom or ion based on its chemical symbol and information available in the periodic table. • Interpret a Lewis diagram of an atom or ion to determine its number of valence electrons.	• Give each student a periodic table that has only the element symbols. Ask students to add the appropriate number of valence electrons to create Lewis diagrams for elements in the first three periods. Then, encourage them to identify patterns relating valence electrons and group numbers in the periodic table. • Play a simple game to provide students with practice using the periodic table as a resource for drawing Lewis diagrams. Create a deck of index cards (or have students create them) by writing information about a different atom or ion on each card (Bohr model, chemical symbol and net charge, number of protons and electrons, or group and period numbers in the periodic table). Students can take turns selecting a card and using the available information to draw the Lewis diagram for the appropriate atom or ion.

Lesson 4: The quantum model

PEs: HS-PS1-1
DCIs: HS-PS1.A.1, HS-PS1.A.2

Resources

Video	Article	Exercise
5	1	1

Objectives	Teaching tips

• Describe the arrangement of electrons in shells, **subshells**, and **orbitals** in the **quantum model**.
• Explain how orbitals differ from electron "orbits" in the Bohr model and how ***s, p, d,* and *f* orbitals** differ from each other.
• Analyze patterns in the periodic table to write the complete **electron configuration** for a given atom or ion.
• Use **noble gas shorthand** to write the electron configuration for an atom or ion based on the element's location in the periodic table.
• Identify pairs of atoms or ions that are **isoelectronic**.
	• Use analogies to help students understand the concept of an atomic orbital. For example, ask students what they would expect to observe if a bunch of fireflies were placed in a dark room with a pheromone that attracts them located in one corner. Students should predict that they would observe flashes of light mainly around the pheromone, but there might also be some flashes in other parts of the room.
	Guide students to recognize the following:
	  ○ They wouldn't see the fireflies moving from one place to another, but in a given instant, they would be able to see some of the fireflies lit up.
	  ○ Based on the observed pattern of flashes, they could predict the general area where most of the fireflies would likely be at any moment.
	Draw parallels between this scenario and the quantum model:
	  ○ We cannot predict the pathway of a specific electron or where it will be at a given moment.
	  ○ We can predict the three dimensional space where an electron with a particular potential energy is most likely to be found.
	• Encourage students to think of the quantum model as a revision or refinement of the Bohr model, rather than as a replacement. After introducing the arrangement of electrons in shells, subshells, and orbitals in the quantum model, ask students to compare and contrast the two models using a Venn diagram. Or, if students created T-charts comparing Lewis diagrams and Bohr models in Lesson 3, they can add a third column for the quantum model. Ask students to consider why we still use the Bohr model in some cases, even though it has significant limitations.
	• When students are learning to write electron configurations, provide an *s*, *p*, *d*, *f*-block version of the periodic table. Give students many opportunities to practice writing the electron configurations of

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increasingly complex atoms by “reading” left to right across the table period by period until they reach the desired element. When students become comfortable with this process, replace the block version of the table with a regular periodic table, and encourage them to recognize the relevant patterns without the explicit block labeling.

Address student misconceptions related to what it means for an atom to become isoelectronic with a noble gas when it forms an ion. Ask students to recall what aspects of atomic structure do not change during ionization (the numbers of protons and neutrons in the nucleus). This will help students recognize that becoming isoelectronic with a noble gas is not the same as becoming a noble gas, as the atom does not change its elemental identity when it forms an ion.

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Lesson 5: The periodic table

PEs: HS-PS1-1
DCIs: HS-PS1.A.2

Resources

Video	Article	Exercise
1	1	2

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<tr><th>Objectives</th><th>Teaching tips</th></tr>
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Apply patterns in the periodic table to determine the number of valence electrons and the valence level for a neutral atom of an element.
Describe common properties of metals, nonmetals, and metalloids, and use patterns in the periodic table to identify elements as belonging to one of these three categories.
Predict the relative reactivities of elements and identify elements that will have similar properties based on their locations in the periodic table.
Identify the locations and common properties of alkali metals, alkaline earth metals, halogens, and noble gases.

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Provide students with modern and historical alternative versions of the periodic table. Encourage students to examine the tables, notice similarities and differences, and discuss why they think our current version of Mendeleev’s table is the one that has been widely adopted. Point out that Mendeleev left blanks in his table for elements that had not yet been discovered and accurately predicted their properties based on patterns in his table.
Ask students to explore interactive periodic tables, such as this one from the Royal Society of Chemistry, and look for patterns in element properties. Encourage students to notice how changes in valence electrons affect the chemical and physical properties of elements.
Introduce the Periodic Table of Videos from the University of Nottingham as an engaging way to learn about the properties of elements. Assign students to watch and take notes on videos for different representative main group elements from the alkali metals, alkaline earth metals, halogens, and noble gases. Then, have them work in groups to develop lists of common properties and applications of elements in these chemical families.
Consolidate student learning about patterns in the periodic table by asking them to summarize everything they can (so far) predict about the properties of an element and the structure of its atoms based on the element’s location in the table. If students have difficulty getting started, use questions to prompt their thinking. For example, ask them to consider how the periodic table can be used to predict:

The number of protons in an atom
The valence level in a neutral atom
The number of valence electrons in a neutral atom
The electron configuration of an element
The relative reactivity of an element
If an element conducts electricity
If two elements will have similar properties

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	• Challenge students to predict the properties of a hypothetical new element based on its position in the periodic table. Alternatively, provide properties of an "unknown" element, and ask students to place it in an appropriate location in the table. Encourage students to support their claims with evidence and reasoning from the patterns they have previously identified. • Ask students to consider why jewelry is made out of gold and not sodium. (*See the "Related phenomena" section below for more information.*) • Provide students with an opportunity to showcase their creativity and learning by designing their own periodic tables based on everyday items of their choice. Every "element" should have a "chemical" symbol, name, "atomic mass," and "atomic number" with a meaning related to the particular item. Students should categorize and organize the items to show patterns in their properties.

Lesson 6: Periodic trends

PEs: HS-PS1-1
DCIs: HS-PS1.A.2

Resources

Video	Exercise
2	2

Objectives	Teaching tips
• Identify and explain the reasoning behind trends in **atomic radius** and **ionization energy** going down a group or across a period in the periodic table. • Predict how the atomic radii or ionization energies of two elements will compare based on their relative locations in the periodic table.	• Guide students to recognize the trends in atomic radius and ionization energy by having them graph data for each of these properties as a function of increasing atomic number. Ask students to analyze their graphs and connect the patterns they observe to the organization of elements in the periodic table. • Review the key relationships in Coulomb's law, focusing on how they explain the trends in atomic radius and ionization energy. Guide students to recognize that electrons are simultaneously attracted inward by the nucleus and repelled outward by other electrons. Emphasize that the force of attraction between the nucleus and electrons depends on the magnitude of the charges and the distance between them. Highlight how increasing the number of protons across a period strengthens the nuclear charge and the attractive force on the valence electrons, leading to a smaller atomic radius and higher ionization energy. • Encourage students to explain the *reasoning* behind each trend rather than relying solely on memorizing the trend directions. Provide opportunities to practice arranging elements in order of increasing/ decreasing atomic radius or ionization energy. Include the key relationships in Coulomb's law, and ask students to use them to explain their ordering of the elements.

Related phenomena

Example phenomenon

How do fireworks produce such a dazzling display of colored light?

Background information

Fireworks display

Fireworks displays rely on a series of chemical reactions, thermal energy transfers, and the absorption and emission of light by atoms to produce the brilliant colors we see when they explode in the night sky.

Aerial fireworks consist of a *shell* with a fuse that is placed in a tube called a *mortar*. When the fuse is lit, thermal energy transfers along the fuse until it reaches the *lift charge* at the bottom of the shell. The gunpowder in the lift charge—made up of potassium nitrate, charcoal, and sulfur—ignites. The resulting chemical reactions quickly release gaseous products and thermal energy, which force the shell up out of the mortar and into the air.

Energy from the gunpowder explosion also sets fire to a *delay fuse* within the shell. This fuse is designed to burn for a specific amount of time, allowing the shell to reach its maximum height before it ignites the gunpowder *bursting charge* in the center of the shell. This time, the release of hot gases causes the entire shell to explode, shooting its energized contents outward in all directions.

The colorful effect of fireworks comes from a bunch of marble-sized pellets, called *stars*, that are packed inside the shell in a specific pattern. Each star contains a metal salt, an oxidizer, and a fuel source. When the shell explodes, energy is transferred to the stars, causing the fuel to ignite in the presence of the oxidizer. As the burning stars travel outward from the center of the shell, electrons in the metal atoms absorb energy and jump to higher energy levels. As they fall back to lower energy states, they release energy in the form of visible light. The color of light emitted corresponds to the specific energy gaps between allowed electron states in the metal atoms. Since atoms of different metals have different sets of energy levels, they emit different colors of light.

Exploring this phenomenon helps students develop and master the following understandings:

- ☐ When atoms absorb energy, their electrons jump to higher energy levels; when their electrons return to lower energy levels, atoms emit energy in the form of electromagnetic radiation.
- ☐ The color of visible light is related to its wavelength, frequency, and photon energy.
- ☐ Different elements will emit different colors of light in the visible spectrum as a result of different arrangements of electrons in their atoms.

Tips for implementing phenomenon-based learning

- Ideas to encourage student engagement:
  - Conduct a flame test demonstration to show students firsthand the phenomenon of colored light being emitted by energized metal atoms. If you don't have access to a Bunsen burner and metal salts, share one of the many videos of this demonstration found online. Ask students to use models to explain how the metal atoms emit light, why different metal atoms emit different colors of light, and why the color is characteristic of a particular metal. Use this short video on The Science of Firework Color to help students get started on their explanations or as a review

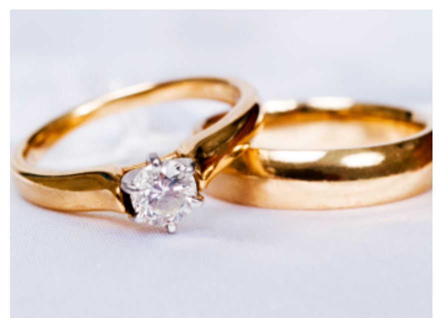
after they have developed and shared their explanations with each other.

- Have students create annotated diagrams of the inside of an aerial shell. Ask them to include the chemicals present in each part of the shell and to explain what the function of each part is. Have students record a short video of themselves using their diagrams to explain to a family member or friend how fireworks produce dazzling displays of colored light. This video on The Science of Fireworks from Khan Academy and this article from ChemMatters are useful resources.
- To get students thinking about connections between this phenomenon and concepts in Units 3 (Chemical bonding), 4 (Chemical reactions), and 7 (Thermochemistry), show Your Body Is A Firework (Scientifically Speaking). Ask students to brainstorm questions from the video, and record these as a list that you post in the classroom. As students learn about relevant concepts throughout future units, return to the list and prompt students to answer their own questions.

- Sample prompts to elicit student ideas and encourage discussion:
  - How are the colors of fireworks related to electron arrangement in atoms?
  - How can we use the Bohr model to explain the brilliant colors of light given off by fireworks?
  - In aerial fireworks, what provides the energy absorbed by electrons in metal atoms to jump to higher energy levels?
  - What would you expect to see if you viewed the colored light given off by fireworks through a diffraction grating or spectroscope?

Example phenomenon

Why is jewelry made out of gold, silver, and platinum, but not sodium or potassium?



Gold rings

Background information

Metals commonly used in jewelry making, like gold, silver, and platinum, are often classified as "noble metals," because of their low reactivity. These elements are chemically stable, so they resist oxidation and corrosion and can be found naturally as pure elements. On the other hand, alkali metals, like sodium or potassium, are very reactive, due to their one valence electron. This electron is easily lost to a reactive nonmetal, like oxygen or chlorine, to form an ionic compound. As a result, alkali metals oxidize quickly in moist air, react explosively with water, and are always found in compounds, rather than as pure elements, in nature.

Gold, silver, and platinum possess additional properties that make them desirable for making jewelry. They are lustrous, malleable, and ductile, which allows them to be shaped into intricate designs without breaking. One ounce of gold, for example, can be hammered into a translucent sheet 0.00018 mm thick and covering 9 square meters or pulled into a wire 80 km long.

Pure gold is generally considered too soft and easily scratched for prolonged wear, so most jewelry is made with an alloy of gold mixed with other metals, such as platinum, copper, zinc, and/or nickel. The identities and percentages of the metals in an alloy determine its properties, such as strength, malleability, resistance to oxidation, and color. Sterling silver is an alloy made of 92.5% silver by weight and 7.5% other metals. Copper is added to strengthen the silver, and zinc may be added to make it less susceptible to tarnishing.

Exploring this phenomenon helps students develop and master the following understandings:

- ☐ The arrangement of electrons in an atom can be modeled using a Lewis diagram or by writing its electron configuration.
- ☐ The properties of an element, including its chemical reactivity, are determined by its atomic structure.
- ☐ Elements in the same group in the periodic table have similar properties, because they have the same number of valence electrons.

Tips for implementing phenomenon-based learning

- Ideas to encourage student engagement:
    - Ask students to brainstorm lists of properties that would make a metal desirable or undesirable for jewelry making. Assign students to work in pairs or small groups to research the properties of one of the noble metals used in jewelry making and an alkali metal. Have students create a slide with the information they learn about each element. Review the slides as a class, and discuss why students think jewelry is made out of gold and not sodium.
    - Ask students to use the periodic table to identify other elements that might be considered "noble metals" and to explain their reasoning. Students should predict that elements in the same groups as gold, silver, and platinum (copper, nickel, and palladium) will have similar properties because they have the same electron configurations. Ruthenium, rhodium, osmium, and iridium are often classified as noble metals, as well.
    - Encourage students to make connections between properties of the elements and their atomic structures. Have students draw the Lewis diagrams and write the electron configurations for gold, silver, platinum, sodium, and potassium. This provides an opportunity to address exceptions to the expected pattern of orbital filling for gold and silver. Ask students to use the Lewis diagrams and electron configurations as evidence to support their reasoning for why jewelry is made out of gold and not sodium.
    - Prepare students for the next unit on chemical bonding by emphasizing that the most reactive elements are the alkali metals and halogens, because their electron configurations are only one valence electron away from that of the nearest noble gas in the periodic table. Have students draw Lewis diagrams for neutral atoms of sodium and chlorine, then ask them to draw Lewis diagrams for the ions they will form to become isoelectronic with a noble gas. Guide students to recognize that the valence electron lost by a sodium atom can be gained by a chlorine atom and that the positive and negative ions will be attracted to each other to form an ionic bond.
- Sample prompts to elicit student ideas and encourage discussion:
    - What properties of gold, silver, and platinum make them ideal for use in jewelry making?
    - What would happen if you tried to wear a ring made of sodium metal?
    - Why are some transition metals found as pure elements, as opposed to the alkali and alkaline earth metals, which are typically found in compounds?
    - Why is it useful to mix silver or gold with other metals, such as copper, zinc, or nickel?

Common student misconceptions

Possible misconception: *Atoms emit light when their electrons jump to higher energy levels.*

Students may associate electrons or atoms becoming "excited" with the phenomenon of *giving off* light. They may not recognize that energy is absorbed when electrons transition to higher energy levels and emitted only when electrons transition back to lower energy levels. If students have not previously studied attractive forces or conservation of energy, this may be a particularly confusing process.

Critical concepts

- Electron shells represent discrete energy levels that electrons can occupy in an atom.
- The potential energy of electrons is greater in shells farther from the nucleus, because energy is required for a negatively charged electron to overcome the attractive force acting on it from the positively charged nucleus.
- Electrons must *absorb* energy to transition to *higher* energy levels farther from the nucleus.
- When electrons relax back to *lower* energy levels closer to the nucleus, they *release* energy in the form of electromagnetic radiation.

How to address this misconception

Ensure that students have a strong understanding of the key relationships in Coulomb's law by reviewing what they learned in Lesson 1 from observing the interactions of bar magnets. In particular, emphasize that energy must be put *into* the system (the atom) for the negatively charged electron to overcome the attractive force acting on it from the positively charged nucleus. Use analogies, such as climbing the rungs of a ladder or stretching a rubber band, to help students recognize the energy *input* required to increase the distance between the charged particles.

Introduce or review the law of conservation of energy to ensure students understand that energy observed in the form of visible light must result from a corresponding *decrease* in energy of the electron. Use the Bohr model for hydrogen to show energy entering the system (atom) in the form of thermal or electrical energy, being absorbed by the electron so that it moves to an energy level farther from the nucleus, and then being released in the form of visible light as the electron is attracted back toward the nucleus.

Run the PhET Neon lights simulation in slow motion, and guide students to examine how the movement of the hydrogen atom's electron from a higher to lower energy level corresponds to the emission of a photon.

Possible misconception: *Elements with higher atomic mass always have larger atomic radii.*

The idea that atomic radius generally *decreases* as atomic number and mass increase *across a period* may seem counterintuitive to students. In addition, they may see a contradiction in the fact that moving down a group, an increase in the number of protons and electrons leads to a larger radius, while moving across a period, it leads to a smaller radius.

Critical concepts

- Atomic radius generally decreases going left to right across a period and increases going down a group in the periodic table.
- Atomic radius is influenced by three main factors:
  - The number of core electrons (increasing this number creates more shielding, which favors a larger radius)
  - The valence electron energy level (a higher valence energy level means a larger distance between the positive nucleus and negative electrons and a correspondingly weaker attraction, which favors a larger radius)
  - Nuclear charge (an increase in the number of protons means a larger positive charge attracting the electrons, which favors a smaller radius)

How to address this misconception

Review the key relationships in Coulomb's law and the three main factors that influence atomic radius (1 - number of core electrons, 2 - valence electron energy level, 3 - number of protons/nuclear charge). Ask students to annotate a copy of the periodic table, showing how each of these three factors changes (increases or decreases) or remains constant left to right across a period and top to bottom in a group. Then, have students analyze these trends to explain why atomic radius decreases left to right across a period and increases top to bottom in a group.

Guide students to recognize that moving across a period, there is no change in factors 1 and 2; only factor 3 increases, which is why the atomic radius generally decreases. Moving down a group, all 3 factors increase, but since two factors (1 and 2) favor a larger radius and only one factor (3) favors a smaller radius, the overall trend is increasing.

Unit resources

Student resources

- PhET Neon lights: Use this simulation for a virtual investigation of atomic emission spectra.
- Royal Society of Chemistry Interactive Periodic Table: Investigate periodic trends and element properties with this interactive periodic table.
- Periodic Table of Videos: Explore element properties with this website from the University of Nottingham.
- The Science of Fireworks (Khan Academy video), The Science of Firework Color (video), and Fireworks! (ChemMatters article): Use these resources for background information about the science of fireworks.
- Your Body Is A Firework (Scientifically Speaking) video: Make connections between the phenomenon of fireworks and chemistry concepts in future units.
- Flame Test Colors video: Watch what happens when metal salts are placed in a Bunsen burner flame.
- Article and video note taking template (Doc | PDF): Use this printable template for structured note taking on the articles and videos in this unit.
- Graph paper template (Doc | PDF): Use this printable template for manual graphing exercises.
- Venn diagram template (Doc | PDF): Use this printable template for comparing and contrasting concepts.

Classroom implementation resources

- PubChem Periodic Table of Elements and Printable Periodic Tables: Download various versions of the periodic table, including a blank template.
- Lab-Aids Ob-Scertainer: See one example of a “black box” activity kit to use with students.
- Weekly Khan Academy quick planning guide (Doc | PDF): Use this template to easily plan your week.
- Using Khan Academy in the classroom (Doc | PDF): Learn about teaching strategies and structures to support your students in their learning with Khan Academy.
- Differentiation strategies for the classroom (Doc | PDF): Read about strategies to support the learning of all students.
- Using phenomena with the NGSS: Learn more about how to incorporate phenomena into NGSS-aligned lessons.
- Hands-on science activities from Khan Academy: Choose from Khan Academy’s collection of high-quality, ready-to-use, and free hands-on science activities. Each one is engaging, three-dimensional, phenomenon-based, and simple to implement.

NGSS standards reference guide

Performance expectations

- **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.
- **HS-ESS1-2:** Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.

Disciplinary core ideas

- **HS-PS1.A.1:** Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons.
- **HS-ESS1.A.2:** The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth.
- **HS-PS4.B.1:** Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identification of the presence of an element, even in microscopic quantities.
- **HS-PS1.A.2:** The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states.

Science and engineering practices (SEPs)

- **Developing and using models**: Students progress to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.
- **Planning and carrying out investigations:** Students progress to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.
- **Analyzing and interpreting data:** Students progress to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.
- **Engaging in argument from evidence:** Students progress to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science.

Crosscutting concepts (CCCs) and their implementation

Crosscutting concept	Unit implementation
Systems and system models: Defining the system under study—specifying its boundaries and making explicitly a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.	Students define and describe different models of atoms.
Structure and function: The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.	Students connect atomic structure to elemental identity, properties, and behavior of matter.

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.	Students consider the movement of energy into and out of the atom to produce atomic emission spectra.
Patterns: Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.	Students identify patterns in the periodic table related to atomic structure and elemental properties.