PISCATAWAY
TOWNSHIP SCHOOLS

Dr. Frank Ranelli
Superintendent of Schools
Dr. William Baskerville
Assistant Superintendent for
Curriculum and Instruction

Chemistry

Content Area: Science
Grade Span: 10
Revised by: Emily Tenenbaum, Matthew Chioffe, & Jessica Pritchard
Presented by: Jessica Pritchard
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Piscataway Township Schools
1515 Stelton Road
Piscataway, NJ 08854-1332
732 572-2289, ext. 2561
Fax 732 572-1540
www.piscatawayschools.org

COURSE OVERVIEW

Description

Students in this high school chemistry course continue to develop their understanding of the four core ideas in the physical sciences. Chemistry is the science of matter and its transformations. Throughout the course, overarching themes that help develop explanations of how matter and energy interact are addressed. Topics included in this course are: Periodic properties of elements, conservation of matter and energy during chemical reactions, atomic structure, bonding, stoichiometry of reactions, states of matter, solutions, behavior of gases, and chemistry of life and the environment. These performance expectations blend the core ideas with scientific and engineering practices and crosscutting concepts to support students in developing usable knowledge to explain ideas across the science disciplines. Students will focus on several scientific practices, including developing and using models, planning and conducting investigations, analyzing and interpreting data, using mathematical and computational thinking, and constructing explanations; and to 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. The course is designed to promote scientific literacy and to develop an understanding of physical phenomena in the real world. Students will acquire an appreciation for the interactions of matter at the macroscopic level and at the atomic level. This course will engage students in activities that involve critical thinking and problem solving skills with real life applications. This five-credit course in Chemistry is intended for all high school students. There are three options to fulfil this science requirement for graduation: Chemistry in the Community, Academic Chemistry, or Honors Chemistry.

Goals

The goals of this inquiry based lab course are to provide students with learning opportunities that are designed to build scientific literacy, critical thinking, problem solving and analytical skills through the process of inquiry. This course is structured to engage students actively in scientific and engineering practices and apply crosscutting concepts to deepen their understanding of the core ideas. The units in this curriculum document guide students through the use of the SEPs, CCC, and DCIs to be able to answer the essential questions. The learning experiences will engage students in the fundamental questions about the world around them and how scientists investigate and find answers to those questions. Students will have the opportunity to carry out scientific investigations and engineering design projects related to the disciplinary core ideas in physical sciences.

Scope and Sequence

Unit	Topic	Length
1	Structure and Properties of Matter	27
2	States of Matter and Interactions of Matter in Chemical Reactions	28
3	Exploration of Solutions, Reaction Kinetics, and Chemical Equilibrium	18
4	Chemistry of Life and the Environment	7

UNIT 1: STRUCTURE AND PROPERTIES OF MATTER

Summary and Rationale

The performance expectations in this unit allow students to understand matter in terms of the types of atoms present and the interactions both between and within them. Students are expected to develop understanding of the substructure of atoms and to provide more mechanistic explanations of the properties of substances. Students are able to use the periodic table as a tool to explain and predict the properties of elements. Atomic structure and the arrangement of the Periodic Table are the foundation for understanding matter and its interactions. The crosscutting concepts of patterns, energy and matter, and stability and change are called out as organizing concepts for these disciplinary core ideas. It is important to note that the performance expectations described are intended as end-of-instructional unit expectations and additional practices should be used throughout instruction.

Recommended Pacing

27 blocks

State Standards

HS-PS1-1 Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.	
Clarification Statement	Examples of properties that could be predicted from patterns could include reactivity of metals, types of bonds formed, numbers of bonds formed, and reactions with oxygen.]
Assessment Boundary	Assessment is limited to main group elements. Assessment does not include quantitative understanding of ionization energy beyond relative trends.
HS-PS1-2 Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.	
Clarification Statement	Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen
Assessment Boundary	Assessment is limited to chemical reactions involving main group elements and combustion reactions.
HS-PS1-3 Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.	
Clarification Statement	Emphasis is on understanding the strengths of forces between particles, not on naming specific intermolecular forces (such as dipole-dipole). Examples of particles could include ions, atoms, molecules, and networked materials (such as graphite). Examples of bulk properties of substances could include the melting point and boiling point, vapor pressure, and surface tension.
Assessment Boundary	Assessment does not include Raoult's law calculations of vapor pressure
HS-PS1-8 Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.	
Clarification Statement	Emphasis is on simple qualitative models, such as pictures or diagrams, and on the scale of energy released in nuclear processes relative to other kinds of transformations
Assessment Boundary	Assessment does not include quantitative calculation of energy released. Assessment is limited to alpha, beta, and gamma radioactive decays
HS-PS4-1 Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.	

Clarification Statement	Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the earth.
Assessment Boundary	Assessment is limited to algebraic relationships and describing those relationships qualitatively
HS-PS4-3 Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other	
Clarification Statement	Emphasis is on how the experimental evidence supports the claim and how a theory is generally modified in light of new evidence. Examples of a phenomenon could include resonance, interference, diffraction, and photoelectric effect
Assessment Boundary	Assessment does not include using quantum theory.
HS-ESS1-1 Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy that eventually reaches Earth in the form of radiation.	
Clarification Statement	Emphasis is on the energy transfer mechanisms that allow energy from nuclear fusion in the sun's core to reach Earth. Examples of evidence for the model include observations of the masses and lifetimes of other stars, as well as the ways that the sun's radiation varies due to sudden solar flares ("space weather"), the 11- year sunspot cycle, and non-cyclic variations over centuries.
Assessment Boundary	Assessment does not include details of the atomic and subatomic processes involved with the sun's nuclear fusion.
HS-ESS1-3 Communicate scientific ideas about the way stars, over their life cycle, produce elements.	
Clarification Statement	Emphasis is on the way nucleosynthesis, and therefore the different elements created, varies as a function of the mass of a star and the stage of its lifetime.
Assessment Boundary	Details of the many different nucleosynthesis pathways for stars of different masses are not assessed.
HS-ESS1-6 Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history.	
Clarification Statement	Emphasis is on using available evidence within the solar system to reconstruct the early history of Earth, which formed along with the rest of the solar system 4.6 billion years ago. Examples of evidence include the absolute ages of ancient materials (obtained by radiometric dating of meteorites, moon rocks, and Earth's oldest minerals), the sizes and compositions of solar system objects, and the impact cratering record of planetary surfaces.

Instructional Focus

Unit Enduring Understandings (Cross Cutting Concepts)

- Patterns (HS-PS1-1),(HS-PS1-2),(HS-PS1-3)
- Energy and Matter (HS-PS1-8), (HSESS1-3)
- Scale, Proportion, and Quantity (HS-ESS1-1)
- Stability and Change (HS-ESS1-6)
- ***Connections to Nature of Science:*** Scientific Knowledge Assumes an Order and Consistency in Natural Systems

Unit Essential Questions

- What is matter made up of?
- Where and how were the Earth's elements formed?
- How are models and experimental data used to explain what is happening on an atomic level?
- How do the interactions of the electrons and nuclei of atoms determine their structure and properties?
- How are the trends in periodicity related to their electronic structure?

Objectives

Students will know (DCIs):

- **Structure and Properties of Matter** Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.
- **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. Spontaneous radioactive decay follows a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials.
- **The Universe and Its Stars** The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years. The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth.

Students will be able to (SEPs):

- Developing and Using Models
- Constructing Explanations and Designing Solutions
- Planning and Carrying Out Investigations
- Using Mathematics and Computational Thinking
- Engaging in Arguments from Evidence
- Obtaining, Evaluating, and Communicating Information

UNIT 2: STATES OF MATTER AND INTERACTIONS OF MATTER IN CHEMICAL REACTIONS

Summary and Rationale

The performance expectations in this unit help students formulate answers to the question: What is happening in a chemical reaction? Many substances react chemically with other substances to form new substances with different properties. This change in properties results from the ways in which atoms from the original substances are combined and rearranged in the new substances. Chemical reactions, including rates of reactions and energy changes, can be understood by students at this level in terms of the collisions of molecules and the rearrangements of atoms. Using this expanded knowledge of chemical reactions, students are able to explain important biological and geophysical phenomena. It is important to note that the performance expectations described are intended as end-of-instructional unit expectations and additional practices should be used throughout instruction.

Recommended Pacing

28 blocks

State Standards

HS-PS1-2 Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.	
Clarification Statement	Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen.
Assessment Boundary	Assessment is limited to chemical reactions involving main group elements and combustion reactions
HS-PS1-4 Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy	
Clarification Statement	Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawings and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved
Assessment Boundary	Assessment does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products.
HS-PS1-7 Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.	
Clarification Statement	Emphasis is on using mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and the products, and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale. Emphasis is on assessing students' use of mathematical thinking and not on memorization and rote application of problemsolving techniques.
Assessment Boundary	Assessment does not include complex chemical reactions
HS-PS3-4 Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).	

Clarification Statement	Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.
Assessment Boundary	Assessment is limited to investigations based on materials and tools provided to students.
HS-ESS3-2 Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.*	
Clarification Statement	Emphasis is on the conservation, recycling, and reuse of resources (such as minerals and metals) where possible, and on minimizing impacts where it is not. Examples include developing best practices for agricultural soil use, mining (for coal, tar sands, and oil shales), and pumping (for petroleum and natural gas). Science knowledge indicates what can happen in natural systems—not what should happen.]

Instructional Focus

Unit Enduring Understandings (Cross Cutting Concepts)

- Patterns (HS-PS1-2)
- Energy and Matter (HS-PS1-7), (HS-PS1-4)
- Systems and System Models (HS-PS3-4)
- ***Connections to Engineering, Technology, and Applications of Science:*** Influence of Engineering, Technology, and Science on Society and the Natural World
- ***Connections to Nature of Science:*** Scientific Knowledge Assumes an Order and Consistency in Natural Systems

Unit Essential Questions

- How are chemical bonds formed through attractive forces?
- What are the different ways that show that mass is conserved in a chemical reaction?
- How can the ratio determined by a chemical reaction be used to calculate an unknown?
- What are the characteristics of each type of chemical reaction?
- How do bonds form and break in a reaction in terms of energy?

Objectives

Students will know (DCIs):

- **Structure and Properties of Matter** 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.
- **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. 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
- **Conservation of Energy and Energy Transfer** Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. 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).
- **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.
- **Natural Resources** All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors.

Students will be able to (SEPs):

- Constructing Explanations and Designing Solutions
- Developing and Using Models
- Using Mathematics and Computational Thinking

- Engaging in Arguments from Evidence

UNIT 3: EXPLORATION OF SOLUTIONS, REACTION KINETICS, AND CHEMICAL EQUILIBRIUM

Summary and Rationale

The performance expectations in this unit allow students to understand chemical reactions, including rates of reactions and energy changes, in terms of the collisions of molecules and the rearrangements of atoms. With their investigations of reaction kinetics and chemical equilibrium, students will answer questions about rate, how fast reactions go, and mechanisms, the paths molecules take in going from reactants to products. They will recognize that many chemical reactions are carried out in solutions, and solutions are also closely related to their everyday lives. The air they breathe, the liquids they drink, and the fluids in their bodies are all solutions. Furthermore, they are surrounded by solutions such as the air and waters (in rivers, lakes and oceans). Students will observe that the study of chemistry is truly the study of our lives and our surroundings. It is important to note that the performance expectations described are intended as end-of-instructional unit expectations and additional practices should be used throughout instruction.

Recommended Pacing

18 blocks

State Standards

HS-PS1-5. Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.	
Clarification Statement	Emphasis is on student reasoning that focuses on the number and energy of collisions between molecules
Assessment Boundary	Assessment is limited to simple reactions in which there are only two reactants; evidence from temperature, concentration, and rate data; and qualitative relationships between rate and temperature.
HS-PS1-6. Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.*	
Clarification Statement	Emphasis is on the application of Le Chatelier's Principle and on refining designs of chemical reaction systems, including descriptions of the connection between changes made at the macroscopic level and what happens at the molecular level. Examples of designs could include different ways to increase product formation including adding reactants or removing products.
Assessment Boundary	Assessment is limited to specifying the change in only one variable at a time. Assessment does not include calculating equilibrium constants and concentrations
HS-PS2-6 Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.*	
Clarification Statement	Emphasis is on the attractive and repulsive forces that determine the functioning of the material. Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, and pharmaceuticals are designed to interact with specific receptors.
Assessment Boundary	Assessment is limited to provided molecular structures of specific designed materials.
HS-ETS1-2 Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.	

Instructional Focus

Unit Enduring Understandings (Cross Cutting Concepts)

- Patterns (HSPS1-5)
- Stability and Change (HS-PS1-6)
- Structure and Function (HS-PS2-6)

Unit Essential Questions

- How is dynamic equilibrium represented?
- How do changes in product or reactant concentration, or temperature affect a reaction's equilibrium and rate?
- How is an everyday material's function related to the material's molecular-level structure?

Objectives

Students will know (DCIs):

- **Chemical Reactions** Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present.
- **Structure and Properties of Matter** The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.
- **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 (tradeoffs) may be needed.

Students will be able to (SEPs):

- Developing and Using Models
- Constructing Explanations and Providing Solutions
- Obtaining, Evaluating, and Communicating Information

UNIT 4: CHEMISTRY OF LIFE AND THE ENVIRONMENT

Summary and Rationale

The performance expectations in this unit provide the foundation for students to begin the study of chemicals and chemical processes within the air, water, and soil. It also involves studying how these chemicals get there, what they do, and how humans are intertwined in all of this. Students will help answer important questions about the environment, the chemicals therein, and what role people play in all of this or how it impacts humans and other species as a result. It is important to note that the performance expectations described are intended as end-of-instructional unit expectations and additional practices should be used throughout instruction.

Recommended Pacing

7 blocks

State Standards

HS-ESS2-2 Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.	
Clarification Statement	Examples should include climate feedbacks, such as how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth's surface, increasing surface temperatures and further reducing the amount of ice. Examples could also be taken from other system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.
HS-ESS2-5 Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.	
Clarification Statement	Emphasis is on mechanical and chemical investigations with water and a variety of solid materials to provide the evidence for connections between the hydrologic cycle and system interactions commonly known as the rock cycle. Examples of mechanical investigations include stream transportation and deposition using a stream table, erosion using variations in soil moisture content, or frost wedging by the expansion of water as it freezes. Examples of chemical investigations include chemical weathering and recrystallization (by testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids).
HS-ESS2-6 Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.	
Clarification Statement	Emphasis is on modeling biogeochemical cycles that include the cycling of carbon through the ocean, atmosphere, soil, and biosphere (including humans), providing the foundation for living organisms.
HS-ESS3-5 Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts on Earth's systems.	
Clarification Statement	Clarification Statement: Examples of evidence, for both data and climate model outputs, are for climate changes (such as precipitation and temperature) and their associated impacts (such as on sea level, glacial ice volumes, or atmosphere and ocean composition).
Assessment Boundary	Assessment is limited to one example of climate change and its associated impacts.

HS-ESS3-6 Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.	
Clarification Statement	Examples of Earth systems to be considered are the hydrosphere, atmosphere, cryosphere, geosphere, and/or biosphere. An example of the far-reaching impacts from human activity is how an increase in atmospheric carbon dioxide results in an increase in photosynthetic biomass on land and an increase in ocean acidification, with resulting impacts on sea organism health and marine populations.
Assessment Boundary	Assessment does not include running computational representations but is limited to using the published results of scientific computational models.
HS-ETS1-1 Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.	

Instructional Focus

Unit Enduring Understandings (Cross Cutting Concepts)

- Energy and Matter (HS-ESS2-6)
- Structure and Function (HS-ESS2-5)
- Stability and Change (HS-ESS2-2)
- ***Connections to Engineering, Technology, and Applications of Science:*** Influence of Engineering, Technology, and Science on Society and the Natural World

Unit Essential Questions

- What are the chemical processes within the air, water, and soil and within the human body?
- What impact do chemical processes have on the environment and on humans?

Objectives

Students will know (DCIs):

- **Earth Materials and Systems** Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.
- **The Roles of Water in Earth's Surface Processes** The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting points of rocks.
- **Weather and Climate** Gradual atmospheric changes were due to plants and other organisms that captured carbon dioxide and released oxygen.
- **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. Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.

Students will be able to (SEPs):

- Developing and Using Models
- Analyzing and Interpreting Data
- Engaging in Arguments from Evidence