Randolph Township Schools
Randolph High School
Chemistry Curriculum

"Nothing in life is to be feared, it is only to be understood. Now is the time to understand more, so that we may fear less."
— Marie Curie

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Mission Statement

We commit to inspiring and empowering all students in Randolph schools to reach their full potential as unique, responsible and educated members of a global society.

Affirmative Action Statement
Equality and Equity in Curriculum

The Randolph Township School district ensures that the district's curriculum and instruction are aligned to the state's standards. The curriculum provides equity in instruction, educational programs and provides all students the opportunity to interact positively with others regardless of race, creed, color, national origin, ancestry, age, marital status, affectional or sexual orientation, gender, religion, disability or socioeconomic status.

N.J.A.C. 6A:7-1.7(b): Section 504, Rehabilitation Act of 1973; N.J.S.A. 10:5; Title IX, Education Amendments of 1972

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EDUCATIONAL GOALS
VALUES IN EDUCATION

The statements represent the beliefs and values regarding our educational system. Education is the key to self-actualization, which is realized through achievement and self-respect. We believe our entire system must not only represent these values, but also demonstrate them in all that we do as a school system.

We believe:

- The needs of the child come first
- Mutual respect and trust are the cornerstones of a learning community
- The learning community consists of students, educators, parents, administrators, educational support personnel, the community and Board of Education members
- A successful learning community communicates honestly and openly in a non-threatening environment
- Members of our learning community have different needs at different times. There is openness to the challenge of meeting those needs in professional and supportive ways
- Assessment of professionals (i.e., educators, administrators and educational support personnel) is a dynamic process that requires review and revision based on evolving research, practices and experiences
- Development of desired capabilities comes in stages and is achieved through hard work, reflection and ongoing growth

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Introduction

This rigorous full-year course engages students in the study of the composition, properties, changes, and interactions of matter, while students engage in explaining and exploring real-world phenomena and inquiry-based learning. This course curriculum is aligned to the three-dimensional learning within the Next Generation Science Standards (NGSS) and New Jersey State Learning Standards (NJSLS) framework. Within three-dimensional learning, students develop and apply skills from the Science and Engineering Practices (SEPs), build on their understanding with concepts that carry throughout each unit of study through Crosscutting Concepts (CCC), and learn key pieces of content knowledge through the Disciplinary Core Ideas (DCIs). The course covers the basic concepts of chemistry and includes laboratory experiments that encourage higher-order thinking applications, designing and implementing investigations, and defending claims based on scientific evidence.

The components of this course include the composition and properties of matter, changes and interactions of matter, quantities of matter, and nuclear chemistry. Throughout the course, students solve problems, reason abstractly, and learn to think critically. Students will engage in a variety of instructional strategies including inquiry-based laboratory investigations, interactive animations, lectures, and demonstrations, and collaborative investigations. The learning experiences in the following curriculum foster learning through rigorous course content, teach competency in chemistry and the sciences through inquiry-based instruction, and allow the students to flourish in the science and technology age of the modern era with real-world application.

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Curriculum Pacing Charts

Honors and A Level Pacing Chart

SUGGESTED TIME ALLOTMENT	UNIT NUMBER	CONTENT - UNIT OF STUDY
3 weeks	I	Chemistry Foundations
3 weeks	II	Atomic Structure
3 weeks	III	The Periodic Table
5 weeks	IV	Chemical Bonding & Properties of Materials
5 weeks	V	Chemical Reactions
3 weeks	VI	Chemical Quantities
4 weeks	VII	Stoichiometry *(A/Honors Level Extension Unit)*
4 weeks	VIII	Solutions
3 weeks	IX	The Behavior of Gases
3 weeks	X	Nuclear Processes

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B Level Pacing Chart

SUGGESTED TIME ALLOTMENT	UNIT NUMBER	CONTENT - UNIT OF STUDY
4 weeks	I	Chemistry Foundations
3 weeks	II	Atomic Structure
4 weeks	III	The Periodic Table
5 weeks	IV	Chemical Bonding & Properties of Materials
5 weeks	V	Chemical Reactions
3 weeks	VI	Chemical Quantities
5 weeks	VIII	Solutions
4 weeks	IX	The Behavior of Gases
3 weeks	X	Nuclear Processes

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Unit I: Chemistry Foundations

<table>
<tr><td colspan="3">TRANSFER: Students will be able to apply scientific skills to solve problems, including constructing and evaluating experimental investigations, explanatory models, and scientific arguments from evidence.</td></tr>
<tr><td rowspan="6">STANDARDS / GOALS:

<u>Performance Expectations:</u>
HS-PS1-3: Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.
HS-PS2-4: Use mathematical representations of Newton’s Law of Gravitation and Coulomb’s Law to describe and predict the gravitational and electrostatic forces between objects.
HS-PS3-5: Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.</td><td>ENDURING UNDERSTANDINGS</td><td>ESSENTIAL QUESTIONS</td></tr>
<tr><td>Sensory observations and measured data are the evidence used to make an informed inferential claim.</td><td>• How does the scientific process support the responsible reporting of information?</td></tr>
<tr><td>Everything is made up of matter, which chemists can study at the macro, molecular, and atomic level.</td><td>• How can matter and the changes it undergoes be described and classified?</td></tr>
<tr><td>Changes that matter undergoes are categorized as physical and/or chemical.</td><td>• What distinguishes a physical change from a chemical change?</td></tr>
<tr><td><u>KNOWLEDGE</u>
Students will know:</td><td><u>SKILLS</u>
Students will be able to:</td></tr>
<tr><td>Observations are made with the five senses, while inferences are informed conclusions based on observations.</td><td>Distinguish between observations and inferences.

Make informed inferences based on observations.

Develop and revise informed claims from observed evidence and thorough explanatory reasoning.</td></tr>
</table>

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Unit I: Chemistry Foundations

Disciplinary Core Ideas: **PS1.A: Structure and Properties of Matter** The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. **PS2.B: Types of Interactions** Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. **PS3.C: Relationship Between Energy and Forces** When two objects interacting through a field change relative position, the energy stored in the field is changed. **Crosscutting Concepts:** **Patterns:** Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. **Cause and Effect:** Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system.	Science is the use of evidence to construct testable explanations and predictions of natural phenomena, as well as the knowledge generated through this process. Chemistry is the study of matter in its four states: solid, liquid, gas, and plasma. A physical change alters the physical properties of a substance without changing its composition, while a chemical change (chemical reaction) involves a change in a substance's composition. Chemical reactions present observable changes that suggest a chemical change has taken place.	Devise explanations for natural phenomena based on observations and/or measured data. Investigate the states of matter (solid, liquid, gas) to classify material. Develop and use a model to illustrate the differences between the states of matter at the atomic level. Classify a phenomenon as a physical change or a chemical change. Develop and use a model to illustrate the differences between a physical change and a chemical change at the atomic level. Identify the signs of a chemical reaction. Use observational evidence to determine whether a physical or chemical change has occurred.

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Unit I: Chemistry Foundations

<table>
<tr>
<td rowspan="2"><u>Science and Engineering Practices:</u>
Planning and Carrying Out Investigations: Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.
Using Mathematical and Computational Thinking: Use mathematical representations of phenomena to describe explanations.
Connections to Nature of Science: Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena.
Developing and Using Models: Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.</td>
<td>Elements cannot be broken down into simpler substances but can be physically blended together to form a mixture or chemically combined (bonded) to form new substances called compounds.

Mixtures can be separated by physical means, while compounds must undergo a chemical change to be separated.</td>
<td>Identify whether a substance is an element, a compound, or a mixture.

Develop explanatory models to represent the differences between an elemental substance, a compound, and a mixture.

Develop models to describe the atomic composition of simple molecules.

Suggest a separation method based on the type of substance.

Describe the process to separate a mixture of elements and compounds based on their physical and chemical properties.</td>
</tr>
<tr>
<td colspan="2">VOCABULARY: solid, liquid, gas, boiling, freezing, melting, condensation, sublimation, deposition, phase change, observation, inference, independent variable, dependent variable, hypothesis, equation, ratio, matter, energy, atom, molecule, bond</td>
</tr>
<tr>
<td colspan="3">ASSESSMENT EVIDENCE: Students will show their learning by:
• Planning and conducting an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles (HS-PS1-3).
• Developing and using a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction (HS-PS3-5).</td>
</tr>
</table>

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Unit I: Chemistry Foundations

KEY LEARNING EVENTS AND INSTRUCTION: • Anchoring Event – Students investigate and develop understanding through exploring real-world phenomena. • Scientific Models – Students explore phenomena by developing models to describe the three states of matter and explain intermolecular forces. • Inquiry Lab – Students explore phase changes and draw conclusions based on evidence.	
SUGGESTED TIME ALLOTMENT	**3 weeks**
SUPPLEMENTAL UNIT RESOURCES	Phenomena-based inquiry questions to anchor instruction: • How do we design materials for a specific function? • Why do solid water and solid carbon dioxide behave differently? • What happens to temperature when ice melts? Savvas *Experience Chemistry* Textbook Teacher Guide Resources Investigation 4 Additional Resources: • American Association of Chemistry Teachers • American Chemical Society • National Science Teaching Association • PhET Interactive Simulations

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Unit II: Atomic Structure

<table>
<tr><td colspan="3">TRANSFER: Students will observe and compare the patterns of atomic structure that distinguish elements from one another and can recognize these differences in their interactions with elements in their own lives (i.e. comparing properties of household cleaning products or understanding why only certain metals conduct electricity).</td></tr>
<tr><td rowspan="5">STANDARDS/GOALS:

<u>Performance Expectations:</u>
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.

<u>Disciplinary Core Ideas:</u>
PS1.A Structure and Properties of Matter
Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons.
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.</td><td>ENDURING UNDERSTANDINGS</td><td>ESSENTIAL QUESTIONS</td></tr>
<tr><td>Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons.</td><td>What are atoms and what are they made of?</td></tr>
<tr><td>The periodic table is a tool that contains useful patterns and information about the elements.</td><td>How does the periodic table aid in the understanding of the atoms?</td></tr>
<tr><td><u>KNOWLEDGE</u>
Students will know:</td><td><u>SKILLS</u>
Students will be able to:</td></tr>
<tr><td>An atom is the smallest particle of an element that maintains the properties of that element.

An atom consists of electrons that have a 1- charge, protons that have 1+ charge, and neutrons that have no charge.</td><td>Describe an atom compared to the other chemical substances and particles.

Develop models to describe the atomic composition of elements.

Describe atomic structure using a model of the atom that includes protons, neutrons, electrons.</td></tr>
</table>

Unit II: Atomic Structure

Crosscutting Concepts: **Patterns:** Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. **Science and Engineering Practices:** **Developing and Using Models:** Use a model to predict the relationships between systems or between components of a system.	The atomic number of an atom is given by its number of protons. The mass number of an atom is the sum of its neutrons and protons. $Atomic\ number = number\ of\ protons$ $Mass\ number = atomic\ number + number\ of\ neutrons$	Use mathematics to calculate the mass number of an element given its subatomic particle data.
	Atoms of the same element with different numbers of neutrons are called isotopes.	Compare and contrast isotopes of the same element.
	The atomic mass of an element is a weighted average of the masses of all of its naturally occurring isotopes.	Use mathematics to calculate the atomic mass of an element given its isotope data.
	Electron configurations can be represented using Bohr models and electron-dot structures.	Develop and use Bohr models of atoms to illustrate electron energy levels and the placement of electrons within those levels. Revise atomic models to present valence electrons only using electron-dot structures.
	Electrons exist in energy levels and move up or down levels depending on energy lost or gained.	Devise a simple explanatory model for what happens on a subatomic level when energy is absorbed and/or released by an atom.

Unit II: Atomic Structure

	A/Honors Level Extension: Bohr's atomic model attributes hydrogen's emission spectrum to electrons dropping from higher-energy to lower-energy orbits. $\Delta E = E_{higher-energy\ orbit} - E_{lower-energy\ orbit} = E_{photon} = h\nu$	Design an experiment to determine which type of gas is present in a gas-discharge lamp. Use the Bohr model to explain why elements have unique atomic emission spectra.
	A/Honors Level Extension: The de Broglie equation relates a particle's wavelength to its mass, its velocity, and Planck's constant. $\lambda = \frac{h}{mv}$	*A/Honors Level Extension:* Relate the spectra of elements to the structure of their atoms, particularly the patterns of electrons and changes in their energy.
	A/Honors Level Extension: Electron configurations can be represented using Bohr models, orbital diagrams, electron configuration notation, and electron-dot structures.	*A/Honors Level Extension:* Develop and use orbital diagrams of atoms to illustrate electron energy levels and the placement of electrons within those levels. Use the periodic table as a tool to describe the electron configuration notation of a specific element.

Unit II: Atomic Structure

	A/Honors Level Extension: Electrons occupy three-dimensional regions of space called atomic orbitals and are arranged in specific electron configurations defined by the Aufbau principle, the Pauli exclusion principle, and Hund's rule.	Develop a model using the periodic table to assist in determining the order in which various atomic orbitals are filled. Predict how the electron configuration for an atom might change if it were to ionize. Investigate exception to the rules for orbital filling and explain said phenomenon.
	VOCABULARY: electron, element, ion, wavelength, frequency, ground state, atomic emission spectra, photon, orbitals, quantum, Aufbau principle, Pauli exclusion principle, Hund's Rule, quantum mechanical model, s-orbital, p- orbital, d-orbital, f-orbital, Joule, Hertz, energy level, spin, sub-level, atom, element, compound, proton, neutron, electron, isotope, ion, atomic mass unit, weighted average, atomic mass, atomic number	

ASSESSMENT EVIDENCE: Students will show their learning by:

- Using 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-PS1-1).
- Articulating observed patterns in the periodic table to construct explanations for various scientific phenomena.

KEY LEARNING EVENTS AND INSTRUCTION:

- Structure of the Atom – Students use the PhET Build an Atom Simulation to explore atomic structure and components.
- Emission Spectrum Lab – Students set up a diffraction grate across from an emission tube. They then use recorded observation data to complete energy calculations.
- Scientific Models – Students develop models of the atom and compare previously suggested models of the atom.

Unit II: Atomic Structure

SUGGESTED TIME ALLOTMENT	**3 weeks**
SUPPLEMENTAL UNIT RESOURCES	Phenomena-based inquiry questions to anchor instruction: • What causes the colors in a firework display? • What is sugar made of? • What's inside the box? • How do we know that water is present on Mars? • Does the same change always produce the same amount? • How do guests decide where to stay in a hotel? Savvas *Experience Chemistry* Textbook Teacher Guide Resources Investigation 1 Additional Resources: • American Association of Chemistry Teachers • American Chemical Society • National Science Teaching Association • PhET Interactive Simulations

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Unit III: The Periodic Table

<table>
<tr><td colspan="3">TRANSFER: Students will use patterns and trends to make predictions about and construct explanations for naturally occurring phenomena.</td></tr>
<tr><td rowspan="5">STANDARDS / GOALS:

<u>Performance Expectations</u>:
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-PS1-2: Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.

<u>Disciplinary Core Ideas:</u>
PS1.A: Structure and Properties of Matter
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.</td><td>ENDURING UNDERSTANDINGS</td><td>ESSENTIAL QUESTIONS</td></tr>
<tr><td>Arrangement of atoms allows scientists to predict physical and chemical properties to describe and predict chemical reactions.</td><td>• In what ways can the periodic table be used as a resource to better understand elements, predict chemical interactions, and develop new materials?</td></tr>
<tr><td>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.</td><td>• How does the periodic table embody trends in the properties of the elements?</td></tr>
<tr><td><u>KNOWLEDGE</u>
Students will know:</td><td><u>SKILLS</u>
Students will be able to:</td></tr>
<tr><td>The periodic table provides useful information about each element, such as atomic number and atomic symbol.

The periodic table organizes the elements by increasing atomic number into periods (rows) and groups/families (columns) so that there is a periodic repetition of their chemical and physical properties; elements with similar properties are in the same group.</td><td>Identify unique elements by their own atomic number and atomic symbol.

Describe how elements in the periodic table are arranged by the numbers of protons in atoms.

Distinguish elements as metals, nonmetals, or metalloids.</td></tr>
</table>

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Unit III: The Periodic Table

PS1.B: Chemical Reactions The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. **<u>Crosscutting Concepts:</u>** **Patterns:** Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. **<u>Science and Engineering Practices:</u>** **Developing and Using Models:** Use a model to predict the relationships between systems or between components of a system. **Constructing and Revising Explanations:** Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.	Electron configuration gives rise to trends in the periodic table, such as: • Atomic and ionic radii decrease from left to right across a period and increase as you move down a group. • Ionization energies generally increase from left to right across a period and decreases down a group. • The octet rule states that atoms gain, lose, or share electrons to acquire a full set of eight valence electrons. • Electronegativity generally increases from left to right across a period and decreases down a group.	Compare two or more elements using any of the periodic trends. Use periodic trends to explain some chemical properties of elements. Explain how the position of an element in the table can be used to predict some of its chemical properties. Investigate and explain reactivity patterns in the periodic table using concepts of ionization energy, net effective charge, and atomic radius. *A/Honors Level Extension:* Construct and revise an explanation based on evidence to describe the patterns of effective nuclear charge across a period of main group elements. *A/Honors Level Extension:* Use Coulomb's law to explain effective nuclear charge and why the positive charge exerted by an atomic nucleus is not equal to the charge of its protons.
	The octet rule states that atoms gain, lose, or share electrons to acquire a full set of eight valence electrons.	Use models of elements to explain the formation of ions.

	An element's number of valence electrons and energy level of those valence electrons can be determined by the group number and period number; this pattern applies to main group elements and exceptions exist.	Identify how the arrangement of the main groups of the periodic table reflects the patterns of outermost electrons Describe how electron configuration gives rise to trends in the periodic table. Explain how the periodic table can be used to predict electron configuration of an element.
	VOCABULARY: periodicity, ionization energy, atomic radius, reactivity, electronegativity, metal, non-metal, metalloid, alkali metal, alkaline earth metal, halogen, noble gas, trend	

ASSESSMENT EVIDENCE: Students will show their learning by:

- Using 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-PS1-1)
- Constructing and revising an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties. (HS-PS1-2)

KEY LEARNING EVENTS AND INSTRUCTION:

- Anchoring Event – Students investigate and develop understanding through exploring real-world phenomena.
- Periodic Trends and Patterns – Students categorize and organize a list of given elements in order of increasing value of a particular periodic trend, followed by an explanation of why each element was arranged in that order.
- Periodic Trends and Patterns – Students develop a colored model of the period table that illustrates the trends in electron configurations across a period or down a group in order to assist in understanding of orbital filling rules.
- Patterns of Chemical Properties Lab – Students design an investigation to quantitatively draw conclusions about periodic trends and patterns and observe the effects of periodicity by combining substances (same group, different periods) with the same reactant.

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Unit III: The Periodic Table

SUGGESTED TIME ALLOTMENT	**3 weeks**
SUPPLEMENTAL UNIT RESOURCES	Phenomena-based inquiry questions to anchor instruction: • Why are elements in pure form so rare? • How can categorizing and arranging objects help use make predictions about their properties? • What's so special about silicon? • What can periodic trends tell us about how reactive an element is? Savvas *Experience Chemistry* Textbook Teacher Guide Resources Investigation 2 Additional Resources: • American Association of Chemistry Teachers • American Chemical Society • National Science Teaching Association • PhET Interactive Simulations

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Unit IV: Chemical Bonding & Properties of Materials

TRANSFER: Students will use patterns and trends to predict the formation of compounds and explain the connection between the molecular level interactions and bulk scale material properties.		
STANDARDS / GOALS:	**ENDURING UNDERSTANDINGS**	**ESSENTIAL QUESTIONS**
<u>Performance Expectations:</u> **HS-PS1-2:** Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties. **HS-PS1-3:** Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles. **HS-PS1-7:** Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. **HS-PS2-4:** Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.	Almost everything a person interacts with in daily life exists because of chemical bonds.	• Why and how do atoms bond to form compounds?
	There are two main classes of bonding forces: Ionic compounds are held together by chemical bonds formed by the attraction of oppositely charged ions, while covalent bonds form when atoms share electrons.	• How do the differences between bonds and attraction affect structures in our everyday lives?
	The nature of the bonds within a material help determine its properties.	• How can knowledge of bonding help to develop new useful materials?
	<u>KNOWLEDGE</u> **Students will know:**	**<u>SKILLS</u>** **Students will be able to:**
	A chemical bond is the force that holds two atoms together, and there are several different types of chemical bonds.	Describe the types of bonds that can form between atoms within molecules. Explain how the electron configuration and electronegativity within a molecule determine the nature of its bonding.

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Unit IV: Chemical Bonding & Properties of Materials

HS-PS3-5: Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction. **<u>Disciplinary Core Ideas:</u>** **PS1.A: Structure and Properties of Matter** 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. The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. **PS1.B: Chemical Reactions** The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.	Some atoms lose or gain valence electrons to gain stability (the number of protons remains unchanged during ion formation). The result is a positive ion (cation) or negative ion (anion) with a stable electron configuration of a complete outer energy level, usually consisting of eight valence electrons. $Charge = Number\ of\ Protons - Number\ of\ Electrons$ Cations and anions combine in a fixed ratio to achieve a net charge of zero. A formula unit gives the ratio of cations to anions in a neutral ionic compound.	Explain how and why atoms gain or lose electrons to form ions. Identify patterns in the location of elements making up ionic compounds on the periodic table. Predict the change that must occur in an atom to achieve a noble-gas configuration. Calculate the resulting charge when atoms form ions. Model the process of electron transfer during the formation of ions to achieve a full valence shell. Use mathematics to determine the formula unit of an ionic compound.

Unit IV: Chemical Bonding & Properties of Materials

PS2.B: Types of Interactions Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. Newton's law of universal gravitation and Coulomb's law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields. **PS3.C: Relationship Between Energy and Forces** When two objects interacting through a field change relative position, the energy stored in the field is changed.	Ionic compounds are formed by the attraction of oppositely charged ions; on a larger scale, they contain ions arranged in a repeating pattern known as a crystal lattice. Ionic compounds are electrolytes; they conduct an electric current in the liquid phase and in aqueous solution.	Explain how and why ionic bonds form electrostatic attractions between cations and anions. Construct and revise models of ionic compounds at different scales to show how the electrostatic attractions between cations and anions create an ionic bond and crystal lattice structure. Describe how the structures of ionic compounds affect their properties. Plan and carry out an investigation to produce data to serve as evidence to support the claim that ionic compounds are electrolytes. Construct and revise an explanation based on evidence to describe the ability of ionic compounds to conduct an electric current in the liquid phase and in aqueous solution.

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Unit IV: Chemical Bonding & Properties of Materials

<u>Crosscutting Concepts:</u> **Patterns:** Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. **Energy and Matter:** The total amount of energy and matter in a closed system is conserved. **Cause and Effect:** Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. **<u>Science and Engineering Practices:</u>** **Developing and Using Models:** Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. **Using Mathematical and Computational Thinking:** Use mathematical representations of phenomena to describe explanations. Use mathematical representations of phenomena to support claims.	There are specific naming rules for ionic compounds and molecular compounds, including: • Roman numbers indicate the oxidation number of cations having multiple possible oxidation states. • To indicate more than one polyatomic ion in a chemical formula, parentheses are placed around the polyatomic ion and a subscript used. • Names of covalent molecular compounds include prefixes for the number of each atom present. A metallic bond forms when metal cations attract freely moving, delocalized valence electrons. In the electron sea model, electrons move through the metallic crystal and are not held by any particular atom. Metal alloys are formed when a metal is mixed with one or more other elements.	Demonstrate how to determine a neutral compound's chemical formula using its name and the periodic table. Describe how to name a chemical compound when given its formula. Apply the rules for naming monatomic ions, ionic compounds, molecular compounds, and acids. Identify bond types in a compound based on its name or formula. Explain the electron sea model of metallic bonds. Describe how delocalized electrons give rise to metallic properties. Model alloy formation. Explain how the bonding in alloys affects their properties.

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Unit IV: Chemical Bonding & Properties of Materials

Planning and Carrying Out Investigations: Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.	Covalent bonds form when atoms share one or more pairs of electrons.	Describe how nonmetals share electrons to complete their valence shell octet and form a covalent bond. Identify patterns in the location of elements making up molecular compounds on the periodic table. Model the sharing of electrons to form a covalent bond between two nonmetals.
	Sharing one pair, two pairs, and three pairs of electrons forms single, double, and triple bonds, respectively.	Describe and identify the differences between single, double, and triple covalent bonds. Draw electron dot diagrams for single, double, and triple covalent bonds.
	The difference in electronegativity of bonding elements determines the character of a bond between two atoms such that nonpolar bonds occur when electrons are shared equally, and polar bonds occur when electrons are not shared equally.	Describe how the electronegativities of bonding elements lead to the formation of nonpolar and polar covalent bonds. Use mathematical representation of electronegativities to determine the character of a bond between two atoms. Identify patterns in the location of elements that form ionic and molecular compounds on the periodic table. Identify the presence of polar bond dipoles within a molecule.

	VSEPR model theory states that electron pairs repel each other and determine both the shape of and bond angles in a molecule.	Construct and revise models of molecules based on understanding of VSEPR theory. *A/Honors Level Extension:* Explain how electron pairs (bonding and lone pairs) effect the shape and bond angles in a molecule.
	Spatial arrangement of polar bonds in a molecule determines the overall polarity of a molecule.	*A/Honors Level Extension:* Determine the overall polarity of a molecule.
	Intermolecular attractions between molecules influence the bulk properties of a material, such as: • Ionic and covalent compound properties are relative to bond strength. • Lattice energy is the energy needed to remove 1 mol of ions from its lattice. • Molecules attract each other by weak intermolecular forces; in a covalent network solid, each atom is covalently bonded to many other atoms. • Bond dissociation energy is needed to break a covalent bond.	Plan and carry out an investigation to produce data to serve as evidence to support the claim that ionic and covalent compounds have different properties. Analyze data comparing metals and nonmetals. Construct explanations to relate the properties of ionic and molecular compounds at the bulk scale to the intermolecular forces and bonds between their particles.

Unit IV: Chemical Bonding & Properties of Materials

	VOCABULARY: element, compound, chemical bond, ionic, covalent, orbital, double bond, triple bond, Lewis structure, octet, valence electron, chemical formula, formula unit,alloy, metallic bond, diatomic molecule, molecular formula, lone pair, polyatomic ion, resonance structure, structural formula, VSEPR theory, tetrahedral, linear, trigonal, planar, pyramidal, bipyramidal, polar bond, nonpolar bond, hydrogen bond

ASSESSMENT EVIDENCE: Students will show their learning by:

- Constructing and revising an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties (HS-PS1-2).
- Planning and conducting an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles (HS-PS1-3).
- Using mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction (HS-PS1-7).

KEY LEARNING EVENTS AND INSTRUCTION:

- Anchoring Event – Students investigate and develop understanding through exploring real-world phenomena.
- Ionic and Molecular Bond Comparison Investigation – Students observe the physical characteristics of a variety of ionic compounds compared to a variety of molecular compounds using the naked eye as well as a magnifying glass, and construct an explanation comparing various types of compounds through claims evidence reasoning.
- Molecular Models Lab – Students apply their understanding of molecule formation, including electron dot structures, by exploring and constructing molecules with proper bond angles using molecular model kits.
- Naming Compounds – Students use data to infer rules for naming compounds.

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Unit IV: Chemical Bonding & Properties of Materials

<table>
<tr><td>SUGGESTED TIME ALLOTMENT</td><td>5 weeks</td></tr>
<tr><td>SUPPLEMENTAL UNIT RESOURCES</td><td>Phenomena-based inquiry questions to anchor instruction:

Why do gems have different properties than metals?
What happens when you mix an explosive metal with a poisonous gas?
Why can metals be formed into different shapes?
How are covalent compounds different from ionic compounds?
Why does hand sanitizer evaporate much more quickly than water?
What can the name of something tell us about its structure and properties?
What have you noticed about crystals?
How does aluminum foil compare with plastic wrap?
Can you make water “wetter?”

Savvas Experience Chemistry Textbook Teacher Guide Resources Investigations 3 and 4

Additional Resources:

Molecule Building Kit
American Association of Chemistry Teachers
American Chemical Society
National Science Teaching Association
PhET Interactive Simulations
</td></tr>
</table>

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Unit V: Chemical Reactions

<table>
<tr><td colspan="3">TRANSFER: Students will construct an explanation for the outcome of a chemical reaction based on knowledge of trends and patterns, applying their understanding of theories and laws that describe the natural world.</td></tr>
<tr><td rowspan="6">STANDARDS / GOALS:

<u>Performance Expectations:</u>
HS-PS1-2: Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.
HS-PS1-4: Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.
HS-PS1-5: Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.
HS-PS1-7: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.</td><td>ENDURING UNDERSTANDINGS</td><td>ESSENTIAL QUESTIONS</td></tr>
<tr><td>Atoms are rearranged in predictable ways when a chemical reaction transforms reactants into new products.</td><td>• What happens as a chemical reaction transforms reactants into products?</td></tr>
<tr><td>Chemical equations are used to represent chemical reactions and show that mass can neither be created nor destroyed.</td><td>• Why must the mass of reactants equal the mass of products in a chemical reaction?</td></tr>
<tr><td>Chemical reactions usually absorb or release energy.</td><td>• How are the energy changes that accompany chemical reactions described and quantified?</td></tr>
<tr><td><u>KNOWLEDGE</u>
Students will know:</td><td><u>SKILLS</u>
Students will be able to:</td></tr>
<tr><td>Some physical changes are evidence that indicate a chemical reaction has occurred.

Particles must collide with each other with sufficient energy and in the correct orientation for a chemical reaction to take place.</td><td>Use evidence to determine whether a physical or chemical change has occurred.

Describe what causes chemical reactions.</td></tr>
</table>

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Unit V: Chemical Reactions

<u>Disciplinary Core Ideas</u> **PS1.A: Structure and Properties of Matter** 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. A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. **PS1.B: Chemical Reactions** The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy.	As bonds break and form during a chemical reaction, the release or absorption of energy depends on the total change in bond energy. The law of conservation of mass states that mass is neither created nor destroyed during a chemical reaction; it is conserved. Balancing a chemical reaction equation involves adjusting the coefficients until the number of atoms of each element is equal on both sides of the equation. $Mass\ reactants = Mass\ products$	Distinguish between endothermic reactions and exothermic reactions. Represent energy changes in exothermic and endothermic reactions using an enthalpy diagram. Describe the flow of energy as heat through a reaction. Plan and carry out an investigation to produce data to serve as evidence to support the claim that mass is conserved during a chemical reaction. Construct and revise an explanation based on valid and reliable evidence such as mathematical representations of phenomena to support claims. Develop an explanation of phenomena related to the law of conservation of mass and solve design problems, considering possible unanticipated effects. Develop a model to represent a balanced chemical reaction. Write balanced equations for chemical reactions.

Unit V: Chemical Reactions

Crosscutting Concepts **Patterns:** Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. **Energy and Matter:** Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. The total amount of energy and matter in a closed system is conserved. **Science and Engineering Practices** **Constructing Explanations and Designing Solutions:** Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. Apply scientific principles and evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects.	Word equations and skeleton equations provide important information about a chemical reaction, while a balanced chemical equation gives the identities and relative amounts of the reactants and products that are involved in a chemical reaction. Classifying chemical reactions makes them easier to understand, remember, and recognize. Reaction products can be predicted based on chemical properties like reactivity and solubility, as well as periodic trends. For example: • Activity series of metals and halogens can be used to predict if single-replacement reactions will occur. • Solubility table can be used to predict if double-replacement reactions will occur.	Utilize different versions of a chemical equation to communicate details of a chemical reaction. Identify the five general types of chemical reactions and describe components that are reactants and products in these reactions. Predict the outcome of certain reactions and make a claim about why the reactants react and/or why the products are formed. Investigate and explain formation of precipitates using knowledge of solubility. Use evidence to make a claim about whether a reaction will form a precipitate in a chemical reaction. Develop a model to represent the reactants, interaction between atoms during the reaction, and the predicted products.

Unit V: Chemical Reactions

Developing and Using Models: Develop a model based on evidence to illustrate the relationships between systems or between components of a system. **Using Mathematics and Computational Thinking:** Use mathematical representations of phenomena to support claims.	*A/Honors Level Extension:* Enthalpy is the heat present in a reaction. The heat lost or gained by a system during a reaction or process carried out at constant pressure is called the change in enthalpy (ΔH). When ΔH is positive, the reaction is endothermic. When ΔH is negative, the reaction is exothermic. $\Delta H^o_{rxn} = \sum \Delta H^o_f(products) - \sum \Delta H^o_f(reactants)$ Energy, the capacity to do work or produce heat, cannot be created, or destroyed, but it can change form or more from one place or system to another. Entropy (ΔS) is a measure of the disorder or randomness of a system; spontaneous processes always result in an increase in the entropy of the universe.	*A/Honors Level Extension:* Use mathematical representations to distinguish between endothermic and exothermic reactions. Calculate enthalpy of reaction from bond energies and molar enthalpy of reaction data. Calculate the change in enthalpy for a reaction using the sum of a system of chemical equations or a table of enthalpies of formation. Understand how and why substances change in enthalpy when transitioning between physical states. Calculate the change in enthalpy for state changes between solid, liquid, and gas. Describe the link between state change enthalpies and the strength of intermolecular forces. Analyze the change in entropy of a reaction to determine if the products are disordered.

<table>
<tr>
<td rowspan="2"></td>
<td>Free energy (ΔG) is the energy available to do work. When ΔG is positive, the reaction is nonspontaneous. When ΔG is negative, the reaction is spontaneous.
$$\Delta G_{system} = \Delta H_{system} - T\Delta S_{system}$$</td>
<td>Describe the conditions necessary to produce a spontaneous chemical reaction.
Calculate the change in free energy to determine if the reaction is spontaneous or nonspontaneous.
Apply scientific principles and evidence to provide an explanation of phenomena related to the spontaneity of reactions and solve design problems associated with real world situations.</td>
</tr>
<tr>
<td colspan="2">VOCABULARY: law of conservation of mass, chemical equation, coefficient,subscript, chemical change, combustion, synthesis, decomposition, single replacement, double replacement, Kelvin, specific heat, enthalpy, entropy, Gibbs free energy, spontaneous, non-spontaneous, endothermic, exothermic</td>
</tr>
<tr>
<td colspan="3">ASSESSMENT EVIDENCE: Students will show their learning by:

Constructing and revising an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties (HS-PS1-2).
Developing a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy (HS-PS1-4).
Applying scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs (HS-PS1-5).
Using mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction (HS-PS1-7).
</td>
</tr>
</table>

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Unit V: Chemical Reactions

KEY LEARNING EVENTS AND INSTRUCTION:	
• Anchoring Event – Students investigate and develop understanding through exploring real-world phenomena. • Chemical Reactions Lab – Students collect evidence regarding various types of chemical reactions in the lab, and construct explanations to compare/contrast and to describe the properties and characteristics of these reactions. • Modeling Chemical Reactions – Students explore types of chemical reactions and balance their equations, predicting the products of reactions. • Bond Energy Calculations – Students calculate the change in total bond energy for a particular reaction observed in class when given bond energy data for each bond in the reaction. • Thermochemistry Lab – Students observe and compare/contrast endothermic and exothermic reactions and construct an explanation to describe these processes. *(A/Honors Extension)* • Calorimetry Lab – Students apply their knowledge of system enthalpy to the example of foods and how to change this variable. *(A/Honors Extension)*	
SUGGESTED TIME ALLOTMENT	**5 weeks**
SUPPLEMENTAL UNIT RESOURCES	Phenomena-based inquiry questions to anchor instruction: • How is energy obtained from chemical reactions? • Does the number of atoms change in a chemical reaction? • What is the outcome of a decomposition reaction? • How do substances combine to make new substances in our everyday lives? *A/Honors Extension (Investigation 8)* • Why do you get hot when you exercise? • How much energy is in the chemical bond inside a sugar cube? • How much heat is released when aluminum oxide is formed? • Can ice water be used to start a fire?

	A/Honors Extension (Investigation 15) • How do batteries store energy? • What's the chemistry that makes jewelry cleaner work? • Do all metals react the same in redox reactions? • What happens when an electric current is applied to a metal in a salt solution? Savvas *Experience Chemistry* Textbook Teacher Guide Resources Investigations 6, 8, and 15 Additional Resources: • American Association of Chemistry Teachers • American Chemical Society • National Science Teaching Association • PhET Interactive Simulations

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Unit VI: Chemical Quantities

<table>
<tr><td colspan="3">TRANSFER: Students will use mathematical representations to simplify the measurement of particles.</td></tr>
<tr><td rowspan="5">STANDARDS/GOALS:

<u>Performance Expectations:</u>
HS-PS1-7: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.

<u>Disciplinary Core Ideas</u>:
PS1.B: Chemical Reactions The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.

<u>Crosscutting Concepts</u>:
Energy and Matter: The total amount of energy and matter in a closed system is conserved.

<u>Science and Engineering Practices</u>:
Using Mathematics and Computational Thinking: Use mathematical representations of phenomena to support claims.</td><td>ENDURING UNDERSTANDINGS</td><td>ESSENTIAL QUESTIONS</td></tr>
<tr><td>The mole represents a large number of extremely small particles.</td><td>• How can scientists quantify the extremely large number of particles involved in chemical processes that cannot be seen?</td></tr>
<tr><td>The mole and molar mass provide information to express the amount of a substance, while dimensional analysis is used to convert to desired units of measurement.</td><td>• How does the measurements of particles support the understanding of chemistry and chemical calculations?</td></tr>
<tr><td><u>KNOWLEDGE</u>
Students will know:</td><td><u>SKILLS</u>
Students will be able to:</td></tr>
<tr><td>Matter can be measured by particle count and mass.

The mole is used to compare relative amounts of extremely small particles.</td><td>Investigate two methods used to measure matter – count and mass (Note: volume will be addressed in the solutions and gases units).

Develop and use a model of different units of measurement.

Use the mathematical representation of the mole to express quantities of atoms, molecules, and formula units.</td></tr>
</table>

	One mole of a substance contains Avogadro's number of representative particles. Conversion factors written from Avogadro's relationship can be used to convert between moles and number of representative particles.	Explain the relationship between the mole and Avogadro's number. Use Avogadro's number to convert from moles to particles and particles to moles.
	The mass in grams of one mole of any pure substance is called its molar mass. Each element has a unique molar mass listed on the periodic table. The molar mass of a compound is calculated from the molar masses of all of the elements in the compound.	Use the periodic table to identify the molar mass of elements. Use the periodic table to calculate the molar mass of compounds.
	Conversion factors based on a compound's molar mass are used to convert between moles and mass of a compound.	Convert mole quantities to masses, and mass quantities to moles.
	The percent by mass of an element in a compound gives the percentage of the compound's total mass due to that element.	Describe how to find the percent composition of a compound. Calculate the percent by mass of an element within a compound. Use mathematical representations of mass percentages to support claims about the composition of a compound.

Unit VI: Chemical Quantities

	The subscripts in an empirical formula give the smallest whole-number ratio of moles of elements in the compound, whereas the molecular formula gives the actual number of atoms of each element in a molecule or formula unit of a substance.	Construct and revise an explanation based on evidence, such as mathematical representations, to compare empirical and molecular formulas. Determine the empirical and molecular formulas for a compound from percent by mass mathematical data. Use subscripts within a chemical formula to represent a mole ratio.
	VOCABULARY: conservation of mass, mole, molar mass, Avogadro's number, percent by mass, particle, molecule, dimensional analysis, empirical formula, molecular formula,hydrate, mole ratio	

ASSESSMENT EVIDENCE: Students will show their learning by:

- Using mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction (HS-PS1-7).
- Applying knowledge of chemical properties of elements and of conservation of mass to predict chemical reactions.
- Using mathematical thinking and dimensional analysis techniques to perform unit conversions.

KEY LEARNING EVENTS AND INSTRUCTION:

- Mole-Mass Relationship – Students design a solution (such as for quantities of ingredients in a bread recipe) and relate that to the phenomenon of quantifying matter in different ways.
- Chemical Quantities Modeling – Students visualize the size of a mole through molecular models. Students compare masses of a mole of everyday objects (such as a mole of marbles) to that of a mole of an element.
- Empirical/Molecular Formula Lab – Students make predictions and draw conclusions about empirical and molecular formulas using chemical reactions of specific elements, such as magnesium oxide.

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Unit VI: Chemical Quantities

SUGGESTED TIME ALLOTMENT	**3 weeks**
SUPPLEMENTAL UNIT RESOURCES	Phenomena-based inquiry questions to anchor instruction: • Why do we quantify matter in different ways? • How can you measure matter? • Can you inflate a balloon with vinegar and baking soda? • What percentage of a marshmallow is Carbon? • How can the concentration of a solution be changed? Savvas *Experience Chemistry* Textbook Teacher Guide Resources Investigation 5 Additional Resources: • American Association of Chemistry Teachers • American Chemical Society • National Science Teaching Association • PhET Interactive Simulations

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Unit VII: Stoichiometry

<table>
<tr><td colspan="3">TRANSFER: Students will use mathematical representations to apply the concept that energy and matter in closed systems are conserved.</td></tr>
<tr><td rowspan="6">STANDARDS / GOALS:

<u>Performance Expectations:</u>
HS-PS1-7: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.

<u>Disciplinary Core Ideas</u>:
PS1.B: Chemical Reactions The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions.

<u>Crosscutting Concepts</u>:
Energy and Matter: The total amount of energy and matter in a closed system is conserved.

<u>Science and Engineering Practices</u>:
Using Mathematics and Computational Thinking: Use mathematical representations of phenomena to support claims.</td><td>ENDURING UNDERSTANDINGS</td><td>ESSENTIAL QUESTIONS</td></tr>
<tr><td>Mass relationships in chemical reactions confirm the law of conservations of mass.</td><td>• How do chemists determine the amounts of reactants consumed and products formed during chemical reactions?</td></tr>
<tr><td>Most natural phenomena are not 100% efficient.</td><td>• How do processes differ from quantitative chemical reaction analysis and how do chemists acknowledge the inefficiencies?</td></tr>
<tr><td>Stoichiometry can help to minimize the quantities of excess waste created during chemical processes, which has society, environmental, and economic benefits.</td><td>• How can the conservation of mass be applied to improve chemical processes?</td></tr>
<tr><td><u>KNOWLEDGE</u>
Students will know:</td><td><u>SKILLS</u>
Students will be able to:</td></tr>
<tr><td>Balanced chemical equations can be interpreted in terms of moles, mass, and representative particles (atoms, molecules, formula units).</td><td>Describe the relationships expressed from a balanced chemical equation.

Construct and revise an explanation based on evidence from a balanced chemical equation that the total amount of matter is conserved in the reaction.</td></tr>
</table>

Unit VII: Stoichiometry

	Stoichiometry is based on the law of conservation of mass while applying conversion factors to understand the relationships between reactants and products.	Develop a model that demonstrates conservation of mass in a chemical equation. Calculate and communicate data on different units of measurement.
	Mole ratios are derived from the coefficients of balanced chemical equations. Each mole ratio relates the number of moles of one reactant or product to the number of moles of another reactant or product in the chemical reaction.	Analyze data on proportionality of reactants and products to predict their stoichiometric ratios in the corresponding chemical equation. Apply mathematical concepts to interpret a chemical equation. Use the mole ratio in a chemical reaction to relate amounts of participating substances.
	Chemists use stoichiometry calculations to predict the amounts of reactants used, and products formed in specific reactions by making use of mole ratios from a balanced chemical equation to convert between mass and moles.	Use dimensional analysis to determine the mass of reactant required to obtain a given amount of product.
	The limiting reactant is the reactant that is completely consumed during a chemical reaction, while the reactants that remain after the reaction stops are called excess reactants.	Explain the concept of limiting reactant and how it affects the amount of product produced in a reaction. Use computational thinking to predict the grams of product given the grams of reactant.

	The theoretical yield of a chemical reaction is the maximum amount of product that can be produced from a given amount of reactant and is calculated from the balanced chemical equation. The actual yield is the amount of product produced obtained through experimentation.	Describe the differences between theoretical and actual yield and why the former is usually larger than the latter.
	Percent yield is the ratio of actual yield to theoretical yield expressed as a percent. High percent yield is important in reducing the cost of every product produced through chemical processes. $Percent\ yield\ =\ actual\ yield/theoretical\ yield\ x\ 100$	Calculate the percent yield based on experimental and theoretical data. Plan and carry out an investigation to produce data to serve as evidence to support the claim that natural phenomena are not 100% efficient. From investigation evidence, explain why the percent yield varies from the 100% predicted by theoretical yield calculations.
	VOCABULARY: stoichiometry, molar mass, mole ratio, limiting reagent, percent yield	

ASSESSMENT EVIDENCE: Students will show their learning by:

- Using mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction (HS-PS1-7).
- Applying knowledge of chemical properties of elements and of conservation of mass to predict chemical reactions.

KEY LEARNING EVENTS AND INSTRUCTION:

- Stoichiometric Calculation Lab – Students apply their understanding of stoichiometric calculations through a titration lab.
- Limiting Reagent – Students develop and use models to what reactant will be depleted first in a given reaction.

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Unit VII: Stoichiometry

SUGGESTED TIME ALLOTMENT	**4 weeks**
SUPPLEMENTAL UNIT RESOURCES	Phenomena-based inquiry questions to anchor instruction: • What can make a recipe fail? • Is there math in my sandwich? • Why do we use different types of measurements? • What is the limiting reagent? Savvas *Experience Chemistry* Textbook Teacher Guide Resources Investigation 7 Additional Resources: • American Association of Chemistry Teachers • American Chemical Society • National Science Teaching Association • PhET Interactive Simulations

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Unit VIII: Solutions and Equilibrium

<table>
<tr><td colspan="3">TRANSFER: Students will develop explanations of natural phenomena by applying their understanding that interactions of matter at the bulk scale are determined by forces at the atomic level.</td></tr>
<tr><td rowspan="6">STANDARDS / GOALS:

<u>Performance Expectations:</u>
HS-PS1-3: Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.
HS-PS2-4: Use mathematical representations of Newton’s Law of Gravitation and Coulomb’s Law to describe and predict the gravitational and electrostatic forces between objects.
HS-PS3-5: Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.

A/Honors Level Extension:
HS-PS1-5: Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.</td><td>ENDURING UNDERSTANDINGS</td><td>ESSENTIAL QUESTIONS</td></tr>
<tr><td>Nearly all of the gases, liquids, and solids that make up our world are mixtures.</td><td>• How do chemists classify and describe mixtures?</td></tr>
<tr><td>Many chemical reactions reach a dynamic equilibrium that can shift when conditions change.</td><td>• What happens to a chemical reaction when conditions change?</td></tr>
<tr><td>Every chemical reaction proceeds at a definite rate, but the speed can be altered by changing the conditions of the reaction.</td><td>• How can scientists manipulate the conditions of a reaction to affect the rate of reaction?</td></tr>
<tr><td><u>KNOWLEDGE</u>
Students will know:</td><td><u>SKILLS</u>
Students will be able to:</td></tr>
<tr><td>Solutions are homogeneous mixtures that can exist when a solute of gas, liquid, or solid become dissolved or mixed in a solvent of gas, liquid, or solid.

Two types of heterogeneous mixtures are suspensions and colloids.</td><td>Describe the formation of various types of solutions.

Differentiate between solutions, suspensions, and colloids.

Develop models to illustrate the relationships between solutes and solvents in a solution.</td></tr>
</table>

Unit VIII: Solutions and Equilibrium

HS-PS1-6: Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium. **HS-PS1-7:** Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. **<u>Disciplinary Core Ideas:</u>** **PS1.A: Structure and Properties of Matter** The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. **PS2.B: Types of Interactions** Newton's law of universal gravitation and Coulomb's law provides the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.	The solvation process involves solute particles surrounded by solvent particles and can be affected by an increase or decrease in the collisions between solute and solvent particles from factors including agitation, surface area, and temperature. Mixtures can be separated by physical means; common separation techniques include filtration, distillation, sublimation, chromatography, and crystallization.	Develop a model that demonstrates the process of solvation within an aqueous solution. Plan and conduct an investigation to produce data to serve as evidence to support the claim that factors such as agitation, surface area, and temperature can affect the solvation process. Revise initial models of the process based on evidence to illustrate how increased collisions affects solvation. Plan and conduct an investigation to test and compare separation methods of a mixture. *Extension*: Refine the design of method based on data and evidence of success from initial trials. Review a solution to a complex real-world problem related to separation of mixtures. *Extension*: Propose alternative revised methods based on scientific knowledge and student-generated sources of evidence.

Unit VIII: Solutions and Equilibrium

PS3.C: Relationship Between Energy and Focus When two objects interacting through a field change relative position, the energy stored in the field is changed. **PS1.B: Chemical Reactions** Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present. The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. **ETS1.C: Optimizing the Design Solution** Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed.	Concentration is a measure of how much solute is dissolved in a specific amount of solvent or solution; concentration can be measured quantitatively: • Molarity is the number of moles of solute dissolved per liter of solution. $molarity\ (M) = \frac{moles\ of\ solute}{liters\ of\ solution}$ • Molality is the ratio of the number of moles of solute dissolved in 1 kg of solvent. $molality\ (m) = \frac{moles\ of\ solute}{kilograms\ of\ solvent}$ • Percent by mass is the ratio of the solute's mass to the solutions mass. $percent\ by\ mass = \frac{mass\ of\ solute}{mass\ of\ solution}\ x\ 100$ • Percent by volume is the ratio of the volume of the solute to the volume of the solution. $percent\ by\ volume = \frac{volume\ of\ solute}{volume\ of\ solution}\ x\ 100$ The number of moles of solute does not change during a dilution. $M_1V_1 = M_2V_2$	Calculate the molarity, molality, percentage of a solution by mass and percentage of a solution by volume. Use mathematical representations of phenomena to show how changes in the amounts of solute and solvent affect the concentration of a solution. Devise a method to make a solution of a specific concentration. Dilute a stock solution to desired concentration.

<u>**Crosscutting Concepts**</u> **Patterns:** Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. **Cause and Effect:** Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. ***A/Honors Level Extension:*** **Stability and Change:** Much of science deals with constructing explanations of how things change and how they remain stable. **Energy and Matter:** The total amount of energy and matter in a closed system is conserved. <u>**Science and Engineering Practices**</u>: **Planning and Carrying out Investigations:** Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.	Solutions can be saturated, unsaturated, or supersaturated. Henry's law states that at a given temperature, the solubility (S) of a gas in a liquid is directly proportional to the pressure (P) of the gas above the liquid. $\frac{S_1}{P_1} = \frac{S_2}{P_2}$	Develop and use a model to illustrate the differences between unsaturated, saturated, and supersaturated solutions. Plan and conduct an investigation that applies scientific principles in order to gather evidence to provide an explanation for the phenomena of supersaturated solutions. Develop and use a model to explain how solutions can become supersaturated. Use mathematical representations of phenomena (graphs depicting solubility curves) to provide evidence supporting explanations for supersaturation. Use Henry's law to discover the relationship between the solubility of a gas and pressure.

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Unit VIII: Solutions and Equilibrium

Using Mathematics and Computational Thinking: Use mathematical representations of phenomena to describe explanations. **Developing and Using Models:** Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. ***A/Honors Level Extension:*** **Constructing Explanations:** Apply scientific principles and evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. **Designing Solutions:** Refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. **Using Mathematics and Computational Thinking:** Use mathematical representations of phenomena to support claims.	Colligative properties (vapor pressure lowering, boiling point elevation, freezing point depression, and osmotic pressure) are affected by the number of particles, not the identity of particles in solution. The following rules apply: • Nonvolatile solutes lower the vapor pressure of a solution. • Boiling point elevation is directly related to the solutions molality. $\Delta T_b = K_b m$ • A solution's freezing point depression is always lower than that of the pure solvent. $\Delta T_f = K_f m$ • Osmotic pressure depends on the number of solute particles in a given volume. The equilibrium constant expression is a ratio of the molar concentrations of the products to the molar concentrations of the reactants with each concentration raised to the power equal to its coefficient in the balanced chemical equation. $a\text{A} + b\text{B} \rightleftharpoons c\text{C} + d\text{D}$ $K_{eq} = \frac{[\text{C}]^c[\text{D}]^d}{[\text{A}]^a[\text{B}]^b}$	Plan and conduct an investigation to produce data to serve as evidence to support the claim that colligative properties are affected by the number of particles, not the identity of particles in solution. Use mathematical representations of phenomena (phase diagrams) to provide evidence that explains colligative properties. Review a solution to a complex real-world problem related to colligative properties then propose and support an alternative solution based on scientific knowledge and student-generated sources of evidence. Calculate the K_{eq} for a reaction based on the molar concentrations and ratios of reactants and products. Construct and revise an explanation based on evidence, such as mathematical representations, to describe if products or reactants are favored at equilibrium.

Unit VIII: Solutions and Equilibrium

	The value of the equilibrium constant expression, K_{eq}, is a constant for a given temperature.	Calculate the equilibrium concentration of a reactant or product based on a known K_{eq} value at constant temperature. Construct and revise an explanation based on evidence, such as mathematical representations, to explain how the formation of a product might be affected by changes in reactant concentrations.
	Le Châtelier's principle describes how an equilibrium system shifts in response to a stress or a disturbance.	Use Le Châtelier's principle to predict the direction a reaction at equilibrium will shift if disrupted by a change in concentration, temperature, or pressure. Construct and revise an explanation based on evidence, such as mathematical representations, to support how and why variables such as temperature and pressure can be adjusted to increase or decrease yield in a reaction. Develop and use a model to show the effect of concentration and temperature on reaction rate.

Unit VIII: Solutions and Equilibrium

	VOCABULARY: equilibrium, equilibrium constant, Le Châtelier's principle, solutions, molarity, concentration, dilution

ASSESSMENT EVIDENCE: Students will show their learning by:

- Planning and conducting an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles (HS-PS1-3).
- Applying scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs (HS-PS1-5).
- Refining the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium (HS-PS1-6).
- Using mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction (HS-PS1-7).

KEY LEARNING EVENTS AND INSTRUCTION:

- Anchoring Event – Students investigate and develop understanding through exploring real-world phenomena.
- Concentrations of Solutions – Students carry out an investigation of concentrations of solutions. They use mathematics to calculate molarity and moles of solute in a solution and design a process for diluting an aqueous solution.
- Le Châtelier's Principle – Students explore a temperature dependent equilibrium reaction to discover the properties that guide this principle.
- Solubility Chart – Students use aa solubility chart to determine the solubility of a compound.
- Dilution Lab – Students dilute solutions and explore concentration reactions in the laboratory setting. Students will observe and make observations and predictions using a reaction chamber. (A/Honors Extension)

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Unit VIII: Solutions and Equilibrium

<table>
<tr><td>SUGGESTED TIME ALLOTMENT</td><td>4 weeks</td></tr>
<tr><td>SUPPLEMENTAL UNIT RESOURCES</td><td>Phenomena-based inquiry questions to anchor instruction: (Investigation 4)
What makes salt dissolve in water?
A/Honors extension (Investigation 12)
How do limestone caves form?
How can you make a reaction go faster?
What makes a match catch fire?
What is happening during equilibrium?
Why is the temperature change different when a solute is added to cups of water at different temperatures?
A/Honors extension (Investigation 13)
How does acid rain impact the environment?
Is there acid in the breath you exhale?
How are a solution’s ionization and pH related?
How do antacids help counteract heartburn symptoms?
How does blood maintain a constant pH?
Savvas Experience Chemistry Textbook Teacher Guide Resources Investigations 4, 12, and 13

Additional Resources:
American Association of Chemistry Teachers
American Chemical Society
National Science Teaching Association
PhET Interactive Simulations</td></tr>
</table>

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Unit IX: The Behavior of Gases

<table>
<tr><td colspan="3">TRANSFER: Students will draw conclusions about causal relationships based on evidence gathered during experimental investigations.</td></tr>
<tr><td rowspan="6">STANDARDS/GOALS:

<u>Performance Expectations:</u>
HS-PS1-3: Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.

<u>Disciplinary Core Ideas:</u>
PS1.A: Structure and Properties of Matter
The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.
PS2.B: Types of Interactions
Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformation of matter, as well as the contact forces between material objects.

<u>Crosscutting Concepts:</u>
Patterns: Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.</td><td>ENDURING UNDERSTANDINGS</td><td>ESSENTIAL QUESTIONS</td></tr>
<tr><td>Gases respond in predictable ways to changes in pressure, temperature, volume, and number of particles.</td><td>• How can you predict the behavior of gases in response to changes in pressure, temperature, volume, and amount?</td></tr>
<tr><td>The behavior of gases is linked to the kinetic molecular theory.</td><td>• How is the kinetic molecular theory used to explain the behavior of matter?</td></tr>
<tr><td>Mathematical relationships can be used to describe trends discovered through experimentation.</td><td>• How are gas laws developed and manipulated to mathematically determine unknown variables?</td></tr>
<tr><td><u>KNOWLEDGE</u>
Students will know:</td><td><u>SKILLS</u>
Students will be able to:</td></tr>
<tr><td>The kinetic-molecular theory explains the properties of gases in terms of the size, motion, and energy of their particles.</td><td>Use the kinetic theory to explain the properties of gases.

Plan and conduct an investigation to gather data to serve as evidence to explain how the compressibility of gases differs from the compressibility of solids and liquids.</td></tr>
</table>

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Unit IX: The Behavior of Gases

<u>Science and Engineering Practices:</u> **Planning and Carrying out Investigations:** Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.	The gas laws (Boyle's, Charles's, Gay-Lussac's, combined) and Avogadro's principle describe the predicted behavior of gases: • Boyle's law states the volume of a fixed amount of gas is inversely proportional to its pressure at constant temperature. $P_1V_1 = P_2V_2$ • Charles's law states the volume of a fixed amount of gas is directly proportional to its Kelvin temperature at constant pressure. $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ • Gay-Lussac's law states the pressure of a fixed amount of gas is directly proportional to its kelvin temperature at constant volume. $\frac{P_1}{T_1} = \frac{P_2}{T_2}$ • The combined gas law related pressure, temperature, and volume in a single statement. $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$ • Avogadro's principle states equal volumes of gases at the same pressure and temperature contain equal numbers of particles. $\frac{V_1}{n_1} = \frac{V_2}{n_2}$	Describe the effects on gases of changes in volume, temperature, pressure, and the number of particles. Plan and carry out an investigation to gather data to serve as evidence to explain the relationship between the volume, temperature, and pressure of a gas. Develop and use models to explain the gas laws. Relate the patterns of interaction between gas particles at the molecular scale to the patterns of gas behavior at the macroscopic scale. Explain the relationship between moles and volumes of gases at STP.

Unit IX: The Behavior of Gases

	The ideal gas law relates the amount of a gas present to its pressure, temperature, and volume. $$PV = nRT$$ It can be used to find the molar mass (M) if the mass (m) of the gas is known or the density of the gas if its molar mass is known. $$M = \frac{mRT}{PV}$$ $$D = \frac{MP}{RT}$$	Investigate and explain the ideal gas law. Construct and revise an explanation based on evidence of how a real gas differs from an ideal gas. Explain how the concept of an ideal gas is helpful. Calculate the density of a gas at STP, given the molar mass of the gas.
	At very high pressures and very low temperatures, real gases behave differently than ideal gases.	Develop an explanation of phenomena related to the behavior of real gases. Solve design problems in context.
	Graham's law is used to compare the diffusion rates of two gases. $$\frac{Rate_A}{Rate_B} = \sqrt{\frac{molar\ mass_B}{molar\ mass_A}}$$	Describe why some gases diffuse faster than others. Explain Graham's law of effusion. Apply scientific principles and evidence to provide an explanation of phenomena to describe the process that causes wind.

Unit IX: The Behavior of Gases

	In combination with the gas laws, Dalton's law of partial pressures is used to determine the pressures of individual gases in gas mixtures. $P_{total} = P_1 + P_2 + P_3 + \cdots P_n$	Explain Dalton's law of partial pressure. Apply scientific principles and evidence to provide an explanation of phenomena to relate relative humidity to water vapor, partial pressure, and air temperature.
	VOCABULARY: intermolecular forces, dipole-dipole interaction, hydrogenbonding, London dispersion forces, Van Der Waals forces, solid, liquid, gas, boiling, freezing, melting, condensation, sublimation, deposition, phase change, kelvin, gas constant, ideal gas law, Boyle's law, Charles'slaw, combined gas Law, Avogadro's law, standard temperature, and pressure (STP)	

ASSESSMENT EVIDENCE: Students will show their learning by:

- Planning and conducting an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles (HS-PS1-3).
- Analyzing data and drawing conclusions about the relationship between gas pressure and temperature.
- Developing and using models to predict the behavior of gases in response to changes in pressure, temperature, volume, and amount.

KEY LEARNING EVENTS AND INSTRUCTION:

- Phase Change Diagram Models – Students add to previously developed models from Unit 1. Students analyze and compare these models to construct deeper understandings of phase changes.
- The Combined Gas Law – Students explore the gas laws of Boyle, Charles, Gay-Lussac, and Avogadro and how the laws are combined into a single mathematic expression.
- Ideal Gases – Students observe how a real gas differs from an ideal gas, comparing the interactions between gas particles at the molecular scale and patterns of gas behavior at the macroscopic scale.
- Students Boiling Point Lab – Students plan and conduct an investigation to explore intermolecular forces.

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Unit IX: The Behavior of Gases

SUGGESTED TIME ALLOTMENT	**3 weeks**
SUPPLEMENTAL UNIT RESOURCES	Phenomena-based inquiry questions to anchor instruction: • What causes the Santa Ana winds? • Can a gas make an object move? • How can you blow up a balloon inside a bottle without blowing air into it? • What causes a marshmallow to shrink and expand? • How do gases spread apart? Savvas *Experience Chemistry* Textbook Teacher Guide Resources Investigation 9 Additional Resources: • American Association of Chemistry Teachers • American Chemical Society • National Science Teaching Association • PhET Interactive Simulations

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Unit X: Nuclear Processes

TRANSFER: Students will recognize the hazards and benefits resulting from the energy potential of nuclear processes.		
STANDARDS / GOALS: **<u>Performance Expectations:</u>** **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-PS1-8:** Develop models to illustrate changes in composition of an atom's nucleus and energy released during the processes of fission, fusion, and radioactive decay. **HS-ESS1-1:** Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy in the form of radiation. **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. **HS-ESS1-3:** Communicate scientific ideas about the way stars, over their life cycle, produce elements. **HS-ESS1-6:** Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history.	**ENDURING UNDERSTANDINGS**	**ESSENTIAL QUESTIONS**
	Nuclear processes, including fusion, fission, and radioactive decay or unstable nuclei, involve release or absorption of energy.	• What happens when the nucleus of an atom changes?
	Nuclear fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation.	• How do chemical processes compare to nuclear processes? • How do nuclear processes influence life on earth?
	Other than hydrogen and helium, nuclear fusion within stars produces all atomic nuclei lighter than and including iron. Heavier elements are produced when certain massive stars achieve a supernova stage and explode.	• How does the study of astronomy overlap with the study of chemistry?
	Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials.	• How can chemists apply knowledge of nuclear processes to analyze materials?

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Unit X: Nuclear Processes

Disciplinary Core Ideas	KNOWLEDGE Students will know:	SKILLS Students will be able to:
PS1.A: Structure and Properties of Matter Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. 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. **PS2.B: Types of Interactions** Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. **PS1.C: Nuclear Processes** Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process. **PS3.D: Energy in Chemical Processes and Everyday Life** Nuclear fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation.	The nucleus of an atom consists of positively charged protons and neutral neutrons held together by the strong nuclear force. The conversion of an atom of one element to an atom of another by radioactive decay processes is called transmutation. There are three types of radiation radioisotopes can emit to attain more stable atomic configurations: alpha, beta, and gamma. Spontaneous radioactive decays follow a characteristic exponential decay law referred to as half-life.	Identify the particles in the atomic nucleus. Describe the forces present in the atomic nucleus. Describe the differences between each type of nuclear radiation. Develop models to illustrate the changes in composition of the atomic nucleus. Develop models to demonstrate the energy released during radioactive decay. Construct an explanation based on understanding of radioactive decay to support the claim that transmutation processes continue until nuclear stability is achieved. Determine the likeliness that a radioactive material is present after a period time has passed.

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Unit X: Nuclear Processes

PS4.B: Electromagnetic Radiation 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. **ESS1.A: The Universe and Its Stars** The star called the sun in changing and will burn out over a lifespan of approximately 10 billion years. The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe. Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode.	Radiochemical dating is a technique for determining the age of an object by using the half-life of the atoms to measure the amount of certain radioisotopes remaining in the object. Atomic number, mass number, and energy are conserved in nuclear reactions. Chemical reactions involve changes involving the electrons surrounding an atom, while nuclear reactions involve changes in the nucleus of an atom.	Use mathematics to calculate the half-life of a radioactive substance and the approximate age of old materials. Compare amounts of initial substance to amount of remaining substance after radioactive decay. Construct an explanation based on understanding of conservation of mass to support the claim that atomic number, mass number, and energy are conserved in nuclear reactions. Develop models to explain the conservation of mass and energy during nuclear fission. Develop models to explain the conservation of mass and energy during nuclear fusion. Construct an explanation based on understanding of chemical changes to describe the differences between chemical reactions and nuclear reactions. Develop models to represent the differences between chemical reactions and nuclear reactions.

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Unit X: Nuclear Processes

ESS1.C: The History of Planet Earth Although active geologic processes, such as plate tectonics and erosion, have destroyed or altered most of the very early rock record on Earth, other objects in the solar system, such as lunar rocks, asteroids, and meteorites, have changed little over billions of years. Studying these objects can provide information about Earth's formation and early history. **<u>Crosscutting Concepts</u>** **Patterns:** Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. **Energy and Matter:** In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. Energy cannot be created or destroyed–only moved between one place and another place, between objects and/or fields, or between systems. **Scale, Proportion, and Quantity:** The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.	Nuclear fission is the splitting of a nucleus into fragments, while nuclear fusion is the combining of atomic nuclei. Induced transmutation is the bombardment of nuclei with particles in order to create new elements. In a chain reaction, one reaction induces others to occur. A sufficient mass of fissionable material is necessary to initiate the chain reaction. Fission and fusion reactions release large amounts of energy. $E = mc^2$	Define nuclear fission and nuclear fusion. Compare the processes of nuclear fission and fusion. Develop models to illustrate the processes of nuclear fission and fusion. Illustrate the process of transmutation. Explain the role of fusion in the formation of new elements. Describe the role of fusion in the star life cycle. Identify fissionable material used historically. Develop and/or use a model to demonstrate the chain reaction process that sustains nuclear power plants and nuclear weapons. Calculate the energy released during fission and fusion. Compare the amounts of energy released during fission and fusion.

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Unit X: Nuclear Processes

<table>
<tr>
<td rowspan="2">Stability and Change: Much of science deals with constructing explanations of how things change and how they remain stable.

<u>Science and Engineering Practices</u>
Developing and Using Models: Use a model to predict the relationships between systems or between components of a system.
Constructing Explanations: Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.
Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.
Obtaining, Evaluating, and Communicating Information: Communicate scientific ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).</td>
<td>There are both beneficial and harmful effects of nuclear technologies nuclear energy, disease diagnoses, radioluminescence, material dating, nuclear weapons, radiation treatments.</td>
<td>Identify real-world applications of nuclear processes.

Determine the positive and negative effects of nuclear process in context.

Explain radiation hazards and how they can be measured.

Describe the risks and benefits of nuclear technologies.

Construct and revise an argument based on valid and reliable evidence to support or oppose the use of nuclear energy.</td>
</tr>
<tr>
<td colspan="2">VOCABULARY: radioactive decay, alpha, beta, gamma, fission, fusion, radiation, half-life, transmutation</td>
</tr>
</table>

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Unit X: Nuclear Processes

ASSESSMENT EVIDENCE: Students will show their learning by:

- Using 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-PS1-1).
- Developing 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 (HS-PS1-8).

KEY LEARNING EVENTS AND INSTRUCTION:

- Radioactivity and Half-Lives – Students explore the fundamental particles, major types of radioactive decay, and half-life.
- Fission and Fusion – Students explore patterns in the binding energies of elements and the conversions between mass and energy.
- Decay Series Modeling – Students model decay series using cards representing various isotopes and radioactive particles such as those leading to the breakdown of Uranium to Lead.
- Nuclear Technologies – Students learn about the opportunities and risks associated with nuclear technologies in energy and medical fields. Students study the damaging effects of ionizing radiation and cosmic rays.

SUGGESTED TIME ALLOTMENT	**3 weeks**
SUPPLEMENTAL UNIT RESOURCES	Phenomena-based inquiry questions to anchor instruction: • What gives robots enough energy to explore Mars for many years? • Is nuclear radiation composed of matter, energy, or both? • Will the sun ever change or die out? • What trade-offs accompany the use of nuclear technologies? Savvas *Experience Chemistry* Textbook Teacher Guide Resources Investigation 17 Additional Resources: • American Association of Chemistry Teachers • American Chemical Society • National Science Teaching Association • PhET Interactive Simulations