CollegeBoard Pre-AP®

Pre-AP® Chemistry

COURSE GUIDE

INCLUDES

- Approach to teaching and learning
- Course map
- Course framework
- Sample assessment questions

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Pre-AP® Chemistry

COURSE GUIDE

Please visit Pre-AP online at **preap.org** for more information and updates about the course and program features.

ABOUT COLLEGE BOARD

College Board is a mission-driven not-for-profit organization that connects students to college success and opportunity. Founded in 1900, College Board was created to expand access to higher education. Today, the membership association is made up of over 6,000 of the world's leading educational institutions and is dedicated to promoting excellence and equity in education. Each year, College Board helps more than seven million students prepare for a successful transition to college through programs and services in college readiness and college success—including the SAT® and the Advanced Placement Program®. The organization also serves the education community through research and advocacy on behalf of students, educators, and schools.

For further information, visit **www.collegeboard.org**.

PRE-AP EQUITY AND ACCESS POLICY

College Board believes that all students deserve engaging, relevant, and challenging grade-level coursework. Access to this type of coursework increases opportunities for all students, including groups that have been traditionally underrepresented in AP and college classrooms. Therefore, the Pre-AP program is dedicated to collaborating with educators across the country to ensure all students have the supports to succeed in appropriately challenging classroom experiences that allow students to learn and grow. It is only through a sustained commitment to equitable preparation, access, and support that true excellence can be achieved for all students, and the Pre-AP course designation requires this commitment.

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1 2 3 4 5 6 7 8 9 10

Contents

APPENDIX

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Roxie Allen, *St. John's School, Houston, TX*

Kristen Cacciatore, *Charlestown High School, Boston, MA*

Michael Diaz, *Achievement First, New Haven, CT*

Kristen Drury, *William Floyd High School, Mastic Beach, NY*

Amy Earle, *Deep Run High School, Richmond, VA*

Ryan Johnson, *Doherty High School, Colorado Springs, CO*

Dena Leggett, *Franklin High School, Franklin, TN*

Paul Price, *Trinity Valley School, Fort Worth, TX*

Kaleb Underwood, *Education Consultant, Charlottesville, VA*

Fred Vital, *Darien High School, Darien, CT*

David Yaron, *Carnegie Mellon University, Pittsburgh, PA*

COLLEGE BOARD STAFF

Laura Casdorph, *Director, Pre-AP Chemistry Curriculum, Instruction, and Assessment*

Karen Lionberger, *Senior Director, Pre-AP STEM Curriculum, Instruction, and Assessment*

Beth Hart, *Senior Director, Pre-AP Assessment*

Mitch Price, *Director, Pre-AP STEM Assessment*

Natasha Vasavada, *Executive Director, Pre-AP Curriculum, Instruction, and Assessment*

About Pre-AP

Introduction to Pre-AP

Every student deserves classroom opportunities to learn, grow, and succeed. College Board developed Pre-AP® to deliver on this simple premise. Pre-AP courses are designed to support all students across varying levels of readiness. They are not honors or advanced courses.

Participation in Pre-AP courses allows students to slow down and focus on the most essential and relevant concepts and skills. Students have frequent opportunities to engage deeply with texts, sources, and data as well as compelling higher-order questions and problems. Across Pre-AP courses, students experience shared instructional practices and routines that help them develop and strengthen the important critical thinking skills they will need to employ in high school, college, and life. Students and teachers can see progress and opportunities for growth through varied classroom assessments that provide clear and meaningful feedback at key checkpoints throughout each course.

DEVELOPING THE PRE-AP COURSES

Pre-AP courses are carefully developed in partnership with experienced educators, including middle school, high school, and college faculty. Pre-AP educator committees work closely with College Board to ensure that the course resources define, illustrate, and measure grade-level-appropriate learning in a clear, accessible, and engaging way. College Board also gathers feedback from a variety of stakeholders, including Pre-AP partner schools from across the nation who have participated in multiyear pilots of select courses. Data and feedback from partner schools, educator committees, and advisory panels are carefully considered to ensure that Pre-AP courses provide all students with grade-level-appropriate learning experiences that place them on a path to college and career readiness.

PRE-AP PROGRAM COMMITMENTS

The Pre-AP Program asks participating schools to make four commitments:

1. **Pre-AP for All:** Pre-AP frameworks and assessments serve as the foundation for all sections of the course at the school.
2. **Course Frameworks:** Teachers align their classroom instruction with the Pre-AP course frameworks.
    - Schools commit to provide the core resources to ensure Pre-AP teachers and students have the materials they need to engage in the course.

3. **Assessments:** Teachers administer at least one learning checkpoint per unit on Pre-AP Classroom and four performance tasks.
4. **Professional Learning:** Teachers complete the foundational professional learning (Online Foundational Modules or Pre-AP Summer Institute) and at least one online performance task scoring module. The current Pre-AP coordinator completes the Pre-AP Coordinator Online Module.

PRE-AP EDUCATOR NETWORK

Similar to the way in which teachers of Advanced Placement® (AP®) courses can become more deeply involved in the program by becoming AP Readers or workshop consultants, Pre-AP teachers also have opportunities to become active in their educator network. Each year, College Board expands and strengthens the Pre-AP National Faculty—the team of educators who facilitate Pre-AP Professional Learning Workshops. Pre-AP teachers can also become curriculum and assessment contributors by working with College Board to design, review, or pilot the course resources.

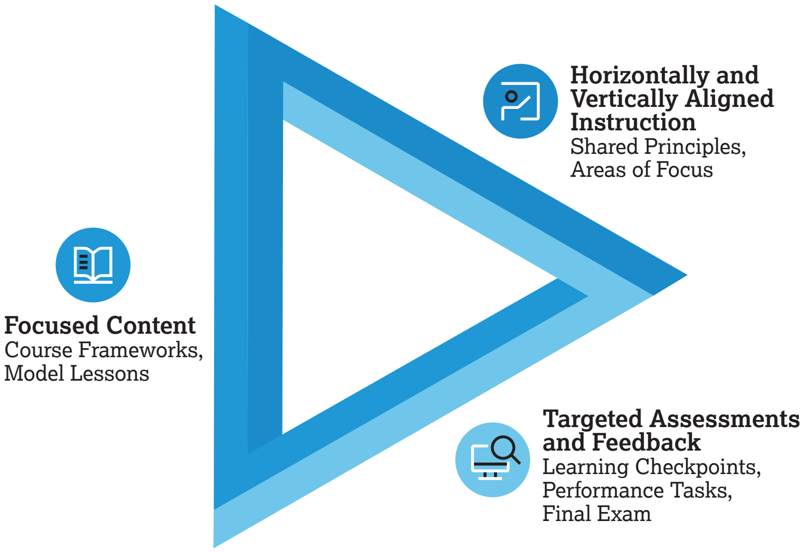
HOW TO GET INVOLVED

Schools and districts interested in learning more about participating in Pre-AP should visit **preap.org/join** or contact us at **preap@collegeboard.org**.

Teachers interested in becoming members of Pre-AP National Faculty or participating in content development should visit **preap.org/national-faculty** or contact us at **preap@collegeboard.org**.

Pre-AP Approach to Teaching and Learning

Pre-AP courses invite all students to learn, grow, and succeed through focused content, horizontally and vertically aligned instruction, and targeted assessments for learning. The Pre-AP approach to teaching and learning, as described below, is not overly complex, yet the combined strength results in powerful and lasting benefits for both teachers and students. This is our theory of action.



FOCUSED CONTENT

Pre-AP courses focus deeply on a limited number of concepts and skills with the broadest relevance for high school coursework and college and career success. The course framework serves as the foundation of the course and defines these prioritized concepts and skills. Pre-AP model lessons and assessments are based directly on this focused framework. The course design provides students and teachers with intentional permission to slow down and focus.

HORIZONTALLY AND VERTICALLY ALIGNED INSTRUCTION

Shared principles cut across all Pre-AP courses and disciplines. Each course is also aligned to discipline-specific areas of focus that prioritize the critical reasoning skills and practices central to that discipline.

SHARED PRINCIPLES

All Pre-AP courses share the following set of research-supported instructional principles. Classrooms that regularly focus on these cross-disciplinary principles allow students to effectively extend their content knowledge while strengthening their critical thinking skills. When students are enrolled in multiple Pre-AP courses, the horizontal alignment of the shared principles provides students and teachers across disciplines with a shared language for their learning and investigation, and multiple opportunities to practice and grow. The critical reasoning and problem-solving tools students develop through these shared principles are highly valued in college coursework and in the workplace.

Close Observation and Analysis

Students are provided time to carefully observe one data set, text, image, performance piece, or problem before being asked to explain, analyze, or evaluate. This creates a safe entry point to simply express what they notice and what they wonder. It also encourages students to slow down and capture relevant details with intentionality to support more meaningful analysis, rather than rushing to completion at the expense of understanding.

Higher-Order Questioning

Students engage with questions designed to encourage thinking that is elevated beyond simple memorization and recall. Higher-order questions require students to make predictions, synthesize, evaluate, and compare. As students grapple with these questions, they learn that being inquisitive promotes extended thinking and leads to deeper understanding.

Evidence-Based Writing

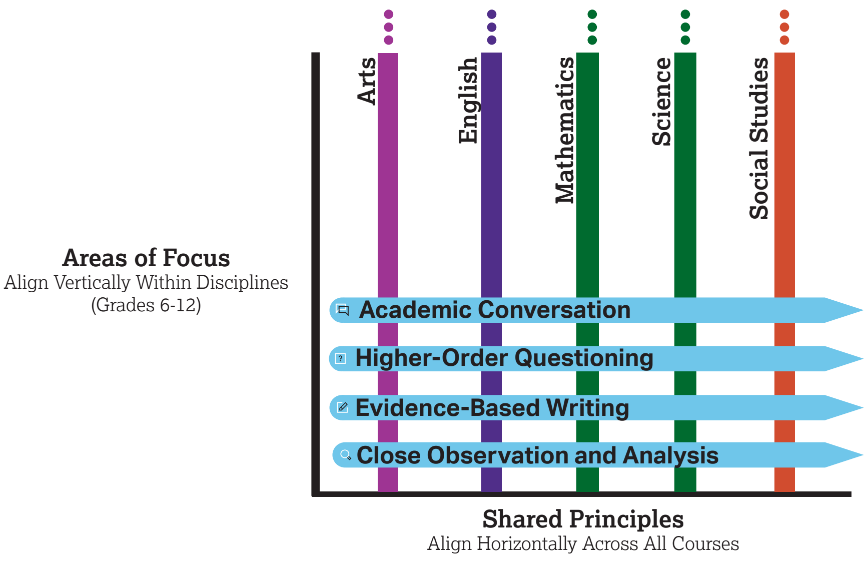
With strategic support, students frequently engage in writing coherent arguments from relevant and valid sources of evidence. Pre-AP courses embrace a purposeful and scaffolded approach to writing that begins with a focus on precise and effective sentences before progressing to longer forms of writing.

Academic Conversation

Through peer-to-peer dialogue, students' ideas are explored, challenged, and refined. As students engage in academic conversation, they come to see the value in being open to new ideas and modifying their own ideas based on new information. Students grow as they frequently practice this type of respectful dialogue and critique and learn to recognize that all voices, including their own, deserve to be heard.

AREAS OF FOCUS

The areas of focus are discipline-specific reasoning skills that students develop and leverage as they engage with content. Whereas the shared principles promote horizontal alignment across disciplines, the areas of focus provide vertical alignment within a discipline, giving students the opportunity to strengthen and deepen their work with these skills in subsequent courses in the same discipline.



For information about the Pre-AP science areas of focus, see page 13.

TARGETED ASSESSMENTS FOR LEARNING

Pre-AP courses include strategically designed classroom assessments that serve as tools for understanding progress and identifying areas that need more support. The assessments provide frequent and meaningful feedback for both teachers and students across each unit of the course and for the course as a whole. For more information about assessments in Pre-AP Chemistry, see page 44.

Pre-AP Professional Learning

As part of the program commitments, Pre-AP teachers agree to engage in two professional learning opportunities:

1. The first commitment is designed to help prepare teachers to teach their specific course. There are two options to meet this commitment: the Pre-AP Summer Institute (Pre-APSI) and the Online Foundational Modules. Both options provide continuing education units upon completion.
    - The Pre-AP Summer Institute provides a collaborative experience that empowers participants to prepare and plan for their Pre-AP course. While attending, teachers engage with Pre-AP course frameworks, shared principles, areas of focus, and sample model lessons. Participants are given supportive planning time where they work with peers to begin building their Pre-AP course plan.
    - Online Foundational Modules are available to all teachers of Pre-AP courses. In their 12- to 20-hour asynchronous course, teachers explore course materials and experience model lessons from the student's point of view. They also begin building their Pre-AP course plan.
2. The second professional learning opportunity helps teachers prepare for the performance tasks. As part of this commitment, teachers agree to complete at least one online performance task scoring module. Online scoring modules offer guidance and practice applying scoring guidelines and examining student work. Teachers may complete the modules independently or with teachers of the same course in their school's professional learning communities.

About Pre-AP Chemistry

Introduction to Pre-AP Chemistry

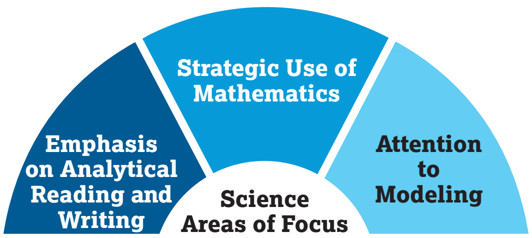
The Pre-AP Chemistry course emphasizes the integration of content with science practices—powerful reasoning tools that support students in analyzing the natural world around them. Having this ability is one of the hallmarks of scientific literacy and is critical for numerous college and career endeavors in science and the social sciences.

Rather than seeking to cover all topics traditionally included in a standard chemistry textbook, this course focuses on the foundational chemistry knowledge and skills that matter most for college and career readiness. The Pre-AP Chemistry Course Framework highlights how to guide students to connect core ideas within and across the units of the course, promoting the development of a coherent understanding of matter at the atomic scale.

The components of this course have been crafted to prepare not only the next generation of chemists, but also a broader base of chemistry-informed citizens who are well equipped to respond to the array of science-related issues that impact our lives at the personal, local, and global levels.

PRE-AP SCIENCE AREAS OF FOCUS

The Pre-AP science areas of focus, shown below, are science practices that students develop and leverage as they engage with content. They were identified through educator feedback and research about where students and teachers need the most curriculum support. These areas of focus are vertically aligned to the science practices embedded in other science courses in high school, including AP, and in college, giving students multiple opportunities to strengthen and deepen their work with these skills throughout their educational career. They also support and align to the NGSS and AP science practices of theory building and refinement.



Emphasis on Analytical Reading and Writing

Students engage in analytical reading and writing to gain, retain, and apply scientific knowledge and to carry out scientific argumentation.

In prioritizing analytical reading, Pre-AP Chemistry classrooms ask students to extract, synthesize, and compare complex information, often by moving between texts, tables and graphs of experimental data, and representations of motions and interactions at the molecular level. Through analytical writing activities, Pre-AP Chemistry students must integrate and translate that information to generate scientific questions, design methods for answering questions, and develop scientific arguments. Moreover, the application of these skills to the understanding of informal science texts, such as articles found in newspapers, online sources, and magazines, prepares students to be discerning consumers of scientific information.

Strategic Use of Mathematics

Students integrate mathematics with conceptual understanding to model chemical phenomena.

Mathematics is an essential tool for the study of chemistry. However, introductory chemistry courses often focus on the use of mathematics without context-focused applications. This practice can result in students being able to solve mathematical problems in chemistry class, but without an understanding of the underlying chemical principles. As an alternative approach, Pre-AP Chemistry requires students to demonstrate their knowledge using multiple representations that integrate conceptual understanding with the use of mathematics. Students are also challenged to use data and observations to build mathematical models that reflect their conceptual understanding and can be used to make predictions.

Attention to Modeling

Students develop and refine models to connect macroscopic observations to structure, motion, and interactions occurring at the atomic scale.

In Pre-AP Chemistry, the development of models to explain their macroscopic observations is a primary means through which students develop an understanding of the molecular world. Engaging students in creating and revising models reinforces other scientific reasoning skills, such as data analysis and scientific argumentation. Modeling also helps illustrate for students how scientific knowledge is constructed and modified over time as new data and evidence emerge and models are revised based on this new information.

PRE-AP CHEMISTRY AND CAREER READINESS

The Pre-AP Chemistry course resources are designed to expose students to a wide range of career opportunities that depend upon chemistry knowledge and skills. Chemistry lies at the interface of the physical and life sciences. As science, engineering, and healthcare move increasingly towards the molecular scale, chemistry provides ideal preparation for 21st century careers. Examples include not only careers within the physical sciences, such as forensic scientist or food chemist, but also other endeavors where chemistry knowledge is relevant such as the work of an engineer, policymaker, or healthcare worker.

Career clusters that involve chemistry, along with examples of careers in chemistry or related to chemistry, are provided below. Teachers should consider discussing these with students throughout the year to promote motivation and engagement.

Career Clusters Involving Chemistry	
agriculture, food, and natural resources healthcare and health science hospitality and tourism information technology	manufacturing STEM (science, technology, engineering, and math)
Examples of Chemistry Careers	**Examples of Chemistry Related Careers**
atmospheric chemist	environmental scientist
chemical engineer	forensic scientist
chemistry teacher/professor	medical assistant
environmental chemist	patent lawyer
food chemist	pharmacist
geochemist	pharmacologist
hazardous waste manager	physician
materials scientist	physician assistant
medicinal chemist	science writer
nanotechnologist	technical sales
synthetic chemist	toxicologist

Source for Career Clusters: "Advanced Placement and Career and Technical Education: Working Together." Advance CTE and the College Board. October 2018. **https://careertech.org/resource/ap-cte-working-together.**

For more information about careers that involve chemistry, teachers and students can visit and explore the College Board's Big Future resources: **https://bigfuture.collegeboard.org/majors/physical-sciences-chemistry-chemistry**.

SUMMARY OF RESOURCES AND SUPPORTS

Teachers are strongly encouraged to take advantage of the full set of resources and supports for Pre-AP Chemistry, which is summarized below. Some of these resources are part of the Pre-AP Program commitments that lead to Pre-AP Course Designation. To learn more about the commitments for course designation, see details below and on page 69.

COURSE FRAMEWORK

Included in this guide as well as in the *Pre-AP Chemistry Teacher Resources*, the framework defines what students should know and be able to do by the end of the course. It serves as an anchor for model lessons and assessments, and it is the primary resource needed to plan the course. **Teachers commit to aligning their classroom instruction with the course framework**. *For more details see page 20.*

MODEL LESSONS

Teacher resources, available in print and online, include a robust set of model lessons that demonstrate how to translate the course framework, shared principles, and areas of focus into daily instruction. **Use of the model lessons is encouraged**. *For more details see page 42.*

LEARNING CHECKPOINTS

Accessed through Pre-AP Classroom (the Pre-AP digital platform), these short formative assessments provide insight into student progress. They are automatically scored and include multiple-choice and technology-enhanced items with rationales that explain correct and incorrect answers. **Teachers commit to administering one learning checkpoint per unit**. *For more details see page 44.*

PERFORMANCE TASKS

Available in the printed teacher resources as well as on Pre-AP Classroom, performance tasks allow students to demonstrate their learning through extended problem-solving, writing, analysis, and/or reasoning tasks. Scoring guidelines are provided to inform teacher scoring, with additional practice and feedback suggestions available in online modules on Pre-AP Classroom. **Teachers commit to using each unit's performance task**. *For more details see page 46.*

PRACTICE PERFORMANCE TASKS

Available in the student resources, with supporting materials in the teacher resources, these tasks provide an opportunity for students to practice applying skills and knowledge as they would in a performance task, but in a more scaffolded environment. **Use of the practice performance tasks is encouraged.** *For more details see page 47.*

FINAL EXAM

Accessed through Pre-AP Classroom, the final exam serves as a classroom-based, summative assessment designed to measure students' success in learning and applying the knowledge and skills articulated in the course framework. **Administration of the final exam is encouraged**. *For more details see page 63.*

PROFESSIONAL LEARNING

Both the Pre-AP Summer Institute (Pre-APSI) and the Online Foundational Modules support teachers in preparing and planning to teach their Pre-AP course. **All Pre-AP teachers make a commitment to either attend the Pre-APSI (in person or virtually) or complete the Online Foundational Modules. In addition, teachers agree to complete at least one Online Performance Task Scoring module**. *For more details see page 9.*

Course Map

PLAN

The course map shows how components are positioned throughout the course. As the map indicates, the course is designed to be taught over 140 class periods (based on 45-minute class periods), for a total of 28 weeks.

Model lessons are included for approximately 50% of the total instructional time, with the percentage varying by unit. Each unit is divided into key concepts.

TEACH

The model lessons demonstrate how the Pre-AP shared principles and science areas of focus come to life in the classroom.

Shared Principles
Close observation and analysis
Higher-order questioning
Evidence-based writing
Academic conversation

Areas of Focus
Emphasis on analytical reading and writing
Strategic use of mathematics
Attention to modeling

ASSESS AND REFLECT

Each unit includes two learning checkpoints and a performance task. These formative assessments are designed to provide meaningful feedback for both teachers and students.

Note: The final exam, offered during a six-week window in the spring, is not represented in the map.

UNIT 1 Structure and Properties of Matter

~30 Class Periods

Pre-AP model lessons provided for approximately 50% of instructional time in this unit

KEY CONCEPT 1.1
Particle View of States of Matter

Learning Checkpoint 1

KEY CONCEPT 1.2
Phase Changes and Particle Interactions

KEY CONCEPT 1.3
Kinetic Molecular Theory

Learning Checkpoint 2

Performance Task for Unit 1

UNIT 2 Chemical Bonding and Interactions

~40 Class Periods

Pre-AP model lessons provided for approximately 40% of instructional time in this unit

KEY CONCEPT 2.1
Classification and Interactions of Matter

KEY CONCEPT 2.2
Learning Objectives 2.2.A.1–2.2.C.1
Molecular Structure and Properties

Learning Checkpoint 1

KEY CONCEPT 2.2 (*continued*)
Learning Objectives 2.2.D.1–2.2.G.1
Molecular Structure and Properties

KEY CONCEPT 2.3
Covalent and Ionic Bonding

Learning Checkpoint 2

Performance Task for Unit 2

UNIT 3 Chemical Quantities

~30 Class Periods

Pre-AP model lessons provided for approximately 30% of instructional time in this unit

KEY CONCEPT 3.1
Counting Particles in Substances

Learning Checkpoint 1

KEY CONCEPT 3.2
Counting Particles in Chemical Reactions

Learning Checkpoint 2

Performance Task for Unit 3

UNIT 4 Chemical Transformations

~40 Class Periods

Pre-AP model lessons provided for approximately 30% of instructional time in this unit

KEY CONCEPT 4.1
Precipitation Chemistry

KEY CONCEPT 4.2
Oxidation–Reduction Chemistry

Learning Checkpoint 1

KEY CONCEPT 4.3
Acid–Base Chemistry

KEY CONCEPT 4.4
Thermochemistry

KEY CONCEPT 4.5
Reaction Rates

Learning Checkpoint 2

Performance Task for Unit 4

Pre-AP Chemistry Course Framework

INTRODUCTION

Based on the Understanding by Design® (Wiggins and McTighe) model, the Pre-AP Chemistry Course Framework is back mapped from AP expectations and aligned to essential grade-level expectations. The course framework serves as a teacher's blueprint for the Pre-AP Chemistry instructional resources and assessments.

The course framework was designed to meet the following criteria:

- **Focused:** The framework provides a deep focus on a limited number of concepts and skills that have the broadest relevance for later high school, college, and career success.
- **Measurable:** The framework's learning objectives are observable and measurable statements about the knowledge and skills students should develop in the course.
- **Manageable:** The framework is manageable for a full year of instruction, fosters the ability to explore concepts in depth, and enables room for additional local or state standards to be addressed where appropriate.
- **Accessible:** The framework's learning objectives are designed to provide all students, across varying levels of readiness, with opportunities to learn, grow, and succeed.

COURSE FRAMEWORK COMPONENTS

The Pre-AP Chemistry Course Framework includes the following components:

Big Ideas

The big ideas are recurring themes that allow students to create meaningful connections between course concepts. Revisiting the big ideas throughout the course and applying them in a variety of contexts allows students to develop deeper conceptual understandings.

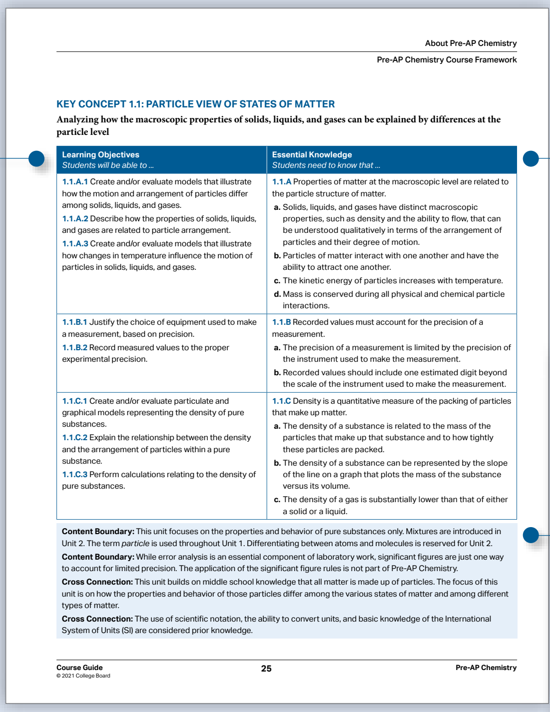
Enduring Understandings

Each unit focuses on a small set of enduring understandings. These are the long-term takeaways related to the big ideas that leave a lasting impression on students. Students build and earn these understandings over time by exploring and applying course content throughout the year.

Key Concepts

To support teacher planning and instruction, each unit is organized by key concepts. Each key concept includes relevant **learning objectives** and **essential knowledge statements** and may also include **content boundary and cross connection statements**. These are illustrated and defined below.

Learning Objectives:
These objectives define what a student needs to be able to do with essential knowledge to progress toward the enduring understandings. The learning objectives serve as actionable targets for instruction and assessment.



About Pre-AP Chemistry

Pre-AP Chemistry Course Framework

KEY CONCEPT 1.1: PARTICLE VIEW OF STATES OF MATTER

Analyzing how the macroscopic properties of solids, liquids, and gases can be explained by differences at the particle level

Learning Objectives *Students will be able to …*	Essential Knowledge *Students need to know that …*
1.1.A.1 Create and/or evaluate models that illustrate how the motion and arrangement of particles differ among solids, liquids, and gases. 1.1.A.2 Describe how the properties of solids, liquids, and gases are related to particle arrangement. 1.1.A.3 Create and/or evaluate models that illustrate how changes in temperature influence the motion of particles in solids, liquids, and gases.	1.1.A Properties of matter at the macroscopic level are related to the particle structure of matter. **a.** Solids, liquids, and gases have distinct macroscopic properties, such as density and the ability to flow, that can be understood qualitatively in terms of the arrangement of particles and their degree of motion. **b.** Particles of matter interact with one another and have the ability to attract one another. **c.** The kinetic energy of particles increases with temperature. **d.** Mass is conserved during all physical and chemical particle interactions.
1.1.B.1 Justify the choice of equipment used to make a measurement, based on precision. 1.1.B.2 Record measured values to the proper experimental precision.	1.1.B Recorded values must account for the precision of a measurement. **a.** The precision of a measurement is limited by the precision of the instrument used to make the measurement. **b.** Recorded values should include one estimated digit beyond the scale of the instrument used to make the measurement.
1.1.C.1 Create and/or evaluate particulate and graphical models representing the density of pure substances. 1.1.C.2 Explain the relationship between the density and the arrangement of particles within a pure substance. 1.1.C.3 Perform calculations relating to the density of pure substances.	1.1.C Density is a quantitative measure of the packing of particles that make up matter. **a.** The density of a substance is related to the mass of the particles that make up that substance and to how tightly these particles are packed. **b.** The density of a substance can be represented by the slope of the line on a graph that plots the mass of the substance versus its volume. **c.** The density of a gas is substantially lower than that of either a solid or a liquid.

Content Boundary: This unit focuses on the properties and behavior of pure substances only. Mixtures are introduced in Unit 2. The term *particle* is used throughout Unit 1. Differentiating between atoms and molecules is reserved for Unit 2.

Content Boundary: While error analysis is an essential component of laboratory work, significant figures are just one way to account for limited precision. The application of the significant figure rules is not part of Pre-AP Chemistry.

Cross Connection: This unit builds on middle school knowledge that all matter is made up of particles. The focus of this unit is on how the properties and behavior of those particles differ among the various states of matter and among different types of matter.

Cross Connection: The use of scientific notation, the ability to convert units, and basic knowledge of the International System of Units (SI) are considered prior knowledge.

Course Guide
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25
Pre-AP Chemistry

Essential Knowledge Statements:
The essential knowledge statements are linked to one or more learning objectives. These statements describe the knowledge required to perform the learning objective(s).

Content Boundary and Cross Connection Statements:
When needed, content boundary statements provide additional clarity about the content and skills that lie within versus outside of the scope of this course.

Cross connection statements highlight important connections that should be made between key concepts within and across the units.

BIG IDEAS IN PRE-AP CHEMISTRY

While the Pre-AP Chemistry framework is organized into four core units of study, the content is grounded in three big ideas, which are cross-cutting concepts that build conceptual understanding and spiral throughout the course. Since these ideas cut across units, they serve as the underlying foundation for the enduring understandings, key concepts, learning objectives, and essential knowledge statements that make up the focus of each unit.

The three big ideas that are central to deep and productive understanding in Pre-AP Chemistry are:

- **Structure and Properties:** All matter is composed of particles that are in constant motion and interact with one another. This movement and interaction is responsible for the observable properties of matter. Observed properties can be used to infer the number and type(s) of particle(s) in a sample of matter.
- **Energy:** Energy is transferred in all physical and chemical processes. During these processes, energy is either redistributed within the system or between systems.
- **Transformations**: At its heart, chemistry is about rearrangements of matter. These rearrangements, or transformations, involve the breaking and forming of intermolecular forces or chemical bonds. Macroscopic observations can be used to quantify and describe these rearrangements at the atomic scale.

OVERVIEW OF PRE-AP CHEMISTRY UNITS AND ENDURING UNDERSTANDINGS

Unit 1: Structure and Properties of Matter	Unit 2: Chemical Bonding and Interactions
▪ Solids, liquids, and gases have different properties as a result of the motion of particles and the interactions among them. ▪ All measurements have uncertainty, and their level of precision must be accounted for in the design of an experiment and the recording of data. ▪ The amount of energy transferred during heating and cooling matter or changing its state is determined by the interactions among the particles that make up the matter. ▪ Observable properties of gases can be measured experimentally and explained using an understanding of particle motion.	▪ The macroscopic physical properties of materials can be explained by the intermolecular forces among particles. ▪ The structure and properties of compounds arise from the periodic properties and bonding patterns of the constituent atoms.
Unit 3: Chemical Quantities	**Unit 4: Chemical Transformations**
▪ The mole concept is used to quantitatively relate the number of particles involved in a reaction to experimental data about that reaction. ▪ In chemical reactions, bonding between atoms changes, leading to new compounds with different properties.	▪ Solubility, electron transfer, and proton transfer are driving forces in chemical reactions. ▪ All chemical reactions are accompanied by a transfer of energy. ▪ Chemical reactions occur at varying rates that are related to the frequency and success of collisions between reactants.

Unit 1: Structure and Properties of Matter

Suggested Timing: Approximately 6 weeks

This course progresses from macroscopic to atomic explorations of properties of matter in order to help students develop a conceptual understanding of matter at the molecular level. The first unit is designed to spark students' interest in chemistry as they make meaningful connections between the familiar world of everyday, macroscopic variables and observations and the less familiar context of the motion and interactions of particles at the atomic level.

By the end of this unit, students develop a set of simple rules to describe the behavior of particles in pure substances through building and revising particulate models. They deepen their understanding throughout the unit as they support and verify predictions of these models using observations of real-world phenomena and calculations of various physical properties such as the density of solids and liquids, the basic parameters of gases such as pressure and volume, and the role energy plays in phase transitions. Students also consider how the attraction among particles influences properties; the factors that establish the strength of those forces will be explored in Unit 2.

ENDURING UNDERSTANDINGS

Students will understand that …

- Solids, liquids, and gases have different properties as a result of the motion of particles and the interactions among them.
- All measurements have uncertainty, and their level of precision must be accounted for in the design of an experiment and the recording of data.
- The amount of energy transferred during heating and cooling matter or changing its state is determined by the interactions among the particles that make up the matter.
- Observable properties of gases can be measured experimentally and explained using an understanding of particle motion.

KEY CONCEPTS

- **1.1: Particle view of states of matter** – Analyzing how the macroscopic properties of solids, liquids, and gases can be explained by differences at the particle level
- **1.2: Phase changes and particle interactions** – Examining the role energy plays in phase transitions and how these transitions can be represented using phase diagrams and heating curves
- **1.3: Kinetic molecular theory** – Investigating gases and how their properties and behavior can be predicted from the kinetic molecular theory

KEY CONCEPT 1.1: PARTICLE VIEW OF STATES OF MATTER

Analyzing how the macroscopic properties of solids, liquids, and gases can be explained by differences at the particle level

Learning Objectives *Students will be able to ...*	**Essential Knowledge** *Students need to know that ...*
1.1.A.1 Create and/or evaluate models that illustrate how the motion and arrangement of particles differ among solids, liquids, and gases. **1.1.A.2** Describe how the properties of solids, liquids, and gases are related to particle arrangement. **1.1.A.3** Create and/or evaluate models that illustrate how changes in temperature influence the motion of particles in solids, liquids, and gases.	**1.1.A** Properties of matter at the macroscopic level are related to the particle structure of matter. **a.** Solids, liquids, and gases have distinct macroscopic properties, such as density and the ability to flow, that can be understood qualitatively in terms of the arrangement of particles and their degree of motion. **b.** Particles of matter interact with one another and have the ability to attract one another. **c.** The kinetic energy of particles increases with temperature. **d.** Mass is conserved during all physical and chemical particle interactions.
1.1.B.1 Justify the choice of equipment used to make a measurement, based on precision. **1.1.B.2** Record measured values to the proper experimental precision.	**1.1.B** Recorded values must account for the precision of a measurement. **a.** The precision of a measurement is limited by the precision of the instrument used to make the measurement. **b.** Recorded values should include one estimated digit beyond the scale of the instrument used to make the measurement.
1.1.C.1 Create and/or evaluate particulate and graphical models representing the density of pure substances. **1.1.C.2** Explain the relationship between the density and the arrangement of particles within a pure substance. **1.1.C.3** Perform calculations relating to the density of pure substances.	**1.1.C** Density is a quantitative measure of the packing of particles that make up matter. **a.** The density of a substance is related to the mass of the particles that make up that substance and to how tightly these particles are packed. **b.** The density of a substance can be represented by the slope of the line on a graph that plots the mass of the substance versus its volume. **c.** The density of a gas is substantially lower than that of either a solid or a liquid.

Content Boundary: This unit focuses on the properties and behavior of pure substances only. Mixtures are introduced in Unit 2. The term *particle* is used throughout Unit 1. Differentiating between atoms and molecules is reserved for Unit 2.

Content Boundary: While error analysis is an essential component of laboratory work, significant figures are just one way to account for limited precision. The application of the significant figure rules is not part of Pre-AP Chemistry.

Cross Connection: This unit builds on middle school knowledge that all matter is made up of particles. The focus of this unit is on how the properties and behavior of those particles differ among the various states of matter and among different types of matter.

Cross Connection: The use of scientific notation, the ability to convert units, and basic knowledge of the International System of Units (SI) are considered prior knowledge.

KEY CONCEPT 1.2: PHASE CHANGES AND PARTICLE INTERACTIONS

Examining the role energy plays in phase transitions and how these transitions can be represented using phase diagrams and heating curves

Learning Objectives *Students will be able to …*	**Essential Knowledge** *Students need to know that …*
1.2.A.1 Create and/or evaluate a claim about the relationship between transfer of thermal energy and the temperature change in different samples. **1.2.A.2** Perform calculations using data gathered from a simple constant-pressure calorimetry experiment.	**1.2.A** The transfer of energy associated with a change in temperature of a sample of matter is heat. Specific heat capacity is a proportionality constant that relates the amount of energy absorbed by a substance to its mass and its change in temperature.
1.2.B.1 Use data to explain the direction of energy flow into or out of a system.	**1.2.B** Energy transfers are classified as endothermic or exothermic. **a.** In endothermic changes, energy flows from the surroundings to the system. **b.** In exothermic changes, energy flows from the system to the surroundings.
1.2.C.1 Explain the relationship between changes in states of matter and the attractions among particles. **1.2.C.2** Create and/or interpret models representing phase changes.	**1.2.C** Substances with stronger attractions among particles generally have higher melting and boiling points than substances with weaker attractions among particles.
1.2.D.1 Create and/or interpret heating and cooling curves and/or phase diagrams of pure substances. **1.2.D.2** Calculate the energy transferred when a substance changes state.	**1.2.D** The transitions between solid, liquid, and gas can be represented with heating and cooling curves and phase diagrams. **a.** Heating and cooling curves represent how a substance responds to the addition or removal of energy (as heat). **b.** The temperature of a substance is constant during a phase change. **c.** Energy changes associated with a phase change can be calculated using heat of vaporization or heat of fusion. **d.** Phase diagrams give information about a pure substance at a specific temperature and pressure, including phase transitions.

Content Boundary: The study of critical points and triple points is beyond the scope of the course. The focus of the study of phase diagrams should be on how the combination of temperature and pressure determine the state of matter of a given substance and identification of phase changes.

Cross Connection: The study of energy transfer in Unit 1 is limited to physical changes. Students will revisit thermochemistry in Unit 4, this time applied to chemical reactions.

Cross Connection: Forces of attraction between particles are identified as stronger or weaker in this unit as a way for students to begin to understand differences in macroscopic properties of substances. Students will revisit these attractive forces in Unit 2 as they learn about the types and relative strengths of intermolecular forces.

KEY CONCEPT 1.3: KINETIC MOLECULAR THEORY

Investigating gases and how their properties and behavior can be predicted from the kinetic molecular theory

Learning Objectives *Students will be able to …*	**Essential Knowledge** *Students need to know that …*
1.3.A.1 Create and/or evaluate models that illustrate how a gas exerts pressure. **1.3.A.2** Explain the relationship between pressure in a gas and collisions.	**1.3.A** The pressure of a gas is the force the gas applies to a unit area of the container it is in. **a.** Pressure arises from collisions of particles with the walls of the container. **b.** Pressure is measured using several different units that are proportional to each other.
1.3.B.1 Explain the relationships between the macroscopic properties of a sample of a gas using the kinetic molecular theory. **1.3.B.2** Create and/or evaluate models that illustrate how a sample of gas responds to changes in macroscopic properties.	**1.3.B** The kinetic molecular theory relates the macroscopic properties of a gas to the motion of the particles that comprise the gas. An ideal gas is a gas that conforms to the kinetic molecular theory.
1.3.C.1 Determine mathematically and/or graphically the quantitative relationship between macroscopic properties of gases. **1.3.C.2** Perform calculations relating to the macroscopic properties of gases.	**1.3.C** The relationships between macroscopic properties of a gas, including pressure, temperature, volume, and amount of gas, can be quantified.

Content Boundary: All gases studied in this unit are considered to be ideal. The derivation and discussion of the ideal gas law has been reserved for Unit 3, after students have been introduced to the mole.

Unit 2: Chemical Bonding and Interactions

Suggested Timing: Approximately 8 weeks

This unit focuses on particle interactions and continues the unit progression from the macroscopic to the atomic level. Building on prior concepts taught in middle school about basic atomic structure, students build on and extend their understanding as they explore how the shape and structure of particles—including atoms, molecules, and ions—provide the explanatory framework for particle interactions. Students first consider intermolecular forces and connect them to both macroscopic observations and molecular structure. They then build on and deepen their preliminary understanding of bonding concepts from middle school and should begin to understand the electrostatic nature of many chemical interactions.

Throughout the unit, students revisit and revise the particulate models they developed in Unit 1 to account for the role of particle interactions. The patterns found in the periodic table are used to explain these phenomena.

ENDURING UNDERSTANDINGS

Students will understand that ...

- The macroscopic physical properties of materials can be explained by the intermolecular forces among particles.
- The structure and properties of compounds arise from the periodic properties and bonding patterns of the constituent atoms.

KEY CONCEPTS

- **2.1: Classification and interactions of matter** – Describing and classifying matter, with a focus on how intermolecular and intramolecular forces determine the properties of matter
- **2.2: Molecular structure and properties** – Relating the properties of molecular compounds to molecular structure
- **2.3: Covalent and ionic bonding** – Analyzing the differences between covalent and ionic bonding, with an emphasis on the electrostatic nature of ionic attractions

KEY CONCEPT 2.1: CLASSIFICATION AND INTERACTIONS OF MATTER

Describing and classifying matter, with a focus on how intermolecular and intramolecular forces determine the properties of matter

Learning Objectives *Students will be able to …*	**Essential Knowledge** *Students need to know that …*
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.	**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. **2.1.B.2** Interpret the results of an experiment involving the separation of a mixture.	**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.
2.1.C.1 Relate the total and partial pressure of a gas mixture to the number of particles and their proportions.	**2.1.C** In a mixture of gases, each gas contributes to the pressure of the gas. **a.** The total pressure of the mixture is the sum of the individual partial pressures of each gas that makes up the mixture. **b.** The partial pressures of each gas can be determined by comparing the fraction of particles of the gas in the mixture to the total number of gas particles.
2.1.D.1 Create and/or evaluate a claim about the types of forces that are overcome during the melting, boiling, and/or dissolving of substances.	**2.1.D** Attractions among particles of matter are the result of electrostatic interactions between particles. **a.** Intermolecular forces are responsible for many physical properties of substances including boiling point, melting point, surface tension, and volatility. **b.** Intramolecular forces hold atoms together in a molecule.

Cross Connection: Unit 1 treats particles as if they have no internal structure and are mostly identical. In this unit, students begin to distinguish between atoms and molecules and between mixtures and pure substances.

Cross Connection: The basics of atomic structure, including the shell model of the atom and the properties of the three basic subatomic particles, are considered prior knowledge from middle school.

KEY CONCEPT 2.2: MOLECULAR STRUCTURE AND PROPERTIES

Relating the properties of molecular compounds to molecular structure

Learning Objectives *Students will be able to ...*	**Essential Knowledge** *Students need to know that ...*
2.2.A.1 Create and/or evaluate models that illustrate how molecular properties influence the type(s) of intermolecular force(s) present in a substance. **2.2.A.2** Create and/or evaluate a claim about the type(s), strength(s), and origin(s) of intermolecular forces present in a substance.	**2.2.A** Intermolecular forces occur between molecules and are the result of electrostatic interactions. **a.** London dispersion forces are attractions among temporary dipoles created by the random movement of electrons; these attractions occur between all types of molecules. Molecules with more electrons tend to have stronger London dispersion forces. **b.** Dipole–dipole forces are attractions among permanent dipoles on interacting molecules. **c.** Hydrogen bonding forces exist when hydrogen atoms covalently bonded to highly electronegative atoms (N, O, or F) are attracted to the negative ends of dipoles formed by highly electronegative atoms (N, O, or F) in other molecules.
2.2.B.1 Create and/or evaluate a claim that uses relative strength of intermolecular forces to explain trends in the physical properties of substances.	**2.2.B** Intermolecular forces can be used to explain trends in physical properties of substances including boiling point, melting point, surface tension, volatility, and solubility.
2.2.C.1 Describe trends in properties of elements based on their position in the periodic table and the shell model of the atom.	**2.2.C** The periodic table is an organizational tool for elements based on their properties. **a.** Patterns of behavior of elements are based on the number of electrons in the outermost shell (valence electrons). **b.** Important periodic trends include electronegativity and atomic radius.
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.
2.2.E.1 Determine molecular geometry from a Lewis diagram using valence shell electron pair repulsion theory.	**2.2.E** Valence shell electron pair repulsion (VSEPR) theory predicts molecular geometry from a Lewis diagram. Molecular geometries include linear, bent, trigonal planar, trigonal pyramidal, and tetrahedral arrangements of atoms.
2.2.F.1 Determine the polarity of a molecule from its molecular geometry and electron distribution.	**2.2.F** Molecules with asymmetric distributions of electrons are polar.
2.2.G.1 Create and/or evaluate a claim about the strength and type(s) of intermolecular forces present in a sample based on molecular polarity.	**2.2.G** Molecular geometry determines if a molecule has a permanent dipole and therefore the type(s) of intermolecular forces present in that molecule.

Content Boundary: The study of expanded octets, resonance structures, and formal charge is beyond the scope of this course. Rather than focusing on exceptions to the octet rule, the focus is on helping students develop a deep understanding of the rationale for molecular structure. If students go on to take AP Chemistry, this introduction will provide the foundation for more advanced study.

Content Boundary: The quantum mechanical model of the atom and the writing of electron configurations are beyond the scope of this course. If students go on to take AP Chemistry, they will study the details of the electron structure of atoms, including electron configurations.

Content Boundary: The study of isomers is limited to structural isomers and is included so students can begin to develop an understanding that in addition to the number and type of atoms in a molecule, the arrangement of the atoms and bonds is also important in determining properties.

Cross Connection: Students should connect their study of phase changes and properties of matter from Unit 1 to intermolecular forces. This key concept leads with the study of intermolecular forces rather than building up to it. This approach enables students to immediately begin connecting macroscopic observations to atomic-level understandings even while they are learning about Lewis structures and molecular geometry. If students go on to take AP Chemistry, they will continue to build on their understanding of intermolecular forces.

KEY CONCEPT 2.3: COVALENT AND IONIC BONDING

Analyzing the differences between covalent and ionic bonding, with an emphasis on the electrostatic nature of ionic attractions

Learning Objectives *Students will be able to …*	**Essential Knowledge** *Students need to know that …*
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.

Content Boundary: The study of ionic compounds should include those compounds containing the polyatomic ions listed on the Pre-AP Chemistry equation sheet. The naming of acids and organic compounds is beyond the scope of this course. Nomenclature should be consistent with recommendations of the International Union of Pure and Applied Chemistry (IUPAC).

Content Boundary: While students should have a conceptual understanding of the role electrostatic interactions play in ionic compounds, quantitative applications of Coulomb's law are beyond the scope of this course. If students go on to take AP Chemistry or AP Physics, they will study Coulomb's law in more detail.

Unit 3: Chemical Quantities

Suggested Timing: Approximately 6 weeks

This unit explores chemical transformations of matter by building on the physical transformations studied in Units 1 and 2. Leveraging what has been learned about particles in Units 1 and 2, this unit introduces students to the importance of the mole concept for collecting data about particles and chemical reactions. Since chemistry deals with large numbers of particles, students are introduced to the idea of counting by weighing. To reinforce the particle nature of matter studied in Units 1 and 2, students use particulate representations of reactions to connect the amount of reactant consumed and the amount of product formed to the rearrangement of particles on the molecular level. Students will also use balanced chemical equations and mathematics to reason about amounts of reactants and products in chemical reactions.

ENDURING UNDERSTANDINGS

Students will understand that ...

- The mole concept is used to quantitatively relate the number of particles involved in a reaction to experimental data about that reaction.
- In chemical reactions, bonding between atoms changes, leading to new compounds with different properties.

KEY CONCEPTS

- **3.1: Counting particles in substances** – Using the mole concept to count by weighing
- **3.2: Counting particles in chemical reactions** – Reasoning about amounts of reactants and products in chemical reactions using balanced chemical equations

KEY CONCEPT 3.1: COUNTING PARTICLES IN SUBSTANCES

Using the mole concept to count by weighing

Learning Objectives *Students will be able to ...*	**Essential Knowledge** *Students need to know that ...*
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.
3.1.B.1 Explain the relationships between macroscopic properties of gas samples. **3.1.B.2** Perform calculations using the ideal gas law. **3.1.B.3** Create and/or evaluate models based on the ideal gas law.	**3.1.B** The ideal gas law describes the mathematical relationship between pressure, volume, number of gas particles, and temperature. **a.** Two samples of gas with the same pressure, volume, and temperature have the same number of particles. **b.** The mass of the particles can be computed from atomic masses. **c.** Because macroscopic samples of a gas contain many particles, moles are useful units for counting particles.

Content Boundary: The determination of empirical and molecular formulas is beyond the scope of this course.

Cross Connection: The focus on gases in this key concept about the mole allows students to draw connections between this unit and what they learned about gases in Units 1 and 2. Gases are a useful context for learning about the mole because a large quantity of gas is needed to measure properties of the gas.

KEY CONCEPT 3.2: COUNTING PARTICLES IN CHEMICAL REACTIONS

Reasoning about amounts of reactants and products in chemical reactions using balanced chemical equations

Learning Objectives *Students will be able to ...*	**Essential Knowledge** *Students need to know that ...*
3.2.A.1 Create and/or evaluate models of chemical transformations.	**3.2.A** All chemical transformations involve the rearrangement of atoms to form new combinations. **a.** Since the atoms are not created or destroyed, the total numbers of each atom must remain constant. **b.** Chemical transformations can be modeled by balanced chemical equations and particulate representations.
3.2.B.1 Explain the relationship between the quantity of reactants consumed and the quantity of products formed in a chemical transformation. **3.2.B.2** Perform stoichiometric calculations involving the quantity of reactants and products in a chemical system.	**3.2.B** A balanced chemical reaction equation, combined with the mole concept, can be used to quantify the amounts of reactants consumed and products formed during a chemical transformation.
3.2.C.1 Create and/or evaluate models of a reaction mixture before and/or after a reaction has occurred, including situations with a limiting reactant.	**3.2.C** The limiting reactant is the reactant that is completely consumed during a chemical reaction. The limiting reactant determines the amount of product formed.
3.2.D.1 Calculate the theoretical yield and/or percent yield of a chemical reaction.	**3.2.D** A balanced chemical reaction equation, combined with the mole concept, can be used to calculate the theoretical and percent yield of a reaction.

Content Boundary: Stoichiometric calculations involving limiting reactants are limited to whole numbers of moles (for both the initial and final quantities), such as what could be represented in particle diagrams to focus on conceptual understanding instead of algorithmic calculations.

Cross Connection: Stoichiometric calculations will be used in Unit 4 to investigate specific types of reactions.

Unit 4: Chemical Transformations

Suggested Timing: Approximately 8 weeks

In this unit, students explore the primary driving forces in chemical reactions through symbolic, particulate, and mathematical representations. The study of precipitation reactions, oxidation–reduction reactions, and acid–base reactions allows students to apply what they have learned about bonding in Unit 2 and stoichiometric relationships in Unit 3 as they explore specific reaction types and predict products of reactions. An emphasis on net ionic equations allows students to focus on the substances that are directly involved in chemical reactions. Students will also revisit and extend the concepts of energy from Unit 1 as they apply them to energy changes involved in chemical transformations, building to the fundamental understanding that breaking chemical bonds requires energy and that bond formation releases energy. Students will also study the rates of chemical reactions and factors that influence the rates, using a particulate perspective.

ENDURING UNDERSTANDINGS

Students will understand that …

- Solubility, electron transfer, and proton transfer are driving forces in chemical reactions.
- All chemical reactions are accompanied by a transfer of energy.
- Chemical reactions occur at varying rates that are related to the frequency and success of collisions between reactants.

KEY CONCEPTS

- **4.1: Precipitation chemistry** – Investigating how solubility is related to precipitation and can drive chemical reactions
- **4.2: Oxidation–reduction chemistry** – Analyzing how electron transfer can drive chemical reactions
- **4.3: Acid–base chemistry** – Examining properties of acids and bases and how proton transfer can drive chemical reactions
- **4.4: Thermochemistry** – Extending the study of energy by analyzing energy transformations that occur during chemical reactions
- **4.5: Reaction rates** – Investigating the factors that influence reaction rates

KEY CONCEPT 4.1: PRECIPITATION CHEMISTRY

Investigating how solubility is related to precipitation and can drive chemical reactions

Learning Objectives *Students will be able to …*	**Essential Knowledge** *Students need to know that …*
4.1.A.1 Predict the products of a precipitation reaction.	**4.1.A** Precipitation reactions may occur when two aqueous solutions are mixed, because some ionic compounds are insoluble in water and therefore precipitate out of solution.
4.1.B.1 Create and/or evaluate models of precipitation reactions.	**4.1.B** Precipitation reactions can be modeled by molecular equations, net ionic equations, and particulate representations.
4.1.C.1 Create and/or evaluate models that represent the concentration of a solution. **4.1.C.2** Perform calculations relating to the molarity of solutions.	**4.1.C** Molarity is one way to quantify the concentration of a solution. It describes the number of dissolved particles in a unit volume of that solution.
4.1.D.1 Predict the amount of solid produced in a precipitation reaction using gravimetric analysis based on the concentrations of the starting solutions. **4.1.D.2** Evaluate the results of a gravimetric analysis.	**4.1.D** Gravimetric analysis is a quantitative method for determining the amount of a substance by selectively precipitating the substance from an aqueous solution.

Content Boundary: The focus of predicting products of precipitation reactions is not to have students memorize solubility rules or use a table of solubilities. Instead, students should focus on understanding that all sodium, potassium, ammonium, and nitrate salts are soluble in water.

Cross Connection: Students continue to use principles of stoichiometry learned in Unit 3, now applied to precipitation reactions.

KEY CONCEPT 4.2: OXIDATION–REDUCTION CHEMISTRY

Analyzing how electron transfer can drive chemical reactions

Learning Objectives *Students will be able to …*	**Essential Knowledge** *Students need to know that …*
4.2.A.1 Identify a reaction as an oxidation–reduction reaction based on the change in oxidation numbers of reacting substances. **4.2.A.2** Create and/or evaluate a claim about which reacting species is oxidized or reduced in an oxidation–reduction reaction.	**4.2.A** Electrons are transferred between reactants in oxidation–reduction (redox) reactions. **a.** Substances lose electrons in the process of oxidation and gain electrons in the process of reduction. **b.** Oxidation numbers are useful for determining if electrons are transferred in a chemical reaction. **c.** Electrons are conserved in redox reactions.
4.2.B.1 Predict whether a redox reaction will occur between two reactants using an activity series. **4.2.B.2** Create and/or evaluate an activity series from experimental measurements.	**4.2.B** An activity series lists elements in order of decreasing ease of oxidation and can be used to determine whether a redox reaction will occur between two species.
4.2.C.1 Create and/or evaluate models of redox reactions.	**4.2.C** Redox reactions can be modeled by molecular equations, net ionic equations, and particulate representations.

Content Boundary: Oxidation–reduction is a broad classification of reactions, including synthesis, decomposition, and combustion reactions. However, predicting products for oxidation–reduction reactions is limited to single-replacement reactions.

Cross Connection: Students continue to use principles of stoichiometry learned in Unit 3, now applied to oxidation–reduction reactions.

KEY CONCEPT 4.3: ACID–BASE CHEMISTRY

Examining properties of acids and bases and how proton transfer can drive chemical reactions

Learning Objectives *Students will be able to ...*	**Essential Knowledge** *Students need to know that ...*
4.3.A.1 Create and/or evaluate models of strong and weak acids and bases. **4.3.A.2** Distinguish between strong and weak acids in terms of degree of dissociation in aqueous solution. **4.3.A.3** Evaluate a claim about whether a compound is a strong or weak acid or base.	**4.3.A** Acids and bases are described as either strong or weak based on the degree to which they dissociate in aqueous solution.
4.3.B.1 Explain the relationship between the hydrogen ion concentration and the pH of a solution. **4.3.B.2** Calculate the pH of a solution.	**4.3.B** The pH of a solution is a measure of the molarity of H_3O^+ (or H^+) in the solution.
4.3.C.1 Predict the products of a reaction between a strong acid and a strong base.	**4.3.C** Acid–base reactions involve the transfer of a hydrogen ion from the acid to the base. Strong acid–base reactions produce water and an aqueous ionic compound.
4.3.D.1 Create and/or evaluate models of a reaction between a strong acid and a strong base.	**4.3.D** Acid–base reactions can be modeled by molecular equations, net ionic equations, and particulate representations.

Content Boundary: The study of acids and bases is limited to the Arrhenius and Brønsted-Lowry definitions. According to these definitions, strong acids include HCl, HBr, HI, H_2SO_4, $HClO_4$, and HNO_3, and strong bases include group 1 and group 2 metal hydroxides (e.g., NaOH and KOH).

Cross Connection: Students continue to use principles of stoichiometry learned in Unit 3, now applied to acid–base reactions.

KEY CONCEPT 4.4: THERMOCHEMISTRY

Extending the study of energy by analyzing energy transformations that occur during chemical reactions

Learning Objectives *Students will be able to …*	**Essential Knowledge** *Students need to know that …*
4.4.A.1 Create and/or evaluate a claim about whether a reaction is endothermic or exothermic from experimental observations. **4.4.A.2** Explain the relationship between the measured change in temperature of a solution and the energy transferred by a chemical reaction. **4.4.A.3** Calculate energy changes in chemical reactions from calorimetry data.	**4.4.A** A temperature change during a reaction is the result of energy transfer during the process of breaking and forming bonds. **a.** Bond breaking is always an endothermic process and bond formation is always an exothermic process. **b.** Calorimetry can be used to quantify energy changes in a reaction.
4.4.B.1 Create and/or evaluate a claim about the energy transferred as a result of a chemical reaction based on bond energies.	**4.4.B** The relative strength of bonds in reactants and products determines the energy change in a reaction. Bond energy tables and Lewis diagrams provide a way to estimate these changes quantitatively for a wide variety of chemical reactions.

Content Boundary: The focus of the study of bond energy should be on the fundamental understanding that bond breaking requires energy and bond formation releases energy rather than on algorithmic calculations.

Cross Connection: Students apply their knowledge of molecular structure from Unit 2 in the study of bond energy.

KEY CONCEPT 4.5: REACTION RATES

Investigating the factors that influence reaction rates

Learning Objectives *Students will be able to …*	**Essential Knowledge** *Students need to know that …*
4.5.A.1 Construct and/or evaluate particulate representations that illustrate how changes in concentration, temperature, or surface area of reactants alter the rate of a chemical reaction. **4.5.A.2** Explain how experimental changes in the rate of a reaction are related to changes in the concentration, temperature, or surface area of the reactants.	**4.5.A** The rate of a chemical reaction can be measured by determining how quickly reactants are transformed into products. **a.** The reaction rate is related to the frequency of collisions between reactant species and the proportion of effective collisions. **b.** The frequency of collisions increases with the concentration of gases or dissolved species and with the surface area of a solid. **c.** The proportion of effective collisions increases directly as temperature increases.

Content Boundary: The study of rate laws and mechanisms is beyond the scope of the course. If students go on to take AP Chemistry, they will study kinetics in much more depth.

Cross Connection: The study of reaction rates relies on an understanding of the particle nature of matter that has been developed in Units 1 through 3.

Pre-AP Chemistry Model Lessons

Model lessons in Pre-AP Chemistry are developed in collaboration with chemistry educators across the country and are rooted in the course framework, shared principles, and areas of focus. Model lessons are carefully designed to illustrate on-grade-level instruction. Pre-AP strongly encourages teachers to internalize the lessons and then offer the supports, extensions, and adaptations necessary to help all students achieve the lesson goals.

The purpose of these model lessons is twofold:

- **Robust instructional support for teachers:** Pre-AP Chemistry model lessons are comprehensive lesson plans that, along with accompanying student resources, embody the Pre-AP approach to teaching and learning. Model lessons provide clear and substantial instructional guidance to support teachers as they engage students in the shared principles and areas of focus.
- **Key instructional strategies:** Commentary and analysis embedded in each lesson highlights not just what students and teachers do in the lesson, but also how and why they do it. This educative approach provides a way for teachers to gain unique insight into key instructional moves that are powerfully aligned with the Pre-AP approach to teaching and learning. In this way, each model lesson works to support teachers in the moment of use with students in their classroom.

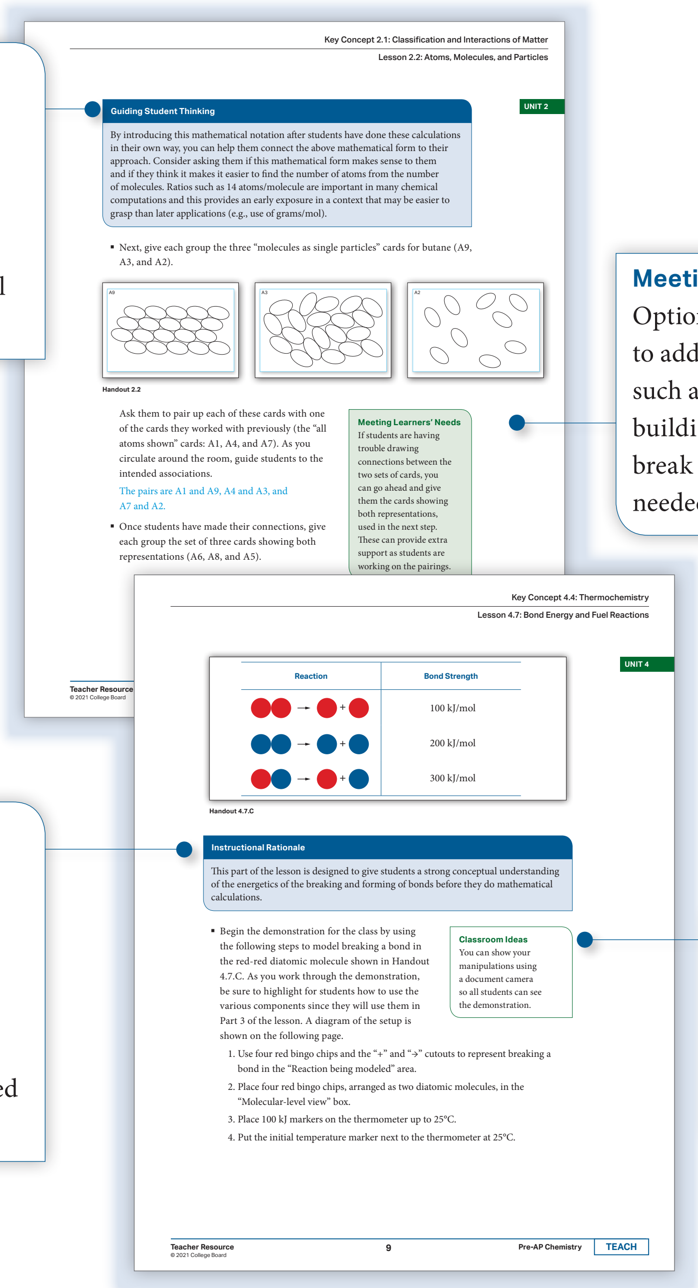
Teachers have the option to use any or all model lessons alongside their own locally developed instructional resources. Model lessons target content areas that tend to be challenging for teachers and students. While the lessons are distributed throughout all four units, they are concentrated more heavily in the beginning of the course to support teachers and students in establishing a strong foundation in the Pre-AP approach to teaching and learning.

SUPPORT FEATURES IN MODEL LESSONS

The following support features recur throughout the Pre-AP Chemistry lessons, to promote teacher understanding of the lesson design and provide direct-to-teacher strategies for adapting lessons to meet their students' needs:

- Instructional Rationale
- Guiding Student Thinking
- Meeting Learners' Needs
- Classroom Ideas

Guiding Student Thinking:
Ways to facilitate productive student thinking and prevent or address student misconceptions in critical areas of the lesson.



Key Concept 2.1: Classification and Interactions of Matter

Lesson 2.2: Atoms, Molecules, and Particles

UNIT 2

Guiding Student Thinking

By introducing this mathematical notation after students have done these calculations in their own way, you can help them connect the above mathematical form to their approach. Consider asking them if this mathematical form makes sense to them and if they think it makes it easier to find the number of atoms from the number of molecules. Ratios such as 14 atoms/molecule are important in many chemical computations and this provides an early exposure in a context that may be easier to grasp than later applications (e.g., use of grams/mol).

- Next, give each group the three "molecules as single particles" cards for butane (A9, A3, and A2).

Handout 2.2

Ask them to pair up each of these cards with one of the cards they worked with previously (the "all atoms shown" cards: A1, A4, and A7). As you circulate around the room, guide students to the intended associations.

The pairs are A1 and A9, A4 and A3, and A7 and A2.

- Once students have made their connections, give each group the set of three cards showing both representations (A6, A8, and A5).

Meeting Learners' Needs

If students are having trouble drawing connections between the two sets of cards, you can go ahead and give them the cards showing both representations, used in the next step. These can provide extra support as students are working on the pairings.

Teacher Resource

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Key Concept 4.4: Thermochemistry

Lesson 4.7: Bond Energy and Fuel Reactions

UNIT 4

Reaction	Bond Strength
	100 kJ/mol
	200 kJ/mol
	300 kJ/mol

Handout 4.7.C

Instructional Rationale

This part of the lesson is designed to give students a strong conceptual understanding of the energetics of the breaking and forming of bonds before they do mathematical calculations.

- Begin the demonstration for the class by using the following steps to model breaking a bond in the red-red diatomic molecule shown in Handout 4.7.C. As you work through the demonstration, be sure to highlight for students how to use the various components since they will use them in Part 3 of the lesson. A diagram of the setup is shown on the following page.

1. Use four red bingo chips and the "+" and "→" cutouts to represent breaking a bond in the "Reaction being modeled" area.
2. Place four red bingo chips, arranged as two diatomic molecules, in the "Molecular-level view" box.
3. Place 100 kJ markers on the thermometer up to 25°C.
4. Put the initial temperature marker next to the thermometer at 25°C.

Classroom Ideas

You can show your manipulations using a document camera so all students can see the demonstration.

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9

Pre-AP Chemistry

TEACH

Meeting Learners' Needs:
Optional differentiation strategies to address diverse learning needs, such as ideas for just-in-time skill building during a lesson or ways to break a task into smaller tasks, if needed, to make it more accessible.

Instructional Rationale:
Insight into the strategic design and purpose of the instructional choices, flow, and scaffolding within the model lesson. Rationales often describe how a concept is continued later in the lesson or unit.

Classroom Ideas:
Tips related to the logistics of the instruction, such as suggestions for alternative laboratory materials, or ways to alleviate pacing concerns.

Pre-AP Chemistry Assessments for Learning

Pre-AP Chemistry assessments function as a component of the teaching and learning cycle. Progress is not measured by performance on any single assessment. Rather, Pre-AP Chemistry offers a place to practice, to grow, and to recognize that learning takes time. The assessments are updated and refreshed periodically.

LEARNING CHECKPOINTS

Based on the Pre-AP Chemistry Course Framework, the learning checkpoints require students to examine data, models, diagrams, and short texts—set in authentic contexts—and to use quantitative reasoning in order to respond to a targeted set of questions that measure students' application of the key concepts and skills from the unit. All eight learning checkpoints are automatically scored, with results provided through feedback reports that contain explanations of all questions and answers as well as individual and class views for educators. Teachers also have access to assessment summaries on Pre-AP Classroom, which provide more insight into the question sets and targeted learning objectives for each assessment event.

The following tables provide a synopsis of key elements of the Pre-AP Chemistry learning checkpoints.

Format	Two learning checkpoints per unit Digitally administered with automated scoring and reporting Questions target both concepts and skills from the course framework
Time Allocated	Designed for one 45-minute class period per assessment
Number of Questions	11–14 questions per assessment ▪ 9–12 four-option multiple choice ▪ 2–5 technology-enhanced questions

Domains Assessed	
Learning Objectives	Learning objectives within each key concept in the course framework
Skills	Three skill categories aligned to the Pre-AP science areas of focus are assessed regularly across all eight learning checkpoints: ▪ emphasis on analytical reading and writing ▪ strategic use of mathematics ▪ attention to modeling

Question Styles	Question sets consist of two to three questions that focus on a single stimulus or group of related stimuli, such as texts, graphs, or tables. Questions are set in authentic chemistry contexts. *Please see page 64 for a sample question set that illustrates the types of questions included in Pre-AP learning checkpoints and the Pre-AP final exam.*

PERFORMANCE TASKS

Each unit includes one performance-based assessment designed to evaluate the depth of student understanding of key concepts and skills that are not easily assessed in a multiple-choice format.

Some performance tasks mirror the AP free-response question style. Others engage students in hands-on data collection and analysis in the laboratory. Students demonstrate their understanding of content by analyzing scientific texts, data, and models in order to develop analytical written responses to open-ended questions. Students also use mathematics to support their chemical reasoning.

The performance tasks give students an opportunity to closely observe and analyze real-world chemistry scenarios and apply the skills and concepts from across the course units.

These tasks, developed for high school students across a broad range of readiness levels, are accessible while still providing sufficient challenge and the opportunity to practice the analytical skills that will be required in AP science courses and for college and career readiness. Teachers participating in the official Pre-AP Program will receive access to online learning modules to support them in evaluating student work for each performance task.

Format	One performance task per unit Administered in print Educator scored using scoring guidelines
Time Allocated	Approximately 45 minutes or as indicated
Number of Questions	An open-response task with multiple parts

Domains Assessed	
Key Concepts	Key concepts and prioritized learning objectives from the course framework
Skills	Three skill categories aligned to the Pre-AP science areas of focus: ▪ emphasis on analytical reading and writing ▪ strategic use of mathematics ▪ attention to modeling

PRACTICE PERFORMANCE TASKS

A practice performance task in each unit provides students with the opportunity to practice applying skills and knowledge in a context similar to a performance task, but in a more scaffolded environment. These tasks include strategies for adapting instruction based on student performance and ideas for modifying or extending tasks based on students' needs.

SAMPLE PERFORMANCE TASK AND SCORING GUIDELINES

The following task and set of scoring guidelines are representative of what students and educators will encounter on the performance tasks. (The example below is a practice performance task from Unit 2.)

PRACTICE PERFORMANCE TASK

Properties of Limonene

OVERVIEW

DESCRIPTION

In this practice performance task, students reason about intermolecular forces from data and a video demonstration and predict relative strengths of London dispersion forces based on molecular structure. They then read about the extraction of limonene and calculate yield. Finally, students construct particulate models to model solutions and mixtures and reason about partial pressure.

CONTENT FOCUS

This task is designed to assess students' understanding of molecules, solutions, and mixtures and to allow them to practice their reasoning about intermolecular forces and partial pressure from data. This task is intended to be used after students have completed their study of Key Concept 2.2: Molecular Structure and Properties.

AREAS OF FOCUS

- Attention to Modeling
- Strategic Use of Mathematics
- Emphasis on Analytical Reading and Writing

SUGGESTED TIMING

~45 minutes

HANDOUT

- Unit 2 Practice Performance Task: Properties of Limonene

MATERIALS

- calculator
- equation sheet
- periodic table

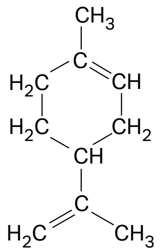
For Part 1, question 2:

- LCD projector, electronic whiteboard, or other technology for showing an online video
- internet access to the video demonstration "Pop a Balloon with an Orange Peel!" (0:29) from the Chemical Education Xchange at **https://www.chemedx.org/blog/how-does-orange-peel-pop-balloon-chemistry-course** (first video on the page)

Properties of Limonene

1. Limonene is a nonpolar substance found in citrus fruits such as oranges and lemons. The structure of limonene is shown at right.

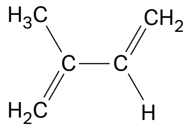
   Circle the term or terms below that apply to a sample of limonene. (There may be more than one.) Justify your answer.



Limonene

atom **compound** **element** **molecule** **mixture**

2. Limonene has many interesting properties, one of which involves its interaction with isoprene. Isoprene is the main component of the rubber found in many kinds of balloons. The structure of isoprene is shown at right.



Isoprene

   You will watch a video demonstration that shows limonene interacting with isoprene. Watch the demonstration and then read and answer the following questions.

   (a) After watching the demonstration, Angel, Kayla, and Jacob make the following statements about what they observed:

   - Angel says, "I think limonene molecules repelled the isoprene molecules since one kind of molecule is polar and the other is nonpolar. This repulsion caused the balloon to pop."
   - Kayla says, "I think the limonene particles hit the balloon with enough force to pop it since the limonene particles are larger than the isoprene particles."
   - Jacob says, "I think the limonene particles dissolved the isoprene molecules since they are both nonpolar particles and 'like dissolves like.'"

Which student do you agree with and why? As part of your explanation, comment on why the rationales of the other students are not valid.

(b) Based on your observations and your answer above, what type(s) of intermolecular forces exist between molecules of isoprene? Justify your answer.

(c) Which substance, limonene or isoprene, would you predict has a higher boiling point? Justify your answer in terms of the intermolecular forces in each substance.

3. There are many ways to obtain limonene, which are discussed in the passage below. Read the passage and answer the questions that follow.

This passage is excerpted and adapted from A. J. Andrews, "How to Extract Oil from the Skin of Oranges." ©2018 by SFGate.

MY NOTES

HOW TO EXTRACT OIL FROM THE SKIN OF ORANGES

1 Orange peels are a source of the limonene, or orange oil, you find in many products, including cosmetics, foods, and cleaning products. Limonene is found in large concentrations close to the surface of the peel. It can be released by rubbing or heating.

2 Commercial oil producers have various methods for extracting (or removing) the limonene from oranges so it can be used in manufacturing. You can replicate a couple of methods in your kitchen using everyday tools. Most commercial producers extract limonene from orange peels left over from juicing oranges, using a method known as cold extraction. Some producers use techniques such as distillation or solvent extraction, and may work with other parts of the plant in addition to just the peels. Distillation yields about 150 milligrams of oil per 15 grams of peel.

At-Home Cold Extraction

3 Cold pressing is one of the oldest methods of oil extraction and one you can do at home with a garlic press. You won't get as much oil pressing the peels as you would by distillation, but you'll extract enough for food flavoring.

MY NOTES

4 To extract oil using a garlic press, first scrape the white pith from the inside of the orange peel. Cut the peels into 1-inch pieces and heat them in warm water (110 to 120 degrees Fahrenheit, or 43 to 49 degrees Celsius) on the stove; "cold" in this sense means not heating the peels enough to damage the oil. Pack the peels into the press and squeeze the oil into a food container.

At-Home Solvent Extraction

5 Using ethanol to separate limonene from the orange peels doesn't require as much force as pressing but it takes more time. Cut the peels into 1/4- to 1/2-inch pieces and place them in a clean glass jar. Add enough ethanol to barely cover the peels and store the container in a room-temperature cupboard for about two weeks. Shake the container at least once a day. When it is ready, strain the ethanol into a shallow dish. Allow the ethanol to evaporate and scrape the oil into a food container.

(a) As stated in the passage, cold extraction involves first heating orange peels to 110 to 120 degrees Fahrenheit (43 to 49 degrees Celsius). Why is this heating useful in terms of the intermolecular forces of limonene in an orange peel?

(b) A perfume recipe calls for 2.0 g of orange oil, or limonene. Calculate how many oranges you would need to peel to obtain 2.0 g of limonene using distillation, according to the article. Assume that the peel from a large orange has a mass of 85 g.

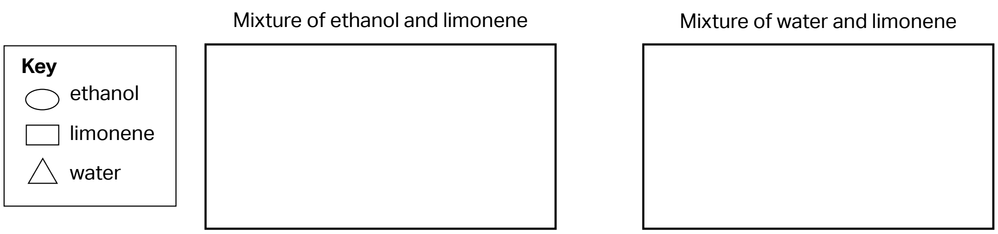
(c) Limonene is soluble in ethanol but insoluble in water. The table below shows the densities of liquid ethanol, limonene, and water.

Substance	Density of Liquid (g/mL)
Ethanol	0.79
Limonene	0.84
Water	1.00

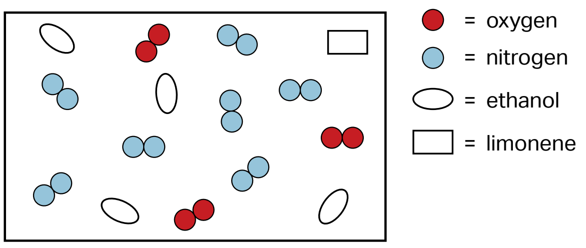
In the boxes below, draw particulate representations of the following two mixtures:

- A mixture of ethanol and limonene
- A mixture of water and limonene

Use the key provided to represent particles of different substances. Draw at least 5 particles of each substance in each diagram.



(d) As stated in the passage, ethanol has to evaporate for the orange oil to be isolated. A chemist takes a sample of the air directly above the evaporating ethanol. A particulate representation of the sample is shown below.



The partial pressure of the nitrogen gas in the sample is 0.70 atm.

(i) Calculate the total pressure of the gas sample.

(ii) Calculate the partial pressure of the ethanol in the sample.

SCORING GUIDELINES

There are 25 possible points for this performance task.

Question 1

Sample Solutions	Points Possible
The words *compound* and *molecule* should be circled. Compounds are formed when two or more different elements are bonded together. Since limonene is a covalent compound, the fundamental unit is the molecule.	**3 points maximum** 1 point for circling *compound* 1 point for circling *molecule* 1 point for correct justification
Targeted Feedback for Student Responses	
Refer students back to the card sort activity in which particles were classified at various levels.	

TEACHER NOTES AND REFLECTIONS

Question 2, part (a)

Sample Solutions	Points Possible
I agree with Jacob. Disrupting the intermolecular forces between particles of isoprene in the balloon causes a tiny hole to form that allows the gases inside to escape. Angel is incorrect because the structures of limonene and isoprene are similar in terms of the type of bonds (only C and H) that both have. Therefore, one can't be polar and the other nonpolar. Kayla's explanation does not make sense, as balloons are often struck by a variety of particles in motion, including gas particles, without popping. Even raindrops and grains of sand can hit a balloon without popping it. So it's not clear why the limonene particles would apply a stronger force than any of these other things that are of a similar or larger size.	**4 points maximum** 1 point for agreeing with Jacob 1 point for explaining why Jacob's rationale is the most logical in terms of intermolecular forces 1 point for explaining why Angel's rationale is incorrect 1 point for explaining why Kayla's rationale is incorrect
Targeted Feedback for Student Responses	
Remind students to think about what holds solid substances such as rubber together on a molecular level.	

TEACHER NOTES AND REFLECTIONS

Question 2, part (b)

Sample Solutions	Points Possible
The forces between isoprene molecules are London dispersion forces. Since isoprene is nonpolar, it only experiences London dispersion forces.	**2 points maximum** 1 point for identification of London dispersion forces 1 point for correct justification

Targeted Feedback for Student Responses
Ask students to refer back to the lessons on intermolecular forces and ask them to identify the type of intermolecular forces present in isoprene based on its structure.

TEACHER NOTES AND REFLECTIONS

Question 2, part (c)

Sample Solutions	Points Possible
I would predict that limonene has a higher boiling point than isoprene. Since both limonene and isoprene are nonpolar, they both only have London dispersion forces. The strength of London dispersion forces depends on the number of electrons. Limonene has significantly more carbon and hydrogen atoms than isoprene and, consequently, has many more electrons that are involved in London dispersion forces. Thus, the intermolecular forces between limonene molecules are greater, and the energy needed to separate one limonene molecule from another, as measured by boiling point, would be greater.	**3 points maximum** 1 point for selection of limonene 1 point for explaining that stronger London dispersion forces in limonene are due to a greater number of electrons 1 point for discussing the relationship of boiling point to the strength of intermolecular forces

Targeted Feedback for Student Responses
Remind students to consider the factors that would increase the strength of intermolecular forces for various types of molecules. They can refer back to the evaporation lab and examine the trends they saw there.

TEACHER NOTES AND REFLECTIONS

Question 3, part (a)

Sample Solutions	Points Possible
The increase in temperature would cause the molecules to move around more, overcoming intermolecular forces between limonene and other substances in the peel.	**1 point maximum** 1 point for a discussion of the agitation of the molecules disrupting the intermolecular forces between limonene and other substances in the peel
Targeted Feedback for Student Responses	
Ask students to recall what temperature actually measures and to consider where the added energy goes when heating a substance.	

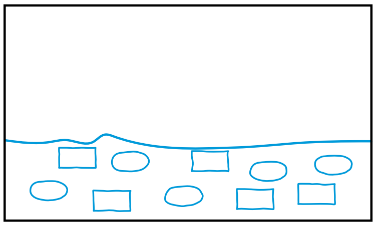
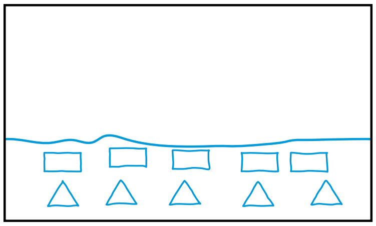
TEACHER NOTES AND REFLECTIONS

Question 3, part (b)

<table>
<tr><th>Sample Solutions</th><th>Points Possible</th></tr>
<tr><td>$$2.0 \text{ g limonene} \times \frac{1{,}000 \text{ mg limonene}}{1 \text{ g limonene}} \times \frac{15 \text{ g peel}}{150 \text{ mg limonene}} \times \frac{1 \text{ orange}}{85 \text{ g peel}} = 2.4 \text{ oranges}$$
The recipe requires about 2.4 (or 3) oranges.</td><td>3 points maximum
1 point for identifying the ratio of the mass of peel to the mass of limonene from the text
1 point for calculating the mass of orange peel needed to extract 2.0 g of limonene (could be implicit in the calculation)
1 point for calculating the number of oranges this would require
Scoring note: Students may give the number of oranges as an integer, but doing so is not required for credit.</td></tr>
<tr><th colspan="2">Targeted Feedback for Student Responses</th></tr>
<tr><td colspan="2">Students do not need to set up a dimensional analysis calculation, but they should use proportional reasoning to arrive at a solution.</td></tr>
</table>

TEACHER NOTES AND REFLECTIONS

Question 3, part (c)

Sample Solutions	Points Possible
 	**5 points maximum** *Mixture of ethanol and limonene* 1 point for showing a particulate representation of at least 5 ethanol and 5 limonene molecules in a liquid state 1 point for a particulate-level representation of the substances completely dissolved in one another (no layering of individual molecules) *Mixture of water and limonene* 1 point for showing a particulate representation of at least 5 water molecules and 5 limonene molecules in a liquid state 1 point for showing a particulate representation of the lack of mixing of the two different types of molecules 1 point for representing the water molecules as the bottom layer and limonene molecules as the top layer *Scoring note*: Students do not need to draw the liquid line.
Targeted Feedback for Student Responses	
Help students think about how the density of the pure substances would manifest in a mixture.	

TEACHER NOTES AND REFLECTIONS

Question 3, part (d)

Sample Solutions	Points Possible
(i) There are a total of 15 gas particles in the sample, 7 of which are nitrogen. Therefore, $\frac{7}{15}$ of the total pressure of the sample is due to the partial pressure of nitrogen. $P_{N_2} = X_{N_2} \times P_{total}$ $P_{total} = \frac{P_{N_2}}{X_{N_2}}$ $P_{total} = \frac{0.70 \text{ atm}}{\left(\frac{7}{15}\right)}$ $P_{total} = 1.5 \text{ atm}$ (ii) Since ethanol particles make up $\frac{4}{15}$ of the total number of gas particles in the sample, they make up $\frac{4}{15}$ of the total pressure. $P_{ethanol} = X_{ethanol} \times P_{total}$ $P_{ethanol} = \left(\frac{4}{15}\right) \times 1.5 \text{ atm}$ $P_{ethanol} = 0.4 \text{ atm}$	**4 points maximum** *(i)* 1 point for the relationship of the number of nitrogen molecules to the total number of molecules in the sample 1 point for correctly setting up and solving the proportion for finding the total pressure (students do not have to explicitly use Dalton's law) *(ii)* 1 point for the relationship of ethanol molecules to nitrogen molecules or ethanol molecules to total number of molecules in the sample 1 point for correctly setting up and solving the proportion for finding the pressure of ethanol (students do not have to explicitly use Dalton's law) *Scoring note*: If a student calculates the total pressure incorrectly in part (i) but uses that pressure correctly in part (ii), they can earn full credit for part (ii).

Targeted Feedback for Student Responses
Encourage students to show all their work and double-check that their answer makes sense. If their answer doesn't make sense, they could have made an algebra mistake.

TEACHER NOTES AND REFLECTIONS

FINAL EXAM

Pre-AP Chemistry includes a final exam featuring multiple-choice and technology-enhanced questions as well as an open-response question. The final exam is a summative assessment designed to measure students' success in learning and applying the knowledge and skills articulated in the Pre-AP Chemistry Course Framework. The final exam's development follows best practices such as multiple levels of review by educators and experts in the field for content accuracy, fairness, and sensitivity. The questions on the final exam have been pretested, and the resulting data are collected and analyzed to ensure that the final exam is fair and represents an appropriate range of the knowledge and skills of the course.

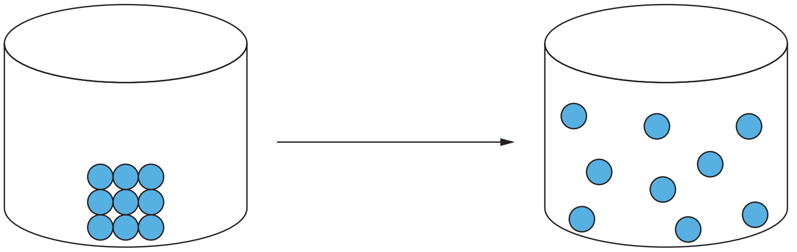
The final exam is designed to be delivered on a secure digital platform in a classroom setting. Educators have the option of administering the final exam in a single extended session or two shorter consecutive sessions to accommodate a range of final exam schedules.

Multiple-choice and technology-enhanced questions are delivered digitally and scored automatically with detailed score reports available to educators. This portion of the final exam is designed to build on the question styles and formats of the learning checkpoints; thus, in addition to their formative purpose, the learning checkpoints provide practice and familiarity with the final exam. The open-response question, modeled after the performance tasks, is delivered as part of the digital final exam but is designed to be scored separately by educators using scoring guidelines that are designed and vetted with the question.

SAMPLE ASSESSMENT QUESTIONS

The following questions are representative of what students and educators will encounter on the learning checkpoints and final exam.

1.



A student places 2.0 g of an unknown substance in a sealed container with no other contents. The student observes the container for 10 minutes and then draws the two particle diagrams shown to represent his observations of the initial and final states.

Which of the following descriptions of the observed change is most consistent with the model?

(A) The unknown substance underwent a phase change from solid to liquid and the mass at the end of the experiment was 2.0 g.

(B) The unknown substance underwent a phase change from solid to liquid and the mass at the end of the experiment was 1.5 g.

(C) The unknown substance underwent a phase change from solid to gas and the mass at the end of the experiment was 2.0 g.

(D) The unknown substance underwent a phase change from solid to gas and the mass at the end of the experiment was 1.5 g.

Assessment Focus

Question 1 requires students to interpret a model of a phase change from solid to gas and to reason based on their understanding of the conservation of mass.

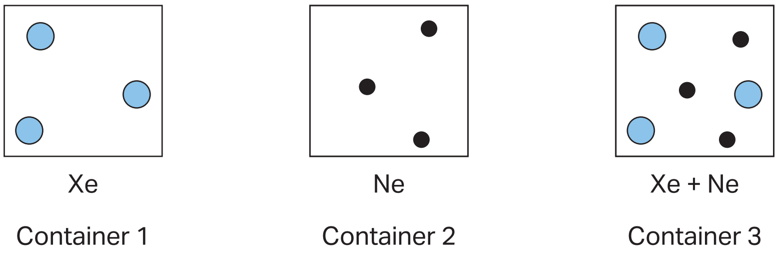
Correct Answer: C

Learning Objective:

1.1.A.2 Describe how the properties of solids, liquids, and gases are related to particle arrangement.

Area of Focus: Attention to Modeling

2.



The figure represents three containers of equal volume at the same temperature, each containing a different gas or mixture of gases.

Which TWO statements best describe the pressure in the containers?

(A) The pressure in Container 1 is greater than the pressure in Container 2 because the Xe atoms are larger than Ne atoms.

(B) The pressure in Container 1 is equal to the pressure in Container 2 because they have the same number of atoms.

(C) The pressure in Container 3 is twice the pressure in Container 2 because Container 3 has twice the number of atoms.

(D) The pressure in all three containers is the same because the containers are at the same temperature.

(E) The pressure in all three containers is the same because the containers have the same volume.

Assessment Focus

In question 2, students use a model to describe the relationship between the quantity of a gas, or mixture of gases, and the resulting pressure. The question assesses students' understanding of partial pressure and the effect of temperature and volume on gas pressure. This question also demonstrates the multiple-select question type that students will encounter in learning checkpoints and the final exam.

Correct Answers: B and C

Learning Objective:

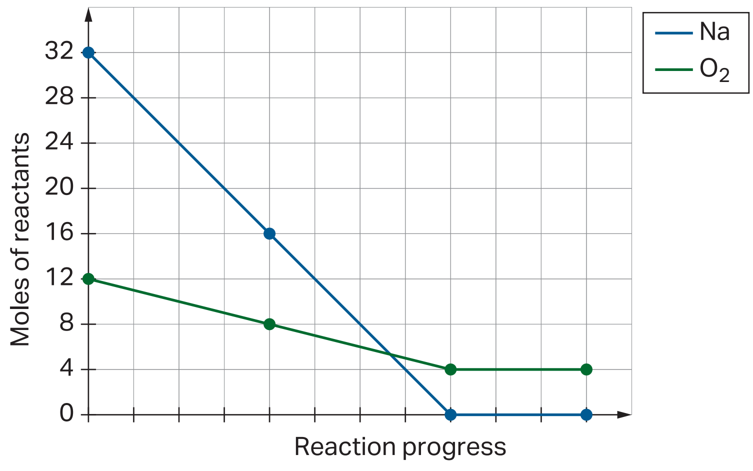
2.1.C.1 Relate the total and partial pressure of a gas mixture to the number of particles and their proportions.

Area of Focus: Attention to Modeling

3.

$$4Na(s) + O_2(g) \rightarrow 2Na_2O(s)$$

Sodium oxide is produced by the reaction of sodium metal with oxygen gas. The reaction is represented by the chemical equation above. A chemical reaction is set up with 32 moles of Na and 12 moles of O_2 in a reaction vessel. As the reaction proceeds to completion, the number of moles of Na and O_2 are monitored and plotted on a graph as shown in the figure.



Which of the following best explains the steeper slope of the line that represents moles of Na compared to the line that represents moles of O_2?

(A) The initial mass of Na is greater than the initial mass of O_2.

(B) For every mole of O_2 consumed in the reaction, 4 moles are Na are needed.

(C) The mass of 4 Na atoms is greater than the mass of 1 O_2 molecule.

(D) The initial number of moles of Na is greater than the initial number of moles of O_2.

Assessment Focus

In question 3, students analyze data about the rate at which reactants in a chemical reaction are used and explain the difference based on the stoichiometry of the balanced chemical equation. All four multiple-choice options are correct statements, but only option B provides an explanation for the difference in slope.

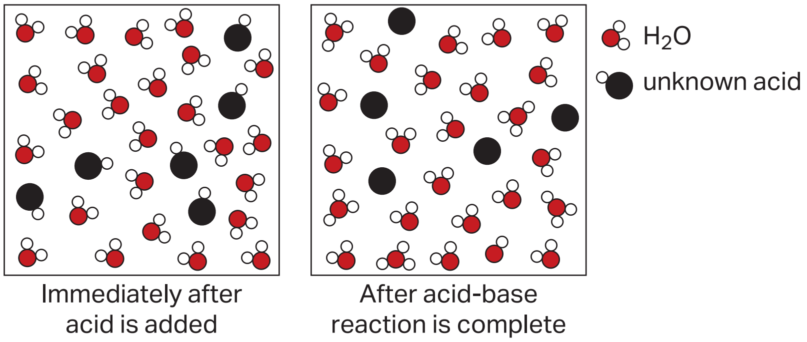
Correct Answer: B

Learning Objective:

3.2.B.1 Explain the relationship between the quantity of reactants consumed and the quantity of products formed in a chemical transformation.

Area of Focus: Strategic Use of Mathematics

4.



The figure shows particle diagrams representing a 13*M* solution of an unknown acid after the acid was added to water.

Based on the particle diagrams, which of the following claims about the unknown acid is most likely correct?

(A) The acid is strong because there are 13 moles of acid in every liter of water.

(B) The acid is strong because all the acid molecules dissociate in solution.

(C) The acid is weak because it produces only one hydronium ion per acid molecule in solution.

(D) The acid is weak because there are fewer acid molecules than water molecules in the solution.

Assessment Focus

In question 4, students evaluate a model of a dissociated acid and use the model to support a claim about the strength of the acid. The question is designed to address the common challenge students have in distinguishing between strong acids and concentrated acids.

Correct Answer: B

Learning Objectives:

4.3.A.1 Create and/or evaluate models of strong and weak acids and bases.

4.3.A.2 Distinguish between strong and weak acids in terms of degree of dissociation in aqueous solution.

Area of Focus: Attention to Modeling

Pre-AP Chemistry Course Designation

Schools can earn an official Pre-AP Chemistry course designation by meeting the program commitments summarized below. Pre-AP Course Audit Administrators and teachers will complete a Pre-AP Course Audit process to attest to these commitments. All schools offering courses that have received a Pre-AP Course Designation will be listed in the Pre-AP Course Ledger, in a process similar to that used for listing authorized AP courses.

PROGRAM COMMITMENTS

- Teachers have read the most recent *Pre-AP Chemistry Course Guide*.
- The school ensures that Pre-AP frameworks and assessments serve as the foundation for all sections of the course at the school. This means that the school must not establish any barriers (e.g., test scores, grades in prior coursework, teacher or counselor recommendation) to student access and participation in the Pre-AP Chemistry coursework.
- Teachers administer at least one of two learning checkpoints per unit on Pre-AP Classroom and one performance task per unit.
- Teachers complete the foundational professional learning (Online Foundational Modules or Pre-AP Summer Institute) and at least one online performance task scoring module. The current Pre-AP coordinator completes the Pre-AP Coordinator Online Module.
- Teachers align instruction to the Pre-AP Chemistry Course Framework and ensure their course meets the curricular commitments summarized below.
- The school ensures that the resource commitments summarized below are met.

CURRICULAR COMMITMENTS

- The course provides opportunities for students to develop understanding of the Pre-AP Chemistry key concepts and skills articulated in the course framework through the four units of study.
- The course provides opportunities for students to engage in the Pre-AP shared instructional principles.
    - close observation and analysis
    - evidence-based writing
    - higher-order questioning
    - academic conversation

- The course provides opportunities for students to engage in the three Pre-AP science areas of focus. The areas of focus are:
  - emphasis on analytical reading and writing
  - strategic use of mathematics
  - attention to modeling
- The instructional plan for the course includes opportunities for students to continue to practice and develop disciplinary skills.
- The instructional plan reflects time and instructional methods for engaging students in reflection and feedback based on their progress.
- The instructional plan reflects making responsive adjustments to instruction based on student performance.

RESOURCE REQUIREMENTS

- The school ensures that participating teachers and students are provided computer and internet access.
- Teachers should have consistent access to a video projector for sharing web-based instructional content and short web videos.
- The school ensures teachers have access to laboratory equipment and consumable resources so that students can engage in the Pre-AP Chemistry inquiry-based model lessons.

Accessing the Digital Materials

Pre-AP Classroom is the online application through which teachers and students can access Pre-AP instructional resources and assessments. The digital platform is similar to AP Classroom, the online system used for AP courses.

Pre-AP coordinators receive access to Pre-AP Classroom via an access code delivered after orders are processed. Teachers receive access after the Pre-AP Course Audit process has been completed.

Once teachers have created course sections, student can enroll in them via access code. When both teachers and students have access, teachers can share instructional resources with students, assign and score assessments, and complete online learning modules; students can view resources shared by the teacher, take assessments, and receive feedback reports to understand progress and growth.

Appendix

Pre-AP Chemistry Equations, Constants, and Tables of Information

Units	
Symbol	**Name**
L	liter(s)
g	gram(s)
atm	atmosphere(s)
Pa	pascal(s)
mm Hg	millimeters of mercury
J	joule(s)
mol	mole(s)
K	kelvin
M	molarity
cal	calorie(s)

Polyatomic Ions	
Name	**Formula**
acetate	CH_3COO^- or $C_2H_3O_2^-$
ammonium	NH_4^+
bicarbonate or hydrogen carbonate	HCO_3^-
carbonate	CO_3^{2-}
chromate	CrO_4^{2-}
cyanide	CN^-
dichromate	$Cr_2O_7^{2-}$
hydroxide	OH^-
nitrate	NO_3^-
nitrite	NO_2^-
phosphate	PO_4^{3-}
sulfate	SO_4^{2-}
sulfite	SO_3^{2-}

Constants	
Constant	**Value**
Avogadro's number	6.02×10^{23} particles per mole
Gas constant, *R*	$0.0821 \dfrac{\text{L} \bullet \text{atm}}{\text{mol} \bullet \text{K}}$
Specific heat capacity of $H_2O(l)$	$4.18 \dfrac{\text{J}}{\text{g} \bullet \text{K}}$
Standard temperature and pressure	273 K and 1 atm

Metric Prefixes		
Factor	**Prefix**	**Symbol**
10^3	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	µ
10^{-9}	nano	n

Conversions
1 atm = 760 mm Hg = 760 torr = 101 kPa
1 cal = 4.18 joules
0°C = 273 K

Activity Series

	Metals
most easily oxidized	Li
↓	K
	Ba
	Ca
	Na
	Mg
	Al
	Mn
	Zn
	Cr
	Fe
	Co
	Ni
	Sn
	Pb
	(H_2)
	Cu
	Hg
	Ag
	Pt
least easily oxidized	Au

Solubility Guidelines

All sodium, potassium, ammonium, and nitrate salts are soluble in water.

Equations		
Density	$D = \frac{m}{V}$	D = density m = mass V = volume
Percent error	$\text{percent error} = \left(\frac{\lvert\text{accepted value} - \text{experimental value}\rvert}{\text{accepted value}}\right) \times 100$	
Percent yield	$\text{percent yield} = \left(\frac{\text{actual yield}}{\text{theoretical yield}}\right) \times 100$	
Molarity	$\text{molarity} = \frac{\text{moles of solute}}{\text{liter of solution}}$	
Gas laws	$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$ $P_A = X_A \times P_{total}$ $P_{total} = P_A + P_B + P_C + \ldots$ $PV = nRT$	P = pressure V = volume T = temperature n = moles of gas R = gas constant X = fraction of the gas
Heat	$q = mc\Delta T$	q = heat m = mass c = specific heat capacity ΔT = change in temperature
pH	$\text{pH} = -\log[H_3O^+]$	

PERIODIC TABLE OF THE ELEMENTS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** Hydrogen 1.008																	2 **He** Helium 4.00
3 **Li** Lithium 6.94	4 **Be** Beryllium 9.01											5 **B** Boron 10.81	6 **C** Carbon 12.01	7 **N** Nitrogen 14.01	8 **O** Oxygen 16.00	9 **F** Fluorine 19.00	10 **Ne** Neon 20.18
11 **Na** Sodium 22.99	12 **Mg** Magnesium 24.30											13 **Al** Aluminum 26.98	14 **Si** Silicon 28.09	15 **P** Phosphorus 30.97	16 **S** Sulfur 32.06	17 **Cl** Chlorine 35.45	18 **Ar** Argon 39.95
19 **K** Potassium 39.10	20 **Ca** Calcium 40.08	21 **Sc** Scandium 44.96	22 **Ti** Titanium 47.87	23 **V** Vanadium 50.94	24 **Cr** Chromium 52.00	25 **Mn** Manganese 54.94	26 **Fe** Iron 55.85	27 **Co** Cobalt 58.93	28 **Ni** Nickel 58.69	29 **Cu** Copper 63.55	30 **Zn** Zinc 65.38	31 **Ga** Gallium 69.72	32 **Ge** Germanium 72.63	33 **As** Arsenic 74.92	34 **Se** Selenium 78.97	35 **Br** Bromine 79.90	36 **Kr** Krypton 83.80
37 **Rb** Rubidium 85.47	38 **Sr** Strontium 87.62	39 **Y** Yttrium 88.91	40 **Zr** Zirconium 91.22	41 **Nb** Niobium 92.91	42 **Mo** Molybdenum 95.95	43 **Tc** Technetium	44 **Ru** Ruthenium 101.07	45 **Rh** Rhodium 102.91	46 **Pd** Palladium 106.42	47 **Ag** Silver 107.87	48 **Cd** Cadmium 112.41	49 **In** Indium 114.82	50 **Sn** Tin 118.71	51 **Sb** Antimony 121.76	52 **Te** Tellurium 127.60	53 **I** Iodine 126.90	54 **Xe** Xenon 131.29
55 **Cs** Cesium 132.91	56 **Ba** Barium 137.33	57–71 *	72 **Hf** Hafnium 178.49	73 **Ta** Tantalum 180.95	74 **W** Tungsten 183.84	75 **Re** Rhenium 186.21	76 **Os** Osmium 190.23	77 **Ir** Iridium 192.22	78 **Pt** Platinum 195.08	79 **Au** Gold 196.97	80 **Hg** Mercury 200.59	81 **Tl** Thallium 204.38	82 **Pb** Lead 207.2	83 **Bi** Bismuth 208.98	84 **Po** Polonium	85 **At** Astatine	86 **Rn** Radon
87 **Fr** Francium	88 **Ra** Radium	89–103 †	104 **Rf** Rutherfordium	105 **Db** Dubnium	106 **Sg** Seaborgium	107 **Bh** Bohrium	108 **Hs** Hassium	109 **Mt** Meitnerium	110 **Ds** Darmstadtium	111 **Rg** Roentgenium	112 **Cn** Copernicium	113 **Nh** Nihonium	114 **Fl** Flerovium	115 **Mc** Moscovium	116 **Lv** Livermorium	117 **Ts** Tennessine	118 **Og** Oganesson

*Lanthanoids	57 **La** Lanthanum 138.91	58 **Ce** Cerium 140.12	59 **Pr** Praseodymium 140.91	60 **Nd** Neodymium 144.24	61 **Pm** Promethium	62 **Sm** Samarium 150.36	63 **Eu** Europium 151.97	64 **Gd** Gadolinium 157.25	65 **Tb** Terbium 158.93	66 **Dy** Dysprosium 162.50	67 **Ho** Holmium 164.93	68 **Er** Erbium 167.26	69 **Tm** Thulium 168.93	70 **Yb** Ytterbium 173.05	71 **Lu** Lutetium 174.97
†Actinoids	89 **Ac** Actinium	90 **Th** Thorium 232.04	91 **Pa** Protactinium 231.04	92 **U** Uranium 238.03	93 **Np** Neptunium	94 **Pu** Plutonium	95 **Am** Americium	96 **Cm** Curium	97 **Bk** Berkelium	98 **Cf** Californium	99 **Es** Einsteinium	100 **Fm** Fermium	101 **Md** Mendelevium	102 **No** Nobelium	103 **Lr** Lawrencium

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