

Fairfield Public Schools Science Curriculum

Draft Units

Advanced Placement Chemistry



AP Chemistry: Description

Students in Advanced Placement Chemistry continue to develop their understanding of physical science, specifically a more in-depth knowledge of chemistry. The high school performance expectations in Chemistry build on the previously learned ideas and skills and allow high school students to explain more in-depth phenomena. There are six disciplinary core ideas in the Advanced Placement Chemistry Course:

- The chemical elements are fundamental building materials of matter, and all matter can be understood in terms of arrangements of atoms. These atoms retain their identity in chemical reactions
- Chemical and physical properties of materials can be explained by the structure and arrangement of atoms, ions, or molecules and the forces between them
- Changes in matter involve the rearrangement and/or reorganization of atoms and/or the transfer of electrons
- Rates of chemical reactions are determined by details of the molecular collisions
- The laws of thermodynamics describe the essential role of energy and explain and predict the direction of changes in matter
- Any bond or intermolecular attraction that can be formed can be broken. These two processes are in dynamic competition, sensitive to initial conditions and external perturbations

These performance expectations blend the core ideas with scientific and engineering practices and crosscutting concepts to support students in developing useable knowledge to explain ideas across the science disciplines. In the chemistry performance expectations at the high school level, there is a focus on several scientific practices. These include developing and using models, planning and conducting investigations, analyzing and interpreting data, using mathematical and computational thinking, and constructing explanations; students will use these practices to demonstrate understanding of the core ideas. Students are also expected to demonstrate understanding of several engineering practices, including design and evaluation.

Standards for this course are taken from the *Next Generation Science Standards* and are of three types:

Disciplinary Core Ideas (DCIs): Shown as content objectives, these standards define what students should know about the most essential ideas in the major science disciplines. The focus is on a limited number of core ideas in science and engineering both within and across the disciplines to avoid the shallow coverage of a large number of topics and to allow more time for teachers and students to explore each idea in greater depth. Reduction of the sheer sum of details to be mastered is intended to give time for students to engage in scientific investigations and argumentation and to achieve depth of understanding of the core ideas presented.

Science and Engineering Practices (SEP): These standards enable students to apply the content in the DCI's and the skills of practicing scientists and engineers to explain phenomena and solve real world problems. Engaging in the practices of science helps students understand how scientific knowledge develops; such direct involvement gives them an appreciation of the wide range of approaches that are used to investigate, model, and

CROSS CUTTING CONCEPTS

Patterns: Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.

Cause and effect: Mechanism and explanation. Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.

Scale, proportion, and quantity. In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.

Systems and system models. Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.

Energy and matter: Flows, cycles, and conservation. Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.

Structure and function. The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.

Stability and change. For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.

explain the world. Engaging in the practices of engineering likewise helps students understand the work of engineers, as well as the links between engineering and science.

Crosscutting Concepts: These standards provide students with connections and intellectual tools that are related across the differing areas of disciplinary content and can enrich their application of practices and their understanding of core ideas. These broad concepts tie together the influence of engineering, technology, and science on society and the natural world.

<http://www.nextgenscience.org/next-generation-science-standards>

AP Chemistry

Course Essential Questions

- How can all matter be understood in terms of arrangement of atoms, and how do these atoms retain their identity in chemical reactions?
- How can chemical and physical properties of materials be explained by the structure and arrangement of atoms, ions, or molecules and the forces between them?
- How do the rearrangement and/or reorganization of atoms and/or the transfer of electrons cause changes in matter?
- How are rates of chemical reactions determined by details of the molecular collisions?
- How do the laws of thermodynamics describe the essential role of energy and explain and predict the direction of changes in matter?
- How are the processes of bond forming and breaking in dynamic competition that are sensitive to initial conditions and external perturbations?

Course: Year-at-a Glance

Unit	Title	Unit Essential Questions
1	Atomic Structure	<ul style="list-style-type: none"> • How is the position of an element on the Periodic Table related to that element's chemical properties? • How does the arrangement of subatomic particles dictate an element's chemical properties? • How do light and the electromagnetic spectrum relate to electrons and energy? • How is the arrangement of electrons related to chemical properties? • How can macroscopic observations of change, chemical equations, and particle views predict structures of matter? • How does the structure of an atom predict physical and chemical properties?
2	Chemical Bonding	<ul style="list-style-type: none"> • How can the VSEPR theory be used to predict geometry of molecules and predict polarity? • What are the types of attraction that exist between and within particles? • How do the types of attraction influence physical properties of matter?
3	Chemical Reactions	<ul style="list-style-type: none"> • What are qualitative and quantitative observations that can be made during a chemical reaction? • How do molecules interact during a chemical reaction?
4	Kinetics	<ul style="list-style-type: none"> • How is the rate of a reaction influenced by the concentration or pressure of reactants, the phase of reactants and products, and environmental factors? • How are reaction rates affected by catalysts? • How do systems at equilibrium respond to external perturbations? • How can the kinetic molecular theory be used to predict gas behavior for real and ideal systems? • Does a reaction mechanism accurately tell scientists what occurs at the molecular level?
5	Thermodynamics	<ul style="list-style-type: none"> • How can heat transfer involved in chemical reactions be connected to distribution of kinetic energy? • How can the Laws of Thermodynamics predict spontaneity and favorability?
6	Equilibrium	<ul style="list-style-type: none"> • What is chemical equilibrium? • How are reversible reactions related to chemical systems at equilibrium? • What factors affect chemical equilibrium? • How can LeChatelier's principle be used to predict the effect of stresses on a system at equilibrium?

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| | | <ul style="list-style-type: none">• How can pH be related to strong and weak acids or bases?• How can a buffered solution be designed given acid/base conjugate pairs• How can the relative strengths of acids and bases be determined given equilibrium concentrations? |
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Unit 1: Atomic Structure

Overview

The chemical elements are fundamental building materials of matter, and all matter can be understood in terms of arrangements of atoms. These atoms retain their identity in chemical reactions.

Unit Content Objectives

At the conclusion of this unit, students will be able to:

- Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.
- Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles
- Communicate scientific and technical information about why the molecular level structure is important in the functioning of designed materials.

Unit Essential Questions

- How is the position of an element on the Periodic Table related to that element's chemical properties?
- How does the arrangement of subatomic particles dictate an element's chemical properties?
- How do light and the electromagnetic spectrum relate to electrons and energy?
- How is the arrangement of electrons related to chemical properties?
- How can macroscopic observations of change, chemical equations, and particle views predict structures of matter?
- How does the structure of an atom predict physical and chemical properties?

Crosscutting Concepts

- **Patterns** Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-PS1-1), (HS-PS1-8) **Structure and Function** Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or function and/or solve a problem. (HS-PS2- 6)

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- Cause and Effect Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS4-1) Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. (HS-PS4-4) Systems can be designed to cause a desired effect. (HS-PS4-5) Systems and System Models Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. (HS-PS4-3) Stability and Change Systems can be designed for greater or lesser stability. (HS-PS4-2)

NGSS Unit Standards

DISCIPLINARY CORE IDEAS (DCI):

PS1.A: Structure and Properties of Matter Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. (HS-PS1-1) The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. (HS-PS1-1) The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (HS-PS1-3), (secondary to HS-PS2-6) **PS1.C: Nuclear Processes** Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process. (HS-PS1-8) **PS2.B: Types of Interactions** Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. (HS-PS1-1), (HS-PS1-3), (HS-PS2-6) **PS4.A: Wave Properties** The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing. (HS-PS4-1) Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. (HS-PS4-3) When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells. (HS-PS4-4) Photoelectric materials emit electrons when they absorb light of a high-enough frequency. (HS-PS4-5)

SCIENCE AND ENGINEERING PRACTICES (SEP):

Developing and Using Models Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS1-8) Use a model to predict the relationships between systems or between components of a system. (HS-PS1-1) **Planning and Carrying Out Investigations** Planning and carrying out investigations in 9–12 builds on K–8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models. Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-PS1-3) **Obtaining, Evaluating, and Communicating**

Information Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs. Communicate scientific and technical information (e.g. about the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (HS-PS2-6) Asking Questions and Defining Problems Asking questions and defining problems in grades 9–12 builds from grades K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations. Evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design. (HS-PS4-2) Using Mathematics and Computational Thinking Mathematical and computational thinking at the 9-12 level builds on K-8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations. (HS-PS4-1) Engaging in Argument from Evidence Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about natural and designed worlds. Arguments may also come from current scientific or historical episodes in science. Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. (HS-PS4-3) Obtaining, Evaluating, and Communicating Information Obtaining, evaluating, and communicating information in 9–12 builds on K–8 and progresses to evaluating the validity and reliability of the claims, methods, and designs. Evaluate the validity and reliability of multiple claims that appear in scientific and technical texts or media reports, verifying the data when possible. (HS-PS4-4) Communicate technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). (HS-PS4-5)

Corresponding CT Core Standards:

ELA/Literacy –

RST.9-10.7 Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words. (HS-PS1-1) RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS1-3),(HS-PS2-6) WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-PS2-6) WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS1-3) WHST.11-12.8 Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS1-3) WHST.9-12.9 Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS1-3)

RST .9-10.8 Assess the extent to which the reasoning and evidence in a text support the author’s claim or a recommendation for solving a scientific or technical problem. (HS-PS4-2),(HS-PS4-3),(HS-PS4-4) (HS-PS4-2),(HS-PS4-3),(HS-PS4-4) RST .11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question

or solve a problem. (HS-PS4-1),(HS-PS4-4) RST .11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.

(HS-PS4-2),(HS-PS4-3),(HS-PS4-4) WHST .9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-PS4-5)

Mathematics –

MP.4 Model with mathematics. (HS-PS1-8)

HSN-Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS1-3),(HS-PS1-8),(HS-PS2-6) HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. (HS-PS1-8),(HS-PS2-6) HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS1-3),(HS-PS1-8),(HS-PS2-6)

MP.2 Reason abstractly and quantitatively . (HS -PS4-1),(HS-PS4-3) MP.4 Model with mathematics. (HS-PS4-1) HSA -SSE.A.1 Interpret expressions that represent a quantity in terms of its context. (HS-PS4-1),(HS-PS4-3) HSA -SSE.B.3 Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. (HS-PS4-1),(HS-PS4- 3) HSA .CED.A.4 Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. (HS-PS4-1),(HS-PS4-3)

Unit 2: Chemical Bonding

Overview

Chemical and physical properties of materials can be explained by the structure and the arrangement of atoms, ions, or molecules and the forces between them.

● Unit Content Objectives

At the conclusion of this unit, students will be able to:

- Predict properties of substances based on their chemical formulas and provide explanations of their properties based on particle views.
- Use KMT and concepts of intermolecular forces to make predictions about the macroscopic properties of gases.
- Explain how solutes can be separated by chromatography based on intermolecular interactions
- Describe the relationships between the structural features of polar molecules and the forces of attraction between the articles
- Design or evaluate a plan to collect and/or interpret data needed to deduce the type of bonding in a sample of a solid.

Unit Essential Questions

- How can the VSEPR theory be used to predict geometry of molecules and predict polarity?
- What are the types of attraction that exist between and within particles?
- How do the types of attraction influence physical properties of matter?

Crosscutting Concepts

- **Patterns** Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-PS2-4) **Cause and Effect** Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS2- 1),(HS-PS2-5) **Systems can be designed to cause a desired effect.** (HS-PS2-3) **Systems and System Models** When investigating or describing a system, the boundaries and initial conditions of the system need to be defined. (HS-PS2-2)

NGSS Unit Standards

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DISCIPLINARY CORE IDEAS (DCI):

- PS2.B: Types of Interactions Newton’s law of universal gravitation and Coulomb’s law provide the mathematical models to describe and predict the effects of gravitational and electrostatic forces between distant objects. (HS-PS2-4) ETS1.A: Defining and Delimiting Engineering Problems Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (secondary to HS-PS2- 3) ETS1.C: Optimizing the Design Solution Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (secondary to HS-PS2-3)

SCIENCE AND ENGINEERING PRACTICES (SEP):

- Planning and Carrying Out Investigations Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical and empirical models. Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-PS2-5) Analyzing and Interpreting Data Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. (HS-PS2-1) Using Mathematics and Computational Thinking Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. Use mathematical representations of phenomena to describe explanations. (HS-PS2-2),(HS-PS2-4) Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects. (HS-PS2-3)

Corresponding CT Core Standards:**ELA/Literacy –**

RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS2-1) RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-PS2-1) WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS2-3),(HS-PS2-5) WHST.11-12.8 Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the

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text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS2-5) WHST.9-12.9 Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS2-1),(HS-PS2-5)

Mathematics –

MP.2 Reason abstractly and quantitatively. (HS-PS2-1),(HS-PS2-2),(HS-PS2-4) MP.4 Model with mathematics.

(HS-PS2-1),(HS-PS2-2),(HS-PS2-4) HSN-Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.

(HS-PS2-1),(HS-PS2-2),(HS-PS2-4),(HS-PS2-5) HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling.

(HS-PS2-1),(HS-PS2-2),(HS-PS2-4),(HS-PS2-5) HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS2-1),(HS-PS2-2),(HS-PS2-4),(HS-PS2-5) HSA-SSE.A.1 Interpret expressions that represent a quantity in terms of its context. (HS-PS2-1),(HS-PS2-4) HSA-SSE.B.3 Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. (HS-PS2-1),(HS-PS2-4) HSA-CED.A.1 Create equations and inequalities in one variable and use them to solve problems. (HS-PS2-1),(HS-PS2-2) HSA-CED.A.2 Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. (HS-PS2-1),(HS-PS2-2) HSA-CED.A.4 Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. (HS-PS2-1),(HS-PS2-2) HSF-IF.C.7 Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases. (HS-PS2-1) HSS-ID.A.1 Represent data with plots on the real number line (dot plots, histograms, and box plots). (HS-PS2-1)

Unit 3: Chemical Reactions

Overview

Changes in matter involve the rearrangement and/or organization of atoms and/or the transfer of electrons.

Unit Content Objectives

At the conclusion of this unit, students will be able to:

- Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.
- Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.
- Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.
- Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.

Unit Essential Questions

- What are qualitative and quantitative observations that can be made during a chemical reaction?
- How do molecules interact during a chemical reaction?

Crosscutting Concepts

- **Patterns** Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-PS1-2),(HS-PS1-5) **Energy and Matter** The total amount of energy and matter in closed systems is conserved. (HS-PS1-7) Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (HS-PS1-4) **Stability and Change** Much of science deals with constructing explanations of how things change and how they remain stable. (HS-PS1-6)

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NGSS Unit Standards

DISCIPLINARY CORE IDEAS (DCI):

PS1.A: Structure and Properties of Matter The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. (HS-PS1-2) (Note: This Disciplinary Core Idea is also addressed by HS-PS1-1.) A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. (HS-PS1-4) **PS1.B: Chemical Reactions** Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. (HS-PS1-4),(HS-PS1-5) In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present. (HS-PS1-6) The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. (HS-PS1-2),(HS-PS1-7) **ETS1.C: Optimizing the Design Solution** Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (secondary to HS-PS1-6)

SCIENCE AND ENGINEERING PRACTICES (SEP):

Developing and Using Models Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS1-4) **Using Mathematics and Computational Thinking** Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. Use mathematical representations of phenomena to support claims. (HS-PS1-7) **Constructing Explanations and Designing Solutions** Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student generated sources of evidence consistent with scientific ideas, principles, and theories. Apply scientific principles and evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. (HS-PS1-5) Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-PS1-2) Refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-PS1-6)

Corresponding CT Core Standards:

ELA/Literacy –

RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS1-5) WHST.9-12.2 Write informative/explanatory texts, including the narration of

historical events, scientific procedures/ experiments, or technical processes. (HS-PS1- 2),(HS-PS1-5) WHST.9-12.5 Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (HS-PS1-2) WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS1-6) SL.11-12.5 Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (HS-PS1-4)

Mathematics –

MP.2 Reason abstractly and quantitatively. (HS-PS1-5),(HS-PS1-7) MP.4 Model with mathematics. (HS-PS1-4) HSN-Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS1-2),(HS-PS1-4),(HS-PS1-5),(HS-PS1-7) HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. (HS-PS1-4),(HS-PS1-7) HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS1-2),(HS-PS1-4),(HS-PS1-5),(HS-PS1-7)

Unit 4: Kinetics

Overview

Rates of chemical reactions are determined by the details of the molecular collisions.

Unit Content Objectives

At the conclusion of this unit, students will be able to:

- Analyze concentration versus time data to determine the rate law for a zeroth-, first-, or second-order reaction.
- Connect the half-life of a reaction to the rate constant.
- Evaluate alternative explanations, as expressed by reaction mechanisms, to determine which are consistent with data regarding the overall rate.
- Explain changes in reaction rates arising from the use of catalysts.
- Explain the differences between collisions that convert reactants to products and those that do not.

Unit Essential Questions

- How is the rate of a reaction influenced by the concentration or pressure of reactants, the phase of reactants and products, and environmental factors?
- How are reaction rates affected by catalysts?
- How do systems at equilibrium respond to external perturbations?
- How can the kinetic molecular theory be used to predict gas behavior for real and ideal systems?
- Does a reaction mechanism accurately tell scientists what occurs at the molecular level?

Crosscutting Concepts

- (HS-PS1-3) Energy and Matter In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.

NGSS Unit Standards

DISCIPLINARY CORE IDEAS (DCI):**SCIENCE AND ENGINEERING PRACTICES (SEP):****PS1.A: Structure and Properties of Matter**

- Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. (HS-PS1-1)
- The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. (HS-PS1-1),(HS-PS1-2)
- The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (HS-PS1-3),(secondary to HS-PS2-6)
- A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. (HS-PS1-4)

SCIENCE AND ENGINEERING PRACTICES (SEP):

- Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS1-8)
- Use a model to predict the relationships between systems or between components of a system. (HS-PS1-1)

Corresponding CT Core Standards:**ELA/Literacy –**

RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS1-5) WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-PS1- 2),(HS-PS1-5) WHST.9-12.5 Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (HS-PS1-2) WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS1-6) SL.11-12.5 Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (HS-PS1-4)

Mathematics –

MP.2 Reason abstractly and quantitatively. (HS-PS1-5),(HS-PS1-7) MP.4 Model with mathematics. (HS-PS1-4) HSN-Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS1-2),(HS-PS1-4),(HS-PS1-5),(HS-PS1-7) HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. (HS-PS1-4),(HS-PS1-7) HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS1-2),(HS-PS1-4),(HS-PS1-5),(HS-PS1-7)

Unit 5: Thermodynamics

Overview

The laws of thermodynamics describe the essential role of energy and explain and predict the direction of changes in matter.

Unit Content Objectives

At the conclusion of this unit, students will be able to:

- Generate explanations or make predictions about the transfer of thermal energy between systems.
- Use conservation of energy to relate the magnitudes of energy changes occurring in two or more interacting systems.
- Use calculations of estimations to relate: energy changes associated with heating/cooling a substance to the heat capacity.
- Draw qualitative and quantitative connections between the reaction enthalpy and the energies involved in the breaking and formation of chemical bonds.
- Use representations and models to predict the sign and relative magnitude of the entropy change associated with the chemical or physical processes.

Unit Essential Questions

- How can heat transfer involved in chemical reactions be connected to distribution of kinetic energy?
- How can the Laws of Thermodynamics predict spontaneity and favorability?

Crosscutting Concepts

- **Cause and Effect** Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. (HS-PS3-5) **Systems and System Models** When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. (HS-PS3-4) **Models** can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. (HS-PS3-1) **Energy and Matter** Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (HS-PS3-3)

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Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems. (HS-PS3-2)

NGSS Unit Standards

DISCIPLINARY CORE IDEAS (DCI):

PS3.A: Definitions of Energy; Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. (HS-PS3-1),(HS-PS3-2) At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (HS-PS3-2)(HS-PS3-3)

PS3.B: Conservation of Energy and Energy Transfer: Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. (HS-PS3-1) Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. (HS-PS3-1),(HS-PS3-4) The availability of energy limits what can occur in any system.

(HS-PS3-1) Uncontrolled systems always evolve toward more stable states— that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). (HS-PS3-4) PS3.D: Energy in Chemical Processes Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.

(HS-PS3-3),(HS-PS3-4) ETS1.A: Defining and Delimiting Engineering Problems Criteria and constraints also include satisfying any requirements set by society , such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (secondary to HS-PS3-3)

SCIENCE AND ENGINEERING PRACTICES (SEP):

Developing and Using Models Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS3-2),(HS-PS3-5) Planning and Carrying Out Investigations Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models. Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly . (HS-PS3-4) Using Mathematics and Computational Thinking Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. Create a computational model or simulation of a phenomenon, designed device, process, or system. (HS-PS3-1) Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9– 12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. Design, evaluate, and/or refine a

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solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HSPS3-3)

Corresponding CT Core Standards:

ELA/Literacy –

RST .11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS3-4) WHST .9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS3-3),(HS-PS3-4),(HS-PS3-5) WHST .11-12.8 Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively ; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS3-4),(HS-PS3-5) WHST .9-12.9 Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS3-4),(HS-PS3-5) SL.11-12.5 Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (HS-PS3-1),(HS-PS3-2),(HS-PS3-5)

Mathematics –

MP.2 Reason abstractly and quantitatively . (HS -PS3-1),(HS-PS3-2),(HS-PS3-3),(HS-PS3-4),(HS-PS3-5) MP.4 Model with mathematics. (HS -PS3-1),(HS-PS3-2),(HS-PS3-3),(HS-PS3-4),(HS-PS3-5) HSN-Q.A .1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data display s. (HS-PS3-1),(HS-PS3-3) HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. (HS-PS3-1),(HS-PS3-3) HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS3-1),(HS-PS3-3)

Unit 6: Equilibrium

Overview

Any bond or intermolecular attraction that can be formed can be broken. These two processes are a dynamic competition sensitive to initial conditions and external perturbations.

NGSS Unit Standards

DISCIPLINARY CORE IDEAS (DCI):

PS1.B: Chemical Reactions, Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. (HS-PS1-4),(HS-PS1-5) In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present. (HS-PS1-6) The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. (HS-PS1-2),(HS-PS1-7) ETS1.C: Optimizing the Design Solution Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (secondary to HS-PS1-6)

SCIENCE AND ENGINEERING PRACTICES (SEP):

Using Mathematics and Computational Thinking Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. Use mathematical representations of phenomena to support claims. (HS-PS1-7) Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student generated sources of evidence consistent with scientific ideas, principles, and theories. Apply scientific principles and evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. (HS-PS1-5) Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-PS1-2) Refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-PS1-6)

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Corresponding CT Core Standards:**ELA/Literacy –**

RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS1-5) WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-PS1- 2),(HS-PS1-5) WHST.9-12.5 Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. (HS-PS1-2) WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS1-6) SL.11-12.5 Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (HS-PS1-4)

Mathematics –

MP.2 Reason abstractly and quantitatively. (HS-PS1-5),(HS-PS1-7) MP.4 Model with mathematics. (HS-PS1-4) HSN-Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS1-2),(HS-PS1-4),(HS-PS1-5),(HS-PS1-7) HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. (HS-PS1-4),(HS-PS1-7) HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS1-2),(HS-PS1-4),(HS-PS1-5),(HS-PS1-7)