UNIT 03 – BONDING AND COMPOUND TYPES
UNIT PLAN

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UNIT NARRATIVE

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Unit Phenomenon Anchoring Event: Self-Healing Roman Concrete Research indicates that Roman concrete possesses a degree of self-healing capability, however modern mixed and poured concrete does not. *Why does concrete from ancient Rome heal itself, but the concrete of modern day will not? What is different about it that lets it last?* Unit 02 examined how single atoms and ions of elements behaved based on the subatomic particle composition and the electrostatic forces between them. Now that we have fully analyzed atoms, scholars will examine what happens when atoms combine into compounds. In Unit 02 students spent a large amount of time analyzing how ions form, ionization energies, and how atoms as individuals behave. Unit 03 builds on this momentum by introducing how atoms interact with one another based on the trends developed in the prior unit. Students will learn what a compound is, how to analyze a single compound, and the types of compounds that exist based on the different types of bonding. The anchoring event centers on the question of why Roman concrete demonstrates self-healing properties while modern concrete does not, even though both are made from similar ingredients. Students investigate Roman concrete through videos and articles, which provide a puzzling contrast: two materials with comparable base components show dramatically different behaviors over time. Teachers should emphasize that this is not simply an interesting historical fact but the guiding question that will sustain student curiosity and connect all lessons in the unit. By returning to this phenomenon repeatedly, students learn to apply quantitative tools (molar mass and percent composition) and bonding models (ionic, metallic, covalent, and structural isomers) to explain how differences in composition and bonding lead to differences in macroscopic properties such as durability and self-healing. The unit unfolds in a three-part progression: **Quantitative Analysis of Compounds**, **Types of Compounds**, and **Creating and Analyzing Compound Models**. Each stage builds conceptually on the last, ensuring students not only classify and calculate with compounds, but also explain and justify bonding and structural representations with increasing sophistication. 1. **Quantitative Analysis of Compounds:** Since compounds are combinations of atoms, students extend the molar mass and dimensional analysis skills developed in Unit 01 to calculate quantities of entire compounds, not just single elements. They also explore percent composition, which reveals the proportion of each element in a compound. These skills provide a quantitative foundation for all later work: before students can explain why different compounds behave differently, they must be fluent in analyzing what elements are present, in what ratios, and in what quantities.

2. **Types of Compounds:** Building on their ability to quantify compounds based on methods that will apply to all compounds regardless of type, students will now qualitatively evaluate different types of compounds based on the widely accepted major categories of bonding character. Ionic bonding is introduced first, where the Law of Conservation of Mass is applied to explain why electron transfer requires equal and opposite charges between cations and anions. Next, metallic bonding is explored through a hands-on activity that highlights how delocalized electrons produce the unique properties of alloys, framed through Coulomb's Law to explain the balance of attractive and repulsive forces. Finally, covalent bonding is introduced through a thinking task simulation that functions as a guided tutorial on how shared electrons create covalent bonds and how potential energy is stored in bonds. This ensures students connect bond formation and electron sharing directly to the concept of stability and energy. Together, these investigations emphasize that compounds are not all the same; the type of bonding determines fundamental differences in structure and macroscopic properties.
3. **Creating and Analyzing Compound Models:** With bonding concepts in place, students turn to representation. They create Lewis structures for ionic and covalent compounds, using formal charge to evaluate which structure is most accurate. This introduces students to the idea that more than one structural possibility can exist, leading naturally to the concept of structural isomers. In a final hands-on activity, students generate isomers, demonstrating that a molecular formula alone does not fully describe a compound's structure. This final stage emphasizes that models are not just drawings but reasoning tools: they allow scientists to justify the stability, reactivity, and macroscopic properties of compounds.

By the end of Unit 03, students can not only calculate, classify, and represent compounds, but also explain how the type of bonding and structure relates to observable properties. This prepares for Unit 04, where intramolecular and intermolecular forces will explain compound interactions in greater detail.

Do not skip the creation of a seamless explanation, as this specifically targets disciplinary literacy within science.

CONTENT STANDARDS

Below are the standards **taught** and **assessed** in this unit.

FIRST INSTRUCTION STANDARDS		
Learning Objectives	**Essential Knowledge**	**Teacher Notes**
2.1.A.1 Distinguish between atoms, molecules, and compounds at the particle level. **2.1.A.2** Create and/or evaluate models of pure substances. *Note: Analysis of compounds is new to scholars in this unit, therefore those components in this standard are considered first instruction.*	**2.1.A** A pure substance always has the same composition. Pure substances include elements, molecules, and compounds. **a.** An element is composed of only one type of atom. **b.** A molecule is a particle composed of more than one atom. **c.** A compound is composed of two or more elements and has properties distinct from those of its component atoms.	
2.2.D.1. Create and/or evaluate Lewis diagrams for molecular compounds and/or polyatomic ions. **2.2.D.2** Determine if given molecules are structural isomers.	**2.2.D** A Lewis diagram is a simplified representation of a molecule. **a.** Lewis diagrams show the bonding patterns between atoms in a molecule. **b.** Molecules with the same number and type of atoms but different bonding patterns are structural isomers, which have different properties from one another.	
2.3.A.1 Create and/or evaluate a claim about the type of bonding in a compound based on its component elements and its macroscopic properties.	**2.3.A** Bonding between elements can be ~~nonpolar~~ covalent, ~~polar covalent~~, or ionic.	

2.3.B.1 Interpret the results of an experiment to determine the type of bonding present in a substance.	**2.3.B** Ionic and covalent compounds have different properties based on their bonding. **a.** Properties of ionic compounds result from electrostatic attractions of constituent ions. **b.** Properties of covalent compounds result from bonds created by the sharing of electrons ~~and intermolecular forces~~.	
2.3.C.1 Explain the relationship between the relative strength of attractions between cations and anions in an ionic solid in terms of the charges of the ions and the distance between them.	**2.3.C** Ionic solids are made of cations and anions. **a.** The relative number of cations and anions retain overall electrical neutrality. **b.** ~~As the charge on each ion increases the relative strength of the interaction will also increase.~~ **c.** ~~As the distance between ions increases the relative strength of the interaction will decrease.~~	
2.3.D.1 Create and/or evaluate representations of ionic and covalent compounds.	**2.3.D** Ionic and covalent compounds can be represented by particulate models, structural formulas, chemical formulas, and ~~chemical nomenclature~~.	

SPIRALED STANDARDS

Learning Objectives	Essential Knowledge	Teacher Notes
2.1.A.1 Distinguish between atoms, ~~molecules, and compounds~~ at the particle level. **2.1.A.2** Create and/or evaluate models of pure substances. *Note: categorizing atoms, isotopes, and ions using subatomic particle distribution.*	**2.1.A** A pure substance always has the same composition. Pure substances include elements, molecules, and compounds. **a.** An element is composed of only one type of atom. **b.** ~~A molecule is a particle composed of more than one atom~~. **c.** ~~A compound is composed of two or more elements and has properties distinct from those of its component atoms~~.	
2.1.B.1 Create and/or evaluate models of mixtures. *Note: Limited to differentiating between particulate models of elements, compounds, mixtures and metal alloys.*	**2.1.B** A mixture is composed of two or more different types of particles that are not bonded. **a.** Each component of a mixture retains its unique properties. **b.** ~~Mixtures can be separated using physical processes such as filtration, evaporation, distillation, and chromatography~~.	
3.1.A.1 Explain the relationship between the mass of a substance, the number of particles of that substance, and the number of moles of that substance. **3.1.A.2** Use the mole concept to calculate the mass, number of particles, or number of moles of a given substance.	**3.1.A** A large number of particles of a substance is needed to measure the physical properties of that substance. **a.** A mole of a substance contains Avogadro's number (6.02×10^{23}) of particles. **b.** The molar mass of an element listed on the periodic table is the mass, in grams, of a mole of atoms of that element.	

FOCUS ON DISCIPLINARY LITERACY	
Science Practices	**Skills**
Science Practice 1: Models and Representations Describe models and representations, including across scales.	**1.A** Describe the components of and quantitative information from models and representations that illustrate particulate-level properties only. **1.B** Describe the components of and quantitative information from models and representations that illustrate both particulate-level and macroscopic-level properties.
Science Practice 2: Question and Method Determine scientific questions and methods.	**2.A** Identify a testable scientific question based on an observation, data, or a model. **2.B** Formulate a hypothesis or predict the results of an experiment. **2.C** Identify experimental procedures that are aligned to a scientific question (which may include a sketch of a lab setup). **2.D** Make observations or collect data from representations of laboratory setups or results, while attending to precision where appropriate. **2.E** Identify or describe potential sources of experimental error. **2.F** Explain how modifications to an experimental procedure will alter results.
Science Practice 3: Representing Data and Phenomena Create representations or models of chemical phenomena.	**3.A** Represent chemical phenomena using appropriate graphing techniques, including correct scale and units. **3.B** Represent chemical substances or phenomena with appropriate diagrams or models (e.g., electron configuration). **3.C** Represent visually the relationship between the structures and interactions across multiple levels or scales (e.g., particulate to macroscopic).
Science Practice 4: Model Analysis Analyze and interpret models and representations on a single scale or across multiple scales.	**4.A** Explain chemical properties or phenomena (e.g., of atoms or molecules) using given chemical theories, models, and representations. **4.B** Explain whether a model is consistent with chemical theories. **4.C** Explain the connection between particulate-level and macroscopic properties of a substance using models and representations. **4.D** Explain the degree to which a model or representation describes the connection between particulate-level properties and macroscopic properties.
Science Practice 5: Mathematical Routines Solve problems using mathematical relationships.	**5.A** Identify quantities needed to solve a problem from given information (e.g., text, mathematical expressions, graphs, or tables). **5.B** Identify an appropriate theory, definition, or mathematical relationship to solve a problem. **5.C** Explain the relationship between variables within an equation when one variable changes. **5.D** Identify information presented graphically to solve a problem. **5.E** Determine a balanced chemical equation for a given chemical phenomenon. **5.F** Calculate, estimate, or predict an unknown quantity from known quantities by selecting and following a logical computational pathway and attending to precision (e.g., performing dimensional analysis and attending to significant figures).

Science Practice 6: Argumentation Develop an explanation or scientific argument.	**6.A** Make a scientific claim. **6.B** Support a claim with evidence from experimental data. **6.C** Support a claim with evidence from representations or models at the particulate level, such as the structure of atoms and/or molecules. **6.D** Provide reasoning to justify a claim using chemical principles or laws or using mathematical justification. **6.E** Provide reasoning to justify a claim using connections between particulate and macroscopic scales or levels. **6.F** Explain the connection between experimental results and chemical concepts, processes, or theories. **6.G** Explain how potential sources of experimental error may affect the experimental results.

Major Content	Supporting & Additional Content
• Molar Masses of Compounds • Dimensional Analysis of Compounds • Percent Composition • Ionic Bonds • Metallic Bonds • Covalent Bonds • Lewis Dot Structures • Formal Charge • Structural Isomers	• Coulomb's Law • Electronegativity • Ionization • Law of Conservation of Mass • Delocalization of Electrons • Lewis Dot Diagrams of Atoms • Electron Configurations and Sharing Electrons • Formal Charge

PACING GUIDE

Use this section to plan when each day of instruction will occur. Use the suggested timing table above to guide your pacing in the table below.

UNIT AT A GLANCE			
Lesson #	**Lesson Date**	**Topic**	**Pacing Notes**
01		Anchoring Event Introduction: Self-Healing Roman Concrete	
02		Compounds Dimensional Analysis: Mass ↔ Moles ↔ Particles	
03		Percent Composition	
04		Ionic Bonding and Crystal Lattices	
05		Metallic Bonding	
06		Covalent Bonding and Lewis Structures	

& 07			
08		Structural Isomers	
REV		Unit 03 Exam Review	
UE		Unit 03 Exam	
FLEX/ER		(Varies by Region)	

UNDERSTANDINGS AND QUESTIONS

Important big ideas and processes for the unit.

KEY UNDERSTANDINGS	TEACHER NOTES
❑ Phenomena are events or processes ("things that happen") that are observable by senses or detectable by instruments. ❑ An answerable scientific question cannot be answered with a yes/no response, is specific and focused, and is based on observable phenomena or patterns ❑ An answerable scientific question cannot be answered with a yes/no response, is specific and focused, and is based on observable phenomena or patterns. ❑ An initial hypothesis is a tentative explanation or prediction to an answerable scientific question based on prior knowledge and observations. ❑ The purpose of an initial hypothesis is to provide a starting point for scientific inquiry that will be revised, refined, or even rejected and rewritten over time as new data and insights are gathered during an investigation. ❑ The mole concept of atoms is extended to molecules in that the sum of the individual molar masses of each molecule is the total molar mass of the compound those atoms make up. ❑ Dimensional analysis of compounds is the same as the dimensional analysis of atoms, in that you can use the molar mass to convert into and out of moles to convert between the mass and number of particles of a compound. ❑ The percent composition of a component in a compound is the percent of the total mass of the compound that is from a specific component. ❑ Ionic bonds form due to the electrostatic attraction that occurs when a metal atom transfers its valence electrons to a non-metal atom. Metal atoms become cations due to the loss of electrons and the non-metal ions become anions due to the gain of electrons. ❑ Ionic compound ratios are determined by the net charge of all metal atoms and the net charge of all non-metal ions being equal and opposite.	

❑ Metal atoms have a significantly lower electronegativity than their non-metal counterparts and the disparity between the lower electronegativity of metal atoms. ❑ The much higher electronegativity of nonmetal atoms is what allows nonmetal atoms to exhibit a strong enough pull on the valence electrons of the metal atoms to enable a complete transfer. ❑ Ionic bonding results in a noble gas configuration (complete octet) for each atom in the bond, which is much more stable for both atoms. ❑ The exact same electrons that are lost by the metal atoms are the exact same electrons that are gained by the anions. ❑ The total number of electrons lost (the positive charge) and the total number of electrons gained (negative charge) must be equal and opposite or all electrons are not accounted for and violates the law of conservation of mass. ❑ Stable structures for ionic compounds result (1) when ions of one charge are surrounded by as many ions as possible of the opposite charge and (2) when the cations and anions are in contact with each other. ❑ Ionic crystal structures are determined by two principal factors: the relative sizes of the ions and the ratio of the numbers of positive and negative ions in the compound. ❑ Ionic bonds form due to the electrostatic attraction that occurs when a metal atom transfers its valence electrons to a non-metal atom. ❑ Metal atoms become cations due to the loss of electrons and the non-metal ions become anions due to the gain of electrons. ❑ Ionic compound ratios are determined by the net charge of all metal atoms and the net charge of all non-metal ions being equal and opposite. ❑ Metal atoms have a significantly lower electronegativity than their non-metal counterparts. ❑ The much higher electronegativity of nonmetal atoms allows them to exert a strong enough pull on the valence electron(s) of the metal atoms, enabling a complete transfer. ❑ Ionic bonding results in a noble gas configuration (complete octet) for each atom in the bond, which is much more stable for both atoms. ❑ The exact same electrons that are lost by the metal atoms are the exact same electrons that are gained by the anions. ❑ The total number of electrons lost (the positive charge) and the total number of electrons gained (negative charge) must be equal and opposite or all electrons are not accounted for and violates the law of conservation of mass. ❑ Stable structures for ionic compounds result (1) when ions of one charge are surrounded by as many ions as possible of the opposite charge and (2) when the cations and anions are in contact with each other. ❑ Ionic crystal structures are determined by two principal factors: the relative sizes of the ions and the magnitude of the charges of ions in the compound. ❑ Metallic bonds are formed when two or more metal atoms or ions combine due to the delocalization of their valence electrons. The metal cations stay close together due to the association and attraction to the “sea” of electrons due to opposite charges. ❑ The electrons are fluid throughout the alloy due to the push and pull attraction experienced by the electrons because of the cations net positive charge and inner core electrons negative charge.	

❑ Covalent bonds are formed when two or more non-metal atoms share electrons. ❑ Since electrons can be shared in either single, double, or triple bonds, the way electrons are shared between atoms can change. ❑ Non-metal atoms are highly electronegative and want to gain electrons to ionize, and the relatively strong attraction to their valence electrons in comparison to each other, the electronegativity difference between non-metals is not enough for one atom to fully take the electron from the other. ❑ The equal or similar strong electronegativities of two nonmetal atoms results in the atoms sharing electrons so both atoms can "gain" a full octet. ❑ Lewis structures show how molecules share electrons using dots and lines. ❑ If there is more than one way to share electrons in a Lewis structure, formal charge is used to determine which is the correct representations. ❑ Structural isomers are two molecules with the exact same molecular formula but a different arrangement of atoms. ❑ Structural isomers have equally stable formal charge justifications; one structural isomer is not more accurate than the other ❑ By determining the molecular formula of two compounds and comparing their molecular geometries, you can determine if two molecules with a different arrangement of atoms are structural isomers. ❑ A seamless explanation for an unknown physical phenomenon integrates evidence from the unit of study, uses scientific concepts in the checklist provided, is comprehensive and includes both inclusionary and exclusionary reasoning for each piece of evidence, reflects understanding and critical thinking, and is clear and logical with no gaps in evidence or reasoning.	
KEY QUESTIONS	**TEACHER NOTES**
➢ How do I develop an answerable question for an observable, physical phenomena? ➢ How do I write an initial hypothesis for observable, physical phenomena? ➢ What is the intention and purpose of an initial hypothesis? ➢ What is a compound and how is a compound represented at the particulate level? ➢ How do I quantify the amount of a compound contained in a sample? ➢ How do I quantify the percent composition of each element within a compound? ➢ What are the key identifying characteristics of an ionic compound? ➢ How do ionic bonds form? ➢ What are the key identifying characteristics of a metallic compound? ➢ How do metallic bonds form? ➢ What are the key identifying characteristics of a covalent compound? ➢ How do covalent bonds form? ➢ How do I draw Lewis structures of molecular and ionic compounds? ➢ How do I decide between two viable Lewis structures based on its formal charge? ➢ How do I classify bonds as metallic, ionic, or covalent? ➢ How do I identify and analyze structural isomers?	

VERTICAL STANDARDS

This section details the **progression** of key scholar expectations/standards** in the courses **before** and **after** this course. This will help you understand what **prior knowledge skills to build upon** and guide you in knowing what **skills you are preparing your scholars** for in the subsequent course.

6th - 8th TEKS

Matter and Energy TEKS Introduction Vertical Alignment

Grade 6: Students build upon their knowledge of properties of solids, liquids, and gases and further explore their molecular energies. In Grade 6, students learn how elements are classified as metals, nonmetals, or metalloids based on their properties on the Periodic Table. Students have previous experience with mixtures in Grade 5. Grade 6 furthers their understanding by investigating the different types of mixtures. Subsequent grades will learn about compounds. In Grade 6, students compare the density of substances relative to fluids and identify evidence of chemical changes.

Grade 7: Students have prior experience with elements in Grade 6 and develop an understanding that compounds are also pure substances in Grade 7. Students investigate the differences between elements and compounds through observations, descriptions of physical properties, and chemical reactions. Students build upon their understanding of solutions by exploring aqueous solutions.

Grade 8: Students make connections between elements, compounds, and mixtures that were introduced in prior grade levels. Students examine the properties of water, acids, and bases. In addition, students understand the basic concept of conservation of mass using chemical equations.

TEKS Content Vertical Alignment

Standards format for TEKS is: Grade Levels.#(Letter)
6-8.1 Scientific and engineering practices. The student, for at least 40% of instructional time, asks questions, identifies problems, and plans and safely conducts classroom, laboratory, and field investigations to answer questions, explain phenomena, or design solutions using appropriate tools and models. The student is expected to:

- ❖ **6-8.1(A) Scientific and engineering practices.** Scientific inquiry is the planned and deliberate investigation of the natural world using scientific and engineering practices. Scientific methods of investigation are descriptive, correlative, comparative, or experimental. The method chosen should be appropriate to the grade level and question being asked. Student learning for different types of investigations includes descriptive investigations, which have no hypothesis that tentatively answers the research question and involve collecting data and recording observations without making comparisons; correlative and comparative investigations, which have a hypothesis that predicts a relationship and involve collecting data, measuring variables relevant to the hypothesis that are manipulated, and comparing results; and experimental investigations, which involve processes similar to comparative investigations but in which a hypothesis can be tested by comparing a treatment with a control.
- ❖ **6-8.1(B)** use scientific practices to plan and conduct descriptive, comparative, and experimental investigations and use engineering practices to design solutions to problems;
- ❖ **6-8.1(C)** use appropriate safety equipment and practices during laboratory, classroom, and field investigations as outlined in Texas Education Agency-approved safety standards
- ❖ **6-8.1(D)** use appropriate tools, such as graduated cylinders, metric rulers, periodic tables, balances, scales, thermometers, temperature probes, laboratory ware, timing devices, pH indicators, hot plates, models, microscopes, slides, life science models, petri dishes, dissecting kits, magnets, spring scales or force sensors, tools that model wave behavior, satellite images, weather maps [grade 8 only], hand lenses, and lab notebooks or journals;

6-8.2 Nature of science. Science, as defined by the National Academy of Sciences, is the "use of evidence to construct testable explanations and predictions of natural phenomena, as well as the knowledge generated through this process." This vast body of changing and increasing knowledge is described by physical, mathematical, and conceptual models. Students should know that some questions are outside the realm of science because they deal with phenomena that are not currently scientifically testable.

6-8.3 Scientific observations, inferences, hypotheses and theories. Students are expected to know that:

- ❖ **6-8.3(A)** observations are active acquisition of either qualitative or quantitative information from a primary source through the senses;
- ❖ **6-8.3(B)** inferences are conclusions reached on the basis of observations or reasoning supported by relevant evidence;
- ❖ **6-8.3(C)** hypotheses are tentative and testable statements that must be capable of being supported or not supported by observational evidence. Hypotheses of durable explanatory power that have been tested over a wide variety of conditions are incorporated into theories; and
- ❖ **6-8.3(D)** scientific theories are based on natural and physical phenomena and are capable of being tested by multiple independent researchers. Unlike hypotheses, scientific theories are well established and highly reliable explanations, but they may be subject to change as new areas of science and new technologies are developed.

6-8.4 Science and social ethics. Scientific decision making is a way of answering questions about the natural world involving its own set of ethical standards about how the process of science should be carried out. Students distinguish between scientific decision-making practices and ethical and social decisions that involve science.

6-8.5 Recurring themes and concepts. The student understands that recurring themes and concepts provide a framework for making connections across disciplines. The student is expected to:

- ❖ **6-8.5(A)** identify and apply patterns to understand and connect scientific phenomena or to design solutions;
- ❖ **3-8.5(B)** identify and investigate cause-and-effect relationships to explain scientific phenomena or analyze problems;
- ❖ **6-8.5(C)** analyze how differences in scale, proportion, or quantity affect a system's structure or performance;
- ❖ **3-8.5(D)** examine and model the parts of a system and their interdependence in the function of the system;
- ❖ **6-8.5(E)** analyze and explain how energy flows and matter cycles through systems and how energy and matter are conserved through a variety of systems;
- ❖ **6-8.5(F)** analyze and explain the complementary relationship between the structure and function of objects, organisms, and systems; and
- ❖ **6-8.5(G)** analyze and explain how factors or conditions impact stability and change in objects, organisms, and systems.

6-8.6 Matter and energy. Matter and energy. (6^{th}) The student knows that matter is made of atoms, can be classified according to its properties, and can undergo changes. (7^{th}-8^{th}) The student distinguishes between elements and compounds, classifies changes in matter, and understands the properties of solutions. The student is expected to:

- ❖ **8.5(A)** Describe the structure of atoms, including the masses, electrical charges, and locations, or protons and neutrons in nucleus and electrons in the electron cloud
- ❖ **8.5(B)** Identify that protons determine an element's identity and valence electrons determine its chemical properties, including reactivity
- ❖ **7.6(A)** compare and contrast elements and compounds in terms of atoms and molecules, chemical symbols, and chemical formulas;
- ❖ **8.6(A)** explain by modeling how matter is classified as elements, compounds, homogeneous mixtures, or heterogeneous mixtures;
- ❖ **6.6(B)** investigate the physical properties of matter to distinguish between pure substances, homogeneous mixtures (solutions), and heterogeneous mixtures;
- ❖ **7.6(B)** use the periodic table to identify the atoms and the number of each kind within a chemical formula;

8.6(B) use the periodic table to identify the atoms involved in chemical reactions;

PreAP Biology

NGSS Science Practices

1. **Asking Questions** Scientific questions lead to explanations of how the natural world works and can be empirically tested using evidence.
   - ❖ Ask questions to develop or refine a model or explanation about the natural world.

- ❖ Ask questions that can be answered using evidence from investigations or gathered by others.

2. **Developing and Using Models** A model is an abstract representation of phenomena that is a tool used to predict or explain the world. Models can be represented as diagrams, 3-D objects, mathematical representations, analogies or computer simulations.
    - ❖ Create models to explain and/or predict scientific phenomena, processes, or relationships.
    - ❖ Evaluate the merits and limitations of models.
3. **Planning and Carrying Out Investigations** An investigation is a systematic way to gather data about the natural world either in the field or in a laboratory setting.
    - ❖ Design investigations that will produce data that can be used to answer scientific questions. This includes determining the goal of the investigation, developing predictions, and designing procedures.
    - ❖ Identify and analyze experimental variables, controls and investigational methods (e.g., how many trials to do).
    - ❖ Conduct investigations to gather data (observations or measurements) using appropriate tools and methods.
4. **Analyzing and Interpreting Data** Analyzing and interpreting data includes making sense of the data produced during investigations. Because patterns are not always obvious, this includes using a range of tools such as tables, graphs and other visualization techniques.
    - ❖ Analyze and interpret data to determine patterns and relationships.
    - ❖ Represent data in tables and graphs to reveal patterns and relationships.
    - ❖ Consider the limitations of data analysis such as sources of error.
5. **Using Mathematics and Computational Thinking** Mathematical and computational thinking involves using tools and mathematical concepts to address a scientific question.
    - ❖ Describe, measure, compare, and estimate quantities (e.g., weight, volume) to answer a scientific question.
    - ❖ Organize data in graphs or charts.
    - ❖ Use mathematical concepts (e.g., ratios) to answer scientific questions.
    - ❖ Use digital tools to accomplish these goals when appropriate.
6. **Constructing Explanations** A scientific explanation is an explanatory account that articulates how or why a natural phenomenon occurs that is supported by evidence and scientific ideas.
    - ❖ Construct an explanation for a natural phenomenon.
    - ❖ Use evidence (e.g. measurements, observations) to construct or support an explanation.
    - ❖ Consider the qualitative or quantitative relationships between variables to explain a phenomenon.
    - ❖ Apply scientific ideas to construct or revise an explanation.
7. **Engaging in Argument from Evidence** Scientific argumentation is a process that occurs when there are multiple ideas or claims (e.g. explanations, models) to discuss and reconcile. An argument includes a claim supported by evidence and reasoning, and students engage in debates to evaluate and critique competing arguments.
    - ❖ Construct and refine arguments based on evidence and reasoning (understanding of disciplinary core ideas).
    - ❖ Critique arguments from peers and other sources by citing relevant evidence and providing scientific questions.
    - ❖ Compare and critique two arguments based on the quality of their evidence and reasoning.
8. **Obtaining, Evaluating, and Communicating Information** Obtaining, evaluating and communicating information occurs through reading and writing texts as well as communicating orally. Scientific information needs to be critically evaluated and persuasively communicated as it supports the engagement in the other science practices.
    - ❖ Read appropriate texts and related features (i.e. graphs) to obtain scientific information.
    - ❖ Evaluate the information gathered from texts and other sources.

- Communicate scientific information in various formats in different modalities (writing, speaking). This characteristic makes explicit the features of communication in the other 7 scientific practices.

Content Essential Knowledge
ECO 1.2.1 Elements that are building blocks of macromolecules are transported from abiotic to biotic systems through gaseous and sedimentary cycles.
CELLS 7.1.1 Cellular respiration is a series of enzymatic reactions that utilize electron carrier molecules to synthesize ATP molecules.

AP CHEMISTRY

Topic 1.1 Moles and Molar Mass
- **1.1.A** Calculate quantities of a substance or its relative number of particles using dimensional analysis and the mole concept.
  - **1.1.A.1** One cannot count particles directly while performing laboratory work. Thus, there must be a connection between the masses of substances reacting and the actual number of particles undergoing chemical changes.
  - **1.1.A.2** Avogadro's number ($N_A = 6.022 \times 10^{23}$ mol^{-1}) provides the connection between the number of moles in a pure sample of a substance and the number of constituent particles (or formula units) of that substance.
  - **1.1.A.3** Expressing the mass of an individual atom or molecule in atomic mass units (amu) is useful because the average mass in amu of one particle (atom or molecule) or formula unit of a substance will always be numerically equal to the molar mass of that substance in grams. Thus, there is a quantitative connection between the mass of a substance and the number of particles that the substance contains.

Topic 1.3 Elemental Composition of Pure Substances
- **1.3.A** Explain the quantitative relationship between the elemental composition by mass and the empirical formula of a pure substance.
  - **1.3.A.1** Some pure substances are composed of individual molecules, while others consist of atoms or ions held together in fixed proportions as described by a formula unit.
  - **1.3.A.2** According to the law of definite proportions, the ratio of the masses of the constituent elements in any pure sample of that compound is always the same.
  - **1.3.A.3** The chemical formula that lists the lowest whole number ratio of atoms of the elements in a compound is the empirical formula.

Topic 1.4 Composition of Mixtures
- **1.4.A** Explain the quantitative relationship between the elemental composition by mass and the composition of substances in a mixture.
  - **1.4.A.1** Pure substances contain atoms, molecules, or formula units of a single type. Mixtures contain atoms, molecules, or formula units of two or more types, whose relative proportions can vary.
  - **1.4.A.2** Elemental analysis can be used to determine the relative numbers of atoms in a substance and to determine its purity.

Topic 1.5 Atomic Structure and Electron Configuration
- **1.5.A** Represent the ground-state electron configuration of an atom of an element or its ions using the Aufbau principle.
  - **1.5.A.1** The atom is composed of negatively charged electrons and a positively charged nucleus that is made of protons and neutrons.
  - **1.5.A.2** Elemental analysis can be used to determine the relative numbers of atoms in a substance and to determine its purity.
  - **1.5.A.3** In atoms and ions, the electrons can be thought of as being in "shells (energy levels)" and "subshells (sublevels)," as described by the ground-state electron configuration. Inner electrons are called core electrons, and outer electrons are called valence electrons. The electron configuration is explained by quantum mechanics, as delineated in the Aufbau principle and exemplified in the periodic table of the elements.
  - **1.5.A.4** The relative energy required to remove an electron from different subshells of an atom or ion or from the same subshell in different atoms or ions (ionization energy) can be estimated through a qualitative application of Coulomb's law. This energy is related to the distance from the nucleus and the effective (shield) charge of the nucleus.

Topic 1.7 Periodic Trends

- ❖ **1.7.A** Explain the relationship between trends in atomic properties of elements and electronic structure and periodicity.
  - **1.7.A.1** The organization of the periodic table is based on patterns of recurring properties of the elements, which are explained by patterns of ground-state electron configurations and the presence of completely or partially filled shells (and subshells) of electrons in atoms.
  - **1.7.A.2** Trends in atomic properties within the periodic table (periodicity) can be predicted by the position of the element on the periodic table and qualitatively understood using Coulomb's law, the shell model, and the concepts of shielding and effective nuclear charge. These properties include:
    i. Ionization energy
    ii. Atomic and ionic radii
    iii. Electron affinity
    iv. Electronegativity
  - **1.7.A.3** The periodicity (in 1.7.A.2) is useful to predict/ estimate values of properties in the absence of data.

Topic 1.8 Valence Electrons and Ionic Compounds

- ❖ **1.8.A** Explain the relationship between trends in the reactivity of elements and periodicity.
  - **1.8.A.1** The likelihood that two elements will form a chemical bond is determined by the interactions between the valence electrons and nuclei of elements.
  - **1.8.A.2** Elements in the same column of the periodic table tend to form analogous compounds.
  - **1.8.A.3** Typical charges of atoms in ionic compounds are governed by the number of valence electrons and predicted by their location on the periodic table.

Topic 2.1 Types of Chemical Bonds

- ❖ **2.1.A** Explain the relationship between the type of bonding and the properties of the elements participating in the bond.
  - **2.1.A.1** Electronegativity values for the representative elements increase going from left to right across a period and decrease going down a group. These trends can be understood qualitatively through the electronic structure of the atoms, the shell model, and Coulomb's law.
  - **2.1.A.2** Valence electrons shared between atoms of similar electronegativity constitute a nonpolar covalent bond. For example, bonds between carbon and hydrogen are effectively nonpolar even though carbon is slightly more electronegative than hydrogen.
  - **2.1.A.3** Valence electrons shared between atoms of unequal electronegativity constitute a polar covalent bond.
    i. The atom with a higher electronegativity will develop a partial negative charge relative to the other atom in the bond.
    ii. In single bonds, greater differences in electronegativity lead to greater bond dipoles.
    iii. All polar bonds have some ionic character, and the difference between ionic and covalent bonding is not distinct but rather a continuum.
  - **2.1.A.4** The difference in electronegativity is not the only factor in determining if a bond should be designated as ionic or covalent. Generally, bonds between a metal and nonmetal are ionic, and bonds between two nonmetals are covalent. Examination of the properties of a compound is the best way to characterize the type of bonding.
  - **2.1.A.5** The difference in electronegativity is not the only factor in determining if a bond should be designated as ionic or covalent. Generally, bonds between a metal and nonmetal are ionic, and bonds between two nonmetals are covalent. Examination of the properties of a compound is the best way to characterize the type of bonding.

Topic 2.2 Intramolecular Force and Potential Energy

- ❖ **2.2.A** Represent the relationship between potential energy and distance between atoms, based on factors that influence the interaction strength.

- 2.2.A.1 A graph of potential energy versus the distance between atoms is a useful representation for describing the interactions between atoms. Such graphs illustrate both the equilibrium bond length (the separation between atoms at which the potential energy is lowest) and the bond energy (the energy required to separate the atoms).
- **2.2.A.2** In a covalent bond, the bond length is influenced by both the size of the atom's core and the bond order (i.e., single, double, triple). Bonds with a higher order are shorter and have larger bond energies.
- **2.2.A.3** Coulomb's law can be used to understand the strength of interactions between cations and anions.
  a. Because the interaction strength is proportional to the charge on each ion, larger charges lead to stronger interactions.
  b. Because the interaction strength increases as the distance between the centers of the ions (nuclei) decreases, smaller ions lead to stronger interactions.

Topic 2.3 Structure of Ionic Solids

- ❖ **2.3.A** Represent an ionic solid with a particulate model that is consistent with Coulomb's law and the properties of the constituent ions.
  - **2.3.A.1** The cations and anions in an ionic crystal are arranged in a systematic, periodic 3-D array that maximizes the attractive forces among cations and anions while minimizing the repulsive forces.

Topic 2.4 Structure of Metals and Alloys

- ❖ **2.4.A** Represent a metallic solid and/or alloy using a model to show essential characteristics of the structure and interactions present in the substance.
  - **2.4.A.1** Metallic bonding can be represented as an array of positive metal ions surrounded by delocalized valence electrons (i.e., a "sea of electrons").
  - **2.4.A.2** Interstitial alloys form between atoms of significantly different radii, where the smaller atoms fill the interstitial spaces between the larger atoms (e.g., with steel in which carbon occupies the interstices in iron).
  - **2.4.A.3** Substitutional alloys form between atoms of comparable radius, where one atom substitutes for the other in the lattice. (e.g., in certain brass alloys, other elements, usually zinc, substitute for copper.)

Topic 2.5 Lewis Diagrams

- ❖ **2.5.A** Represent a molecule with a Lewis diagram.
  - **2.5.A.1** Lewis diagrams can be constructed according to an established set of principles.

Topic 2.6 Resonance and Formal Charge

- ❖ **2.6.A** Represent a molecule with a Lewis diagram that accounts for resonance between equivalent structures or that uses formal charge to select between nonequivalent structures.
  - **2.6.A.1** Metallic bonding can be represented as an array of positive metal ions surrounded by delocalized valence electrons (i.e., a "sea of electrons").
  - **2.6.A.2** The octet rule and formal charge can be used as criteria for determining which of several possible valid Lewis diagrams provides the best model for predicting molecular structure and properties.
  - **2.6.A.3** As with any model, there are limitations to the use of the Lewis structure model, particularly in cases with an odd number of valence electrons.

Topic 4.4 Physical and Chemical Changes

- ❖ **4.4.A** Represent a molecule with a Lewis diagram that accounts for resonance between equivalent structures or that uses formal charge to select between nonequivalent structures.

- **4.4.A.1** Processes that involve the breaking and/or formation of chemical bonds are typically classified as chemical processes. Processes that involve only changes in intermolecular interactions, such as phase changes, are typically classified as physical processes.
  - **4.4.A.2** Sometimes physical processes involve the breaking of chemical bonds. For example, plausible arguments could be made for the dissolution of a salt in water, as either a physical or chemical process, involves breaking of ionic bonds, and the formation of ion-dipole interactions between ions and solvent.

AP Biology

Topic 1.2 Elements of Life

- ❖ **ENE–1** The highly complex organization of living systems requires constant input of energy and the exchange of macromolecules.
  - **ENE–1.A** Describe the composition of macromolecules required by living organisms.
    - **ENE–1.A.2** Atoms and molecules from the environment are necessary to build new molecules—
      - **a.** Carbon is used to build biological molecules such as carbohydrates, proteins, lipids, and nucleic acids. Carbon is used in storage compounds and cell formation in all organisms.
      - **b.** Nitrogen is used to build proteins and nucleic acids. Phosphorus is used to build nucleic acids and certain lipids.

Topic 2.2 Cell Structure and Function

- ❖ **SYI–1** Living systems are organized in a hierarchy of structural levels that interact.
  - **SYI–1.F** Describe the structural features of a cell that allow organisms to capture, store, and use energy..
    - **SYI–1.F.4** Membranes contain chlorophyll pigments and electron transport proteins that comprise the photosystems.

Topic 2.5 Membrane Permeability

- ❖ **ENE–2** Cells have membranes that allow them to establish and maintain internal environments that are different from their external environments.
  - **ENE–2.C** Explain how the structure of biological membranes influences selective permeability.
    - **ENE–2.C.4** Small nonpolar molecules, including N_2, O_2, and CO_2, freely pass across the membrane. Hydrophilic substances, such as large polar molecules and ions, move across the membrane through embedded channel and transport proteins.

Topic 2.7 Facilitated Diffusion

- ❖ **ENE–2** Cells have membranes that allow them to establish and maintain internal environments that are different from their external environments.
  - **ENE–2.G** Explain how the structure of a molecule affects its ability to pass through the plasma membrane.
    - **ENE–2.G.1** Membrane proteins are required for facilitated diffusion of charged and large polar molecules through a membrane—
      - **a.** Charged ions, including Na^+ and K^+, require channel proteins to move through the membrane.
      - **b.** Membranes may become polarized by movement of ions across the membrane.

Topic 2.9 Mechanisms of Transport

- ❖ **ENE–2** Cells have membranes that allow them to establish and maintain internal environments that are different from their external environments.
  - **ENE–2.J** Describe the processes that allow ions and other molecules to move across membranes.
    - **ENE–2.J.1** A variety of processes allow for the movement of ions and other molecules across membranes, including passive and active transport, endocytosis and exocytosis.

Topic 3.5 Photosynthesis

- ❖ **ENE–1** The highly complex organization of living systems requires constant input of energy and the exchange of macromolecules.
  - **ENE–1.J** Explain how cells capture energy from light and transfer it to biological molecules for storage and use.
    - **ENE–1.J.1** During photosynthesis, chlorophylls absorb energy from light, boosting electrons to a higher energy level in photosystems I and II.

- **ENE–1.J.2** Photosystems I and II are embedded in the internal membranes of chloroplasts and are connected by the transfer of higher energy electrons through an electron transport chain (ETC).
- **ENE–1.J.3** When electrons are transferred between molecules in a sequence of reactions as they pass through the ETC, an electrochemical gradient of protons (hydrogen ions) is established across the internal membrane.
- **ENE–1.J.4** The formation of the proton gradient is linked to the synthesis of ATP from ADP and inorganic phosphate via ATP synthase.

Topic 3.6 Cellular Respiration

- **ENE–1** The highly complex organization of living systems requires constant input of energy and the exchange of macromolecules.
  - **ENE–1.K** Describe the processes that allow organisms to use energy stored in biological macromolecules.
    - **ENE–1.K.3** The electron transport chain transfers energy from electrons in a series of coupled reactions that establish an electrochemical gradient across membranes—
      - **b.** In cellular respiration, electrons delivered by NADH and FADH are passed to a series of electron acceptor2 s as they move toward the terminal electron acceptor, oxygen. In photosynthesis, the terminal electron acceptor is NADP+. Aerobic prokaryotes use oxygen as a terminal electron acceptor, while anaerobic prokaryotes use other molecules.
      - **c.** The transfer of electrons is accompanied by the formation of a proton gradient across the inner mitochondrial membrane or the internal membrane of chloroplasts, with the membrane(s) separating a region of high proton concentration from a region of low proton concentration. In prokaryotes, the passage of electrons is accompanied by the movement of protons across the plasma membrane.
      - **d.** The flow of protons back through membrane-bound ATP synthase by chemiosmosis drives the formation of ATP from ADP and inorganic phosphate. This is known as oxidative phosphorylation in cellular respiration, and photophosphorylation in photosynthesis.
  - **ENE–1.L** Explain how cells obtain energy from biological macromolecules in order to power cellular functions.
    - **ENE–1.L.3** In the Kreb's cycle, carbon dioxide is released from organic intermediates, ATP is synthesized from ADP and inorganic phosphate, and electrons are transferred to the coenzymes NADH and $FADH_2$.
    - **ENE–1.L.4** Electrons extracted in glycolysis and Krebs cycle reactions are transferred by NADH and $FADH_2$ to the electron transport chain in the inner mitochondrial membrane.
- **ENE–1.L.5** When electrons are transferred between molecules in a sequence of reactions as they pass through the ETC, an electrochemical gradient of protons (hydrogen ions) across the inner mitochondrial membrane is established.

AP CHEMISTRY

Topic 1.5 Atomic Structure and Electron Configuration

- **SAP-1** Atoms and molecules can be identified by their electron distribution and energy.
  - **SAP-1.A** Represent the electron configuration of an element or ions of an element using the Aufbau principle.
    - **SAP-1.A.1** The atom is composed of negatively charged electrons and a positively charged nucleus that is made of protons and neutrons.

Topic 1.6 Photoelectron Spectroscopy

- **SAP-1** Atoms and molecules can be identified by their electron distribution and energy.
  - **SAP-1.B** Explain the relationship between the photoelectron spectrum of an atom or ion and (a) the electron configuration of the species (b) the interactions between the electrons and the nucleus:

- **SAP-1.B.1** The energies of the electrons in a given shell can be measured experimentally with photoelectron spectroscopy (PES). The position of each peak in the PES spectrum is related to the energy required to remove an electron from the corresponding subshell, and the height of each peak is (ideally) proportional to the number of electrons in that subshell.

Topic 1.8 Valence Electrons and Ionic Compounds

- ❖ **SAP-2** The periodic table shows patterns in electronic structure and trends in atomic properties.
  - **SAP-2.B** Explain the relationship between trends in the reactivity of elements and periodicity.
    - **SAP-2.B.3** Typical charges of atoms in ionic compounds are governed by their location on the periodic table and the number of valence electrons.

Topic 2.2 Intramolecular Force and Potential Energy

- ❖ **SAP-3** Atoms or ions bond due to interactions between them, forming molecules.
  - **SAP-3.B** Represent the relationship between potential energy and distance between atoms, based on factors that influence the interaction strength.
    - **SAP-3.B.1** A graph of potential energy versus the distance between atoms is a useful representation for describing the interactions between atoms. Such graphs illustrate both the equilibrium bond length (the separation between atoms at which the potential energy is lowest) and the bond energy (the energy required to separate the atoms).
    - **SAP-3.B.2** In a covalent bond, the bond length is influenced by both the size of the atom's core and the bond order (i.e., single, double, triple). Bonds with a higher order are shorter and have larger bond energies.
    - **SAP-3.B.3** Coulomb's law can be used to understand the strength of interactions between cations and anions.
      - **a.** Because the interaction strength is proportional to the charge on each ion, larger charges lead to stronger interactions.
      - **b.** Because the interaction strength increases as the distance between the centers of the ions (nuclei) decreases, smaller ions lead to stronger interactions.

Topic 2.3 Structure of Ionic Solids

- ❖ **SAP-3** Atoms or ions bond due to interactions between them, forming molecules.
  - **SAP-3.C** Represent an ionic solid with a particulate model that is consistent with Coulomb's law and the properties of the constituent ions.
    - **SAP-3.C.1** The cations and anions in an ionic crystal are arranged in a systematic, periodic 3-D array that maximizes the attractive forces among cations and anions while minimizing the repulsive forces.

Topic 2.5 Lewis Diagrams

- ❖ **SAP-4** Molecular compounds are arranged based on Lewis diagrams and Valence Shell Electron Pair Repulsion (VSEPR) theory.
  - **SAP-4.A** Represent a molecule with a Lewis diagram.
    - **SAP-4.A.1** Lewis diagrams can be constructed according to an established set of principles.

Topic 4.4 Physical and Chemical Changes

- ❖ **TRA-1** A substance that changes its properties, or that changes into a different substance, can be represented by chemical equations.
  - **TRA-1.D** Explain the relationship between macroscopic characteristics and bond interactions for (a) chemical processes (b) physical processes.
    - **TRA-1.D.1** Processes that involve the breaking and/or formation of chemical bonds are typically classified as chemical processes. Processes that involve only changes in intermolecular interactions, such as phase changes, are typically classified as physical processes.

- **TRA-1.D.2** Sometimes physical processes involve the breaking of chemical bonds. For example, plausible arguments could be made for the dissolution of a salt in water, as either a physical or chemical process, involves breaking of ionic bonds, and the formation of ion-dipole interactions between ions and solvent.

AP ENVIRONMENTAL SCIENCE

Science Practice: Mathematical Routines Apply quantitative methods to address environmental concepts.

- **6.A** Determine an approach or method aligned with the problem to be solved.
  - **Topic 8.12** Lethal Dose 50% (LD_{50})
- **6.B** Apply appropriate mathematical relationships to solve a problem, with work shown (e.g., dimensional analysis).
  - **Topic 3.5** Population Growth and Resource Availability
  - **Topic 7.7** Acid Rain
  - **Topic 8.2** Human Impacts on Ecosystems
  - **Topic 8.10** Waste Reduction Methods
  - **Topic 9.7** Ocean Acidification
- **6.C** Calculate an accurate numeric answer with appropriate units.
  - **Topic 1.10** Energy Flow and the 10% Rule
  - **Topic 6.2** Global Energy Consumption
  - **Topic 6.13** Energy Conservation

Math Skills:

- **Dimensional Analysis:** Using unit conversions to manipulate known quantities will always appear on the AP exam.
- ~~**Density:** Must understand density qualitatively and calculate with density quantitatively~~.
- ~~**pH:** Must know the basics of the pH scale, that each whole number on the pH scale is a factor of 10 change in hydrogen ion concentration~~.
- **Scientific Notation**. Will often use scientific notation in the givens of a problem and scholars must know how to understand what the number means and quantify larger or smaller numbers in scientific notation as well as multiply or divide with scientific notation using the calculator.
- **Percentages:** Must know how to add, subtract, multiply or divide using percentages without a calculator.
- ~~**Percent Change:** Must know how to calculate percent change with the same mathematical routine chemistry uses for percent yield~~.
- **Metric Conversion:** Convert between metric prefixes using dimensional analysis.

~~**Algebraic Equations:** Scholars must know how to identify givens and unknowns, rearrange algebraic equations to isolate a variable, and solve for the unknown value~~.

VOCABULARY GLOSSARY

Domain-specific words and definitions for this unit.

Key Content Vocabulary
Definitions of key terms are listed below. New terms are listed in blue.
Bond: General term used to describe the intramolecular forces that hold atoms together in compounds.
Bonded Electrons: The electrons that are shared, delocalized, or transferred between atoms during the formation of a chemical bond.
Chemical Formula: A symbolic representation of a chemical compound or molecule that shows the types and numbers of atoms in the compound.
Coefficient: The number in front of a chemical formula in a chemical equation.

Compound: A pure substance composed of identical particles containing atoms from more than one elemens held together by bonds that can only be separated or changed by chemical reactions.

Conductivity: A measure of a substance's or solution's ability to conduct electricity.

Conductor: The materials or substances which allow electricity to flow through them.

Covalent Bond: A bond that involves two highly electronegativity atoms, usually nonmetals, sharing electrons in a distinctive location in such a way that all atoms in the particle achieve a stable octet.

Delocalized: Detached or removed from a particular place or location.

Electrolyte: A substance that dissolves in water to form solutions that conduct electricity.

Formal Charge: The charge assigned to an atom in a molecule that assumes all electrons in all chemical bonds are shared equally between atoms regardless of relative electronegativity.

Ionic Bond: A bond that involves a low electronegativity metal transferring its valence electrons to a high electronegativity nonmetal in a fixed ratio which results in oppositely charged ions that are strongly attracted in accordance with Coulomb's Law forming a crystal lattice.

Lone Pair Electrons: An electron pair in the outermost shell of an atom that is not shared or bonded to another atom.

Molecule: A group of atoms covalently bonded together, representing the smallest fundamental unit of a chemical compound that can take part in a chemical reaction.

Nonelectrolyte: A substance that form solutions that do not conduct electricity.

Percent Composition: The percent by mass of each element in a compound.

Polyatomic Ion: An ion composed of two or more atoms covalently bonded together in such a way that it results in a charged particle that behaves as a single ion.

Salt: Common categorical name for an ionic compound.

Subscript: Number to the right of and slightly below the element symbol that communicates how many atoms of that element are within the substance.

Accuracy: A measure of how close the average of all trials of for a measured value are to the true value of the measurement.

Analytical Balance: A highly precise instrument used to accurately measure the mass of small samples.

Anchoring Event: Specific instances of a phenomenon that require scholars to pull together a number of science ideas in order to explain.

Anion: Negatively charged ion; more electrons than protons.

Atom: The smallest particle of an element.

Atomic Number (Z): The number of protons in the nucleus of the atom. This determines the identity of the element of the atom.

Attraction: The non-contact force or interaction that pulls two or more substances or particles toward each other.

Balance (Lab Instrument): A lab instrument that measures the mass.

Balancing: The mathematical routine, which is necessary to adhere to the law of conservation of mass, for finding the coefficients that allow the number of atoms of each element to be the same on both sides of the yield arrow in a chemical equation.

Cation: Positively charged ion.

Charge: The net charge of a particle found by comparing the number of electrons to the number of protons.

Chemical Reaction (aka Chemical Change): A process by which one or more substances convert to one or more different substances; a change that alters the composition of one or more chemical species through breaking and forming bonds.

Claim: A statement made as an explanation of data collected and analyzed or as an answer to a question.

Control Variable (aka Constant): Anything that is held constant or limited in an investigation to minimize risk of error in the results.

Conversion Factor: A ratio of equivalent measurements; mainly used in dimensional analysis and stoichiometry.

Core Electrons: Electrons that do not occupy the outermost energy level of an atom; electrons between the nucleus and the valence shell.

Coulomb's Law: Like charges repel; opposite charges attract. The force is proportional to the magnitude of the charges and inversely proportional to the square of the distance between them.

Dependent Variable: The variable being tested and measured in an experiment, and is 'dependent' on the independent variable.

Dimensional Analysis (aka Factor-Label Method): An orderly problem-solving process that establishes relationships between different units of measurement through multiplying measured values by one or more known conversion factor(s); the mathematical conversion between an amount in one unit to the corresponding amount in a desired unit through multiplying by one or more conversion factors.

Directly Proportional: When an increase (or decrease) in one quantity causes a proportional increase (or decrease) in the other, maintaining a constant ratio between them.

Effective Nuclear Charge (Z_{eff}): The actual amount of positive (nuclear) charge experienced by an electron, defined as the sum of the charge of the nucleus and charge of the shielding electrons; comparison of the number of positive protons and the number of core electrons shielding the attractive force of the nucleus resulting in the actual nuclear charge experienced by valence electrons.

Electron: Subatomic particle found outside the nucleus of the atom that has negligible mass and a negative charge equal and opposite to the proton.

Electron Cloud: The region of negative charge surrounding an atomic nucleus that is associated with the locations where electrons have greater than 95% probability of existing. Since electrons are always moving it is impossible to know their exact location, only the most likely area they will be located within.

Electron Configuration: The arrangement of electrons around the nucleus of a particular atom or molecule.

Electron Shielding: The blocking of valence shell electron attraction by the nucleus, due to the presence of inner-shell (core) electrons.

Electronegativity: A measure of an atom's ability to attract shared electrons; how strongly a nucleus attracts the electrons of another atom.

Element: Substance that is composed of a single type of atom; a substance that cannot be decomposed by a chemical change; determined by the number of protons in the atom.

Element Symbol: The letter designation for that element that will be found on the periodic table. This is usually one or two letters, with the first letter always being upper case and any subsequent letters present are lower case.

Energy (E): The capacity to do work, usually measured in Joules (J).

Energy Level (aka Shell): A fixed distance from the nucleus of an atom where electrons may be found.

Essential Question: A question developed from an anchoring event that is investigated in order to develop an underlying explanatory model for the phenomenon.

Estimation: The process of approximating or making an informed guess about a value or quantity using the information provided without performing precise calculations.

Evidence: Knowledge, facts, or data (qualitative or quantitative) that supports the claim.

Explanatory Model: A proposed explanation made based on limited evidence as a starting point for further investigation.

Family: A group of elements on the periodic table that share common properties.

First Ionization Energy: The energy required to remove the outermost, or least bound, electron from a neutral atom of the element.

Gas (g): Matter that has an indefinite shape and indefinite volume.

Ground State: The most stable, lowest energy conformation of an atom's electron configuration. All electrons are in their most favorable and lowest energy positions.
Group: Vertical row of the periodic table.
Independent Variable: The variable the experimenter manipulates or changes, and in many cases is assumed to have a direct effect on the dependent variable.
Inference: A conclusion reached on the basis of evidence and reasoning.
Inversely Proportional: When an increase in one quantity leads to a proportional decrease in the other, and vice versa.
Ion: An atom of a single element that has gained or lost electrons, but the number of protons remains the same, causing a positively or negatively charged particle. This is not an oxidation number and the + or – sign is placed behind the number (i.e. 1+ not +1).
Ionic Configuration: The electron configuration of an ion, which is an atom or molecule with a net electrical charge.
Ionic Radius: The average distance between the nucleus of an ion and the outermost shell or orbital of electrons.
Ionization: The process of an atom gaining or losing electrons to become an ion.
Isomers: Covalently bonded molecules that have the same chemical formula but a different arrangement of bonded atoms.
Law of Conservation of Energy: Energy can neither be created nor destroyed - only converted from one form of energy to another.
Law of Conservation of Mass: Matter can neither be created nor destroyed - only converted from one form of matter to another.
Lewis Dot Structure: Simplified model of an atom in the form of a diagram that represents the valence electrons of atoms in a particle.
Liquid (l): Matter that has an indefinite shape and definite volume.
Mass: The amount of matter present; measured in the base SI unit of grams (g).
Metal: Element found on the left side of the zig zag demarcation of the periodic table and made of multiple metal families with low electronegativities.
Metallic Bond: A type of chemical bonding between two or more metal atoms, which arises from the attraction between positively charged metal nuclei and their delocalized valence electrons.
Mixture: Consists of two or more chemically distinct components that do not react with each other and retain their original properties.
Molar Mass: The mass, in grams, of one mole of a substance expressed in units of grams per mole (g/mol). The average atomic mass determined using the natural abundance of all isotopes of an element is the same as the molar mass of an element.
Mole: A way to count the number of particles of a substance by group, similar to a "pair" or a "dozen"; the amount of substance containing the same number of atoms, molecules, ions, or other entities as the number of atoms in exactly 12 grams of 12C.
Neutron: Subatomic particle found in the nucleus of the atom that as an approximate mass of 1 amu that is neutral (no charge).
Nonmetal: Element found on the upper right of the zig zag demarcation on the periodic table made of multiple nonmetal families with nearly full or full octets.
Nuclear Charge: Total positive charge of the nucleus due to protons.
Nucleus: The small, dense region consisting of protons and neutrons at the center of an atom.
Observation: Any data collected using any of the five senses, can be quantitative or qualitative.
Octet Rule: The tendency of atoms to prefer to have eight electrons in the valence shell.
Particle: Any basic unit of matter such as atoms, ions, molecules, formula units, etc.

Particulate Diagram: A visual representation in chemistry that depicts the microscopic structure of matter, usually using small circles or spheres to represent atoms or molecules, showing their arrangement and relative numbers within a substance, allowing for visualization of states of matter (solid, liquid, gas) and chemical reactions by illustrating the substances involved in chemical and physical processes.

Period: Horizontal row of the periodic table.

Periodic Trend: Specific patterns present in the periodic table that illustrate different aspects of certain elements when grouped by period, group, or position.

Periodicity: The properties of the elements in the periodic table have a tendency to recur at intervals, can help you estimate the properties of atoms that haven't even been discovered yet.

Phase (aka State of Matter): A distinct form of matter based on its homogeneity and physical properties.

Phenomenon: Events or processes (“things that happen”) that are observable by the senses, or detectable by instruments.

Photoelectron Spectroscopy (PES): An experimental technique used to determine the relative binding energies of electrons in particles.

Potential Energy: Stored energy based on position.

Precision: A measure of how close all trials for a measured value are to one another.

Prefix: A word, letter, or number placed before the root word; in chemistry it can communicate the quantity present (naming compounds) or modify the value of the root word (unit prefixes).

Proton: Subatomic particle found in the nucleus of the atom that as an approximate mass of 1 amu and positive charge equal and opposite to the electron.

Pure Substance: A single type of matter that cannot be separated into other kinds of matter by any physical means.

Qualitative: The determination of non-numerical information about a chemical species, a reaction, a system, etc.

Quantitative: The determination of numerical information about a chemical species, a reaction, a system, etc.

Random Error: An unpredictable, chance variation in a measurement that can occur due to inconsistent application of the procedure or other variables.

Ratio: Numerical comparison or relationship between two or more values.

Reactivity: The degree to which a substance shows chemical change when mixed with another substance.

Reasoning: The explanation of the “how” or “why” the evidence you have chosen supports your claim.

Repulsion: The non-contact force or interaction that pushes two or more substances or particles away from each other.

Roman Numeral: Symbols used in a system of numerical notation based on the ancient Roman system. The symbols needed are capital letters I (1) and V (5).

Scientific Notation: A way to express very large or very small numbers in a compact form in terms of a decimal number between 1 and 10 multiplied by a power of 10

Shell (aka Energy Level): A fixed distance from the nucleus of an atom where electrons may be found.

Solid (s): Matter that has a definite shape and a definite volume.

Subshell: The division of energy levels (such as n=1, n=2, and so on) into distinct shells of distinct positions different orbital types will occupy (1s, 2p, 3d, etc.).

Systematic Error: Errors that result from predictable changes in an experiment; errors that causes all measured quantities to be off by the same amount or the same proportion usually resulting in decreased investigative accuracy.

Trend: A recognizable pattern in a data set that communicates information about the data collected and associated processes.

Valence Electron: An electron located in the outermost shell (or valence shell) of an atom.

Volume: The amount of space occupied by a substance, typically expressed in liters (L).

Weigh Boat: Open containers that is used to mass granulated, liquid, or solid samples.