CURRICULUM

FOR

ADVANCED PLACEMENT CHEMISTRY

GRADES 11-12

This curriculum is part of the Educational Program of Studies of the Rahway Public Schools.

ACKNOWLEDGMENTS

Dr. Susan Dube, Program Supervisor of Science, Technology Education, Business, and World Languages

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Janet Tuohy

Dr. TiffanyA. Beer, Director of Curriculum and Instruction

Subject/Course Title:
AP Chemistry
Grades 11-12

Date of Board Adoptions:
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RAHWAY PUBLIC SCHOOLS CURRICULUM

AP Chemistry: Grades 11-12

PACING GUIDE

Unit	Title	Pacing
1	Mass Relationships and the Mole Concept	2 weeks
2	Molecular and Ionic Compound Structure and Properties	2 1/2 weeks
3	Intermolecular Forces, Properties and Applications	3 weeks
4	Chemical Reactions	3 weeks
5	Kinetics	2 1/2 weeks
6	Thermodynamics	2 weeks
7	Chemical Equilibrium	3 weeks
8	Acid-Base Chemistry	3 weeks
9	Thermodynamics and Electrochemistry	3 weeks

ACCOMMODATIONS

504 Accommodations:

- Provide scaffolded vocabulary and vocabulary lists.
- Provide extra visual and verbal cues and prompts.
- Provide adapted/alternate/excerpted versions of the text and/or modified supplementary materials.
- Provide links to audio files and utilize video clips.
- Provide graphic organizers and/or checklists.
- Provide modified rubrics.
- Provide a copy of teaching notes, especially any key terms, in advance.
- Allow additional time to complete assignments and/or assessments.
- Provide shorter writing assignments.
- Provide sentence starters.
- Utilize small group instruction.
- Utilize Think-Pair-Share structure.
- Check for understanding frequently.
- Have student restate information.
- Support auditory presentations with visuals.
- Weekly home-school communication tools (notebook, daily log, phone calls or email messages).
- Provide study sheets and teacher outlines prior to assessments.
- Quiet corner or room to calm down and relax when anxious.
- Reduction of distractions.
- Permit answers to be dictated.
- Hands-on activities.
- Use of manipulatives.
- Assign preferential seating.
- No penalty for spelling errors or sloppy handwriting.
- Follow a routine/schedule.
- Provide student with rest breaks.
- Use verbal and visual cues regarding directions and staying on task.
- Assist in maintaining agenda book.

IEP Accommodations:

- Provide scaffolded vocabulary and vocabulary lists.
- Differentiate reading levels of texts (e.g., Newsela).
- Provide adapted/alternate/excerpted versions of the text and/or modified supplementary materials.
- Provide extra visual and verbal cues and prompts.
- Provide links to audio files and utilize video clips.
- Provide graphic organizers and/or checklists.
- Provide modified rubrics.
- Provide a copy of teaching notes, especially any key terms, in advance.
- Provide students with additional information to supplement notes.
- Modify questioning techniques and provide a reduced number of questions or items on tests.
- Allow additional time to complete assignments and/or assessments.
- Provide shorter writing assignments.
- Provide sentence starters.
- Utilize small group instruction.
- Utilize Think-Pair-Share structure.
- Check for understanding frequently.
- Have student restate information.
- Support auditory presentations with visuals.
- Provide study sheets and teacher outlines prior to assessments.
- Use of manipulatives.
- Have students work with partners or in groups for reading, presentations, assignments, and analyses.
- Assign appropriate roles in collaborative work.
- Assign preferential seating.
- Follow a routine/schedule.

Gifted and Talented Accommodations:

- Differentiate reading levels of texts (e.g., Newsela).
- Offer students additional texts with higher lexile levels.
- Provide more challenging and/or more supplemental readings and/or activities to deepen understanding.
- Allow for independent reading, research, and projects.
- Accelerate or compact the curriculum.
- Offer higher-level thinking questions for deeper analysis.
- Offer more rigorous materials/tasks/prompts.
- Increase number and complexity of sources.
- Assign group research and presentations to teach the class.
- Assign/allow for leadership roles during collaborative work and in other learning activities.

ELL Accommodations:

- Provide extended time.
- Assign preferential seating.
- Assign peer buddy who the student can work with.
- Check for understanding frequently.
- Provide language feedback often (such as grammar errors, tenses, subject-verb agreements, etc…).
- Have student repeat directions.
- Make vocabulary words available during classwork and exams.
- Use study guides/checklists to organize information.
- Repeat directions.
- Increase one-on-one conferencing.
- Allow student to listen to an audio version of the text.
- Give directions in small, distinct steps.
- Allow copying from paper/book.
- Give student a copy of the class notes.
- Provide written and oral instructions.
- Differentiate reading levels of texts (e.g., Newsela).

	• Shorten assignments. • Read directions aloud to student. • Give oral clues or prompts. • Record or type assignments. • Adapt worksheets/packets. • Create alternate assignments. • Have student enter written assignments in criterion, where they can use the planning maps to help get them started and receive feedback after it is submitted. • Allow student to resubmit assignments. • Use small group instruction. • Simplify language. • Provide scaffolded vocabulary and vocabulary lists. • Demonstrate concepts possibly through the use of visuals. • Use manipulatives. • Emphasize critical information by highlighting it for the student. • Use graphic organizers. • Pre-teach or pre-view vocabulary. • Provide student with a list of prompts or sentence starters that they can use when completing a written assignment. • Provide audio versions of the textbooks. • Highlight textbooks/study guides. • Use supplementary materials. • Give assistance in note taking • Use adapted/modified textbooks. • Allow use of computer/word processor. • Allow student to answer orally, give extended time (time-and-a-half). • Allow tests to be given in a separate location (with the ESL teacher). • Allow additional time to complete assignments and/or assessments. • Read question to student to clarify. • Provide a definition or synonym for words on a test that do not impact the validity of the exam. • Modify the format of assessments. • Shorten test length or require only selected test items. • Create alternative assessments. • On an exam other than a spelling test, don’t take points off for spelling errors.

RAHWAY PUBLIC SCHOOLS AP CHEMISTRY CURRICULUM

UNIT OVERVIEW

Content Area: AP Chemistry

Unit Title: Unit 1 Mass Relationships and the Mole

Target Course/Grade Level: Grade 11, 12

Unit Summary: Mass-particle relationships of atoms will be analyzed to determine compositions of substances. The atomic structure will be analyzed using the periodic table so that atomic trends and chemical reactivity can be assessed.

Approximate Length of Unit: 10 class periods

LEARNING TARGETS

NJ Student Learning Standards:
H.S.PS1-1. Matter and Its Interaction: 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
H.S.PS1-2. Matter and Its Interaction: 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
H.S.PS1-7. Matter and Its Interaction: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
HS-PS4-4. Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.

Science and Engineering Practices:
Developing and using models
- Use a model to predict the relationships between systems or between components of a system. (HS-PS1-1)

Constructing explanations and Designing Solutions:
- Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-PS1-2)

Obtaining, evaluating, and communicating information:
- 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)

Disciplinary Core Ideas:
PS1.B: Chemical Reactions:
- The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. (HS-PS1-2),(HS-PS1-7)

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-PS2-6) (secondary to HS-PS1-1),(secondary to HS-PS1-3)

PS4.B: Electromagnetic Radiation:

- When light or longer wavelength electromagnetic reactions are 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)

Cross Cutting 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-PS1-2),(HS-PS1-3),(HS-PS1-5)

Energy and Matter:

- The total amount of energy and matter in closed systems is conserved. (HS-PS1-7)

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-PS4-4)

Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems:

- Science assumes the universe is a vast single system in which basic laws are consistent. (HS-PS1-7)
- Technological advances have influenced the progress of science and science has influenced advances in technology.(HS-PS4-4)

Career Readiness, Life Literacies, and Key Skills:

SCIENCE, TECHNOLOGY, ENGINEERING & MATHEMATICS (ST)

9.3.ST.1 Apply engineering skills in a project that requires project management, process control and quality assurance.

9.3.ST.3 Describe and follow safety, health and environmental standards related to science, technology, engineering and mathematics (STEM) workplaces.

9.3.ST.6 Demonstrate technical skills needed in a chosen STEM field. ENGINEERING & TECHNOLOGY CAREER PATHWAY (ST-ET)

9.3.ST-ET.2 Display and communicate STEM information. SCIENCE & MATHEMATICS CAREER PATHWAY (ST-SM)

9.3.ST-SM.2 Apply science and mathematics concepts to the development of plans, processes and projects that address real world problems.

9.3.ST-SM.3 Analyze the impact that science and mathematics has on society.

Career Readiness, Life Literacies, and Key Skills:

Career Ready Practices:

CRP1. Act as a responsible and contributing citizen and employee.
CRP2. Apply appropriate academic and technical skills.
CRP4. Communicate clearly and effectively and with reason.
CRP5. Consider the environmental, social and economic impacts of decisions.
CRP6. Demonstrate creativity and innovation.
CRP7. Employ valid and reliable research strategies.
CRP8. Utilize critical thinking to make sense of problems and persevere in solving them.
CRP9. Model integrity, ethical leadership and effective management.
CRP11. Use technology to enhance productivity.
CRP12. Work productively in teams while using cultural global competence.

Interdisciplinary Connections and Standards:

ELA Literacy:
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)
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),(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-PS1-2),(HS-PS1-3),(HS-PS1-4),(HS-PS1-5),(HS-PS1-7),(HS-PS1-8)

Computer Science and Design Thinking:
8.1.12.DA.1: Create interactive data visualizations using software tools to help others better understand real world phenomena, including climate change.
8.1.12.DA.5: Create data visualizations from large data sets to summarize, communicate, and support different interpretations of real-world phenomena.
8.1.12.DA.6: Create and refine computational models to better represent the relationships among different elements of data collected from a phenomenon or process.
8.1.12.NI.3: Explain how the needs of users and the sensitivity of data determine the level of security implemented.

NJ SLS Companion Standards: Reading and Writing Standards for History, Social Studies, Science, and Technical Subjects:
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.9-10.8 Determine if 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)
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-PS1-5)
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-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)

Unit Understandings:
Students will understand that…
- The moles allow different units to be compared.
- Chemical formulas identify substances by their unique combination of atoms.
- Atoms and molecules can be identified by their electron distribution and energy.
- The periodic table shows patterns in electronic structure and trends in atomic properties.

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Unit Essential Questions:
- How does the mole concept allow different substances to be compared?
- What is the basic structure of the atom and how does this determine chemical properties and reactivity?

Knowledge and Skills:
Students will know…..

- Relationship of Avogadro's number of particles to molar mass (moles= mass/ molar mass).
- Isotope structure, mass, and calculating average atomic mass.
- Explain the quantitative relationship between the elemental composition by mass and the empirical formula of a pure substance.
- Atomic structure, Coulombic Force of attraction, electron energy and the shell model, photoelectron spectroscopy (PES) data analysis.
- Valence electrons and ion charge.
- Organization and atomic trends in the periodic table and use to predict chemical reactivity.

Students will be able to …

- Calculate quantities of a substance or its relative number of particles using dimensional analysis and the mole concept.
- Explain the quantitative relationship between the mass spectrum of an element and the masses of the element's isotopes.
- Explain the quantitative relationship between the elemental composition by mass and the composition of substances in a mixture.
- Represent the electron configuration of an element or ions of an element using the Aufbau principle.
- Explain the relationship between the photoelectron spectrum of an atom or ion and: The electron configuration of the species. The interactions between the electrons and the nucleus.
- Explain the relationship between trends in atomic properties of elements and electronic structure and periodicity.

EVIDENCE OF LEARNING

Assessment:
What evidence will be collected and deemed acceptable to show that students truly "understand"?

- Students can apply mathematical concepts to determine the percent composition of compounds based on the quantitative analysis of experimental data from a chemical reaction.
- Students can determine the empirical formula of compounds based on percent composition experimental data.
- Students can analyze and predict the chemical substances for mass spectrometry and photoelectron spectroscopy data.
- Students can apply an understanding of the atomic structure and electron energies (shell model) using the periodic table and predict relative reactivity of elements.
- Students will solve conceptual problems and chemistry math –based problems in guided practice, independent practice, and as homework.
- Students will complete AP Classroom assessments as well as a comprehensive exam on the unit, which will be composed of multiple choice, short answer, essay and lab practicum problems.

Learning Activities:

- Unit PowerPoint slide presentations.
- Mini-group peer activities.
- Online simulations of electron structure, periodic trends, mass spectrometry, photoelectron spectroscopy

(PES) and live demonstrations of chemical properties of substances.

- Activities and laboratory experiments including:
  - % composition of Cu in brass. % sulfate in an unknown ionic compound to determine compound percent composition and empirical formula.
- AP Classroom videos, formative assessments and progress checks.

RESOURCES

Teacher Resources:

- Zumdahl, Steven S., et.al. Chemistry, 10th Edition, Boston New York, Cengage Learning, 2018
- AP Chemistry Guided Inquiry Experiments: Applying the Science Practices. 2019.
- Volz, Donald, Smola, Ray. Investigating Chemistry through Inquiry 1st edition. Vernier Software & Technology, 2010.
- AP Chemistry Classroom, College Board web access.

Equipment Needed:

- Computer, projector and laptop connections. Vernier Labquest, calculators.
- Laboratory equipment and chemicals for demonstrations and labs.

RAHWAY PUBLIC SCHOOLS AP CHEMISTRY CURRICULUM

UNIT OVERVIEW

Content Area: AP Chemistry

Unit Title: Unit 2 Molecular and Ionic Compound Structure and Properties

Target Course/Grade Level: Grade 11, 12

Unit Summary: In this unit knowledge of atomic structure at the particulate level is translated to the macroscopic properties of substances through an explanation of how bonds form, types and strengths of bonds, and resulting structures.

Approximate Length of Unit: 12 class periods

LEARNING TARGETS

NJ Student Learning Standards:
HS-PS1-1.Matter and Its Interactions: Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.
HS-PS1-4. Matter and Its Interactions: 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
H.S.PS2-6. Motion and Stability: Forces and Interactions: Communicate scientific and technical information about why the molecular level structure is important in the functioning of designed materials.
HS-PS3-2. Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects).

Science and Engineering Practices:
Developing and using models:

- Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS1-4),(HS-PS1-8),(HS-PS3-2), (HS-PS3-5)
- Use a model to predict the relationships between systems or between components of a system. (HS-PS1-1)

Obtaining, evaluating, and communicating information:

- 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)

Disciplinary Core Ideas:
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)

- 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)
- The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (secondary to HS-PS2-6)

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. There is a single quantity called energy 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)
- These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. (HS-PS3-2)

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)

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. (secondary to HS-PS1-1),(secondary to HS-PS1-3)
- 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-PS2-6), (secondary to HS-PS1-1), (secondary to HS-PS1-3)

Cross Cutting 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-PS1-2),(HS-PS1-3),(HS-PS1-5)

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-PS1-4)

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 solve a problem. (HS-PS2- 6**)**

Connections to Nature of Science Scientific Knowledge Assumes an Order and Consistency in Natural Systems:

Models, mechanisms, and explanations collectively serve as tools in the development of a scientific theory (HS-PS1-4), (HS-PS3-2)

Career Readiness, Life Literacies, and Key Skills:

SCIENCE, TECHNOLOGY, ENGINEERING & MATHEMATICS (ST)

9.3.ST.1 Apply engineering skills in a project that requires project management, process control and quality assurance.

9.3.ST.3 Describe and follow safety, health and environmental standards related to science, technology, engineering and mathematics (STEM) workplaces.

9.3.ST.6 Demonstrate technical skills needed in a chosen STEM field.

ENGINEERING & TECHNOLOGY CAREER PATHWAY (ST-ET)
9.3.ST-ET.2 Display and communicate STEM information.

SCIENCE & MATHEMATICS CAREER PATHWAY (ST-SM)
9.3.ST-SM.2 Apply science and mathematics concepts to the development of plans, processes and projects that address real world problems.
9.3.ST-SM.3 Analyze the impact that science and mathematics has on society.

Career Readiness, Life Literacies, and Key Skills:
Career Ready Practices:
CRP1. Act as a responsible and contributing citizen and employee.
CRP2. Apply appropriate academic and technical skills.
CRP4. Communicate clearly and effectively and with reason.
CRP5. Consider the environmental, social and economic impacts of decisions.
CRP6. Demonstrate creativity and innovation.
CRP7. Employ valid and reliable research strategies.
CRP8. Utilize critical thinking to make sense of problems and persevere in solving them.
CRP9. Model integrity, ethical leadership and effective management.
CRP11. Use technology to enhance productivity.
CRP12. Work productively in teams while using cultural global competence.

Interdisciplinary Connections and 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)
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.4 Model with mathematics. (HS-PS1-4),(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-PS1-2),(HS-PS1-3),(HS-PS1-4),(HS-PS1-5),(HS-PS1-7),(HS-PS1-8)
HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. (HS-PS1-4),(HS-PS1-7),(HS-PS1-8)
HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS1-2),(HS-PS1-3),(HS-PS1-4),(HS-PS1-5),(HS-PS1-7), (HS-PS1-8)

Computer Science and Design Thinking:
8.1.12.DA.1: Create interactive data visualizations using software tools to help others better understand real world phenomena, including climate change.
8.1.12.DA.5: Create data visualizations from large data sets to summarize, communicate, and support different interpretations of real-world phenomena.
8.1.12.DA.6: Create and refine computational models to better represent the relationships among different elements of data collected from a phenomenon or process.
8.1.12.NI.3: Explain how the needs of users and the sensitivity of data determine the level of security implemented.

NJ SLS Companion Standards: Reading and Writing Standards for History, Social Studies, Science, and Technical Subjects:

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)
WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-PS2-6),(HS-PS3-2)
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-PS2-6),(HS-PS3-2)
WHST.9-12.9 Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS2-6), (HS-PS3-2)

Unit Understandings:
Students will understand that…
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- Atoms or ions bond due to interactions between them, forming molecules.
- Molecular compounds are arranged based on Lewis diagrams and Valence Shell Electron Pair Repulsion (VSEPR) theory.

Unit Essential Questions:
- How do bonds form to characterize different structures?

Knowledge and Skills:

Students will know…..
- Types of bonds formed and resulting structures based on valence electrons, periodic trends and element classification.
- The bonding properties of substances based on analysis of Maxwell-Boltsman curves bond potential energy diagrams.
- The strength of bonds and compounds based on the application of Coulomb's Law to explain.
- How to represent the types of bonding in different solid structures.
- The creation and analysis of LEWIS structures with VSEPR notations to predict the following: resonance, formal charge and molecular geometry, bond angles, relative bond energies based on bond order, relative bond length , presence of a dipole moment, and hybridization of valence orbitals of the molecule.

Students will be able to …
- Explain the relationship between the type of bonding and the properties of the elements participating in the bond.
- Represent the relationship between potential energy and distance between atoms, based on factors that influence the interaction strength.
- Represent an ionic solid with a particulate model that is consistent with Coulomb's law and the properties of the constituent ions.
- Represent a metallic solid and/or alloy using a model to show essential characteristics of the structure and interactions present in the substance.
- Represent a molecule with a Lewis diagram.
- Represent a molecule with a Lewis diagram that accounts for resonance between equivalent structures or that uses formal charge to select between nonequivalent Structures.
- Based on the relationship between Lewis diagrams, VSEPR theory, bond orders, and bond polarities: a. Explain structural properties of molecules. b. Explain electron properties of molecules.

EVIDENCE OF LEARNING

Assessment:

What evidence will be collected and deemed acceptable to show that students truly "understand"?

- Students will apply principles of electron atomic structure to explain energetics of bonding.
- Students will differentiate and represent the types bonding in different substance's structures.
- Students use LEWIS structures and VSEPR to explain the properties of structures.
- Students will solve conceptual problems and chemistry math –based problems in guided practice, independent practice, and as homework.
- Students will complete AP Classroom assessments as well as a comprehensive exam on the unit, which will be composed of multiple choice, short answer, essay and lab practicum problems.

Learning Activities:

What differentiated learning experiences and instruction will enable all students to achieve the desired results?

- Bonding, molecular structure (LEWIS, VSEPR), solid structure PowerPoint slide class notes and word problem packets.
- Mini-group, peer activities.
    - POGIL on molecular LEWIS structure properties and application of VSEPR
    - Formal Charge online learning check.
    - Framework building exercise on bonding for amorphous crystals, ionic crystals, network solids, molecular solids, ionic solids, metals, metal alloys.
- Online simulations of bonding, bond energy, molecular structures, solid structures.
- AP Classroom videos, formative assessments and progress checks.

RESOURCES

Teacher Resources:

- Zumdahl, Steven S., et.al. Chemistry, 10th Edition, Boston New York, Cengage Learning, 2018
- AP Chemistry Guided Inquiry Experiments: Applying the Science Practices. 2019.
- Volz, Donald, Smola, Ray. Investigating Chemistry through Inquiry 1st edition. Vernier Software & Technology, 2010.
- AP Chemistry Classroom, College Board web access.

Equipment Needed:

- Computer, projector and laptop connections. Vernier Labquest, calculators.
- Laboratory equipment and chemicals for demonstrations and labs.

RAHWAY PUBLIC SCHOOLS AP CHEMISTRY CURRICULUM

UNIT OVERVIEW

Content Area: AP Chemistry

Unit Title: Unit 3 Intermolecular Forces, Properties and Application

Target Course/Grade Level: Grade 11, 12

Unit Summary: The properties of solids, liquids, and gases are a result of the relative orderly arrangement, their relative freedom of motion, size as well as the nature and strength of the interactions between particles. The relationship between the macroscopic properties of solids, liquids, and gases, as well as the underlying structure of the constituent particles of those materials on the molecular and atomic scale is important to understand the physical properties, chemical properties and analytical methods to separate or quantify substances.

Approximate Length of Unit: 14 class periods

LEARNING TARGETS

NJ Student Learning Standards:
HS-PS1-3. Matter and Its Interactions: 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.
H.S.PS1 -7. Matter and Its Interaction: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
H.S.PS2-6. Motion and Stability: Forces and Interactions: Communicate scientific and technical information about why the molecular level structure is important in the functioning of designed materials.
HS- PS4-1. Waves and Their Applications in Technologies for Information Transfer: Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.
HS-PS4-2. Evaluate questions about the advantages of using a digital transmission and storage of information.
HS- PS4-3. Waves and Their Applications in Technologies for Information Transfer: 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.
HS- PS4-5. Waves and Their Applications in Technologies for Information Transfer: Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.

Science and Engineering Practices:
Asking questions and defining problems:
- 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)

Planning and carrying out investigations:
- Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-PS1-3)

Using mathematics and computational thinking:

- Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations. (HS-PS1-7) , (HS-PS4-1)

Engaging in Argument from Evidence:

- 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:

- 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)
- 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)

Disciplinary Core Ideas:

PS1.A: Structure and Properties of Matter

- The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (HS-PS1-3),(secondary to HS-PS2-6)

PS1.B: Chemical Reactions

- The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. (HS-PS1-2),(HS-PS1-7).

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. (secondary to HS-PS1- 1),(secondary to HS-PS1-3)
- 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-PS2-6), (secondary to HS-PS1-1), (secondary to HS-PS1-3)

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)
- Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses. (HS-PS4-2), (HS-PS4-5)

PS4.A: Electromagnetic Radiation

- 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)
- Photoelectric materials emit electrons when they absorb light of a high-enough frequency. (HS-PS4-5)

PS4.C: Information Technologies and Instrumentation

- Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them. (HS-PS4-5)

Cross Cutting 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-PS1-2),(HS-PS1-3),(HS-PS1-5)

Energy and Matter:

- The total amount of energy and matter in closed systems is conserved. (HS-PS1-7)

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 solve a problem. (HS-PS2-6**)**

Cause and Effect:

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS4-1)
- 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. (HSPS4-2)

Connections to Engineering, Technology, and Applications of Science
Interdependence of Science Engineering, and Technology:
Science and engineering complement each other in the cycle known as research and development (R&D). (HS-PS4-5)
Influence of Engineering, Technology, and Science on Society and the Natural World:
Modern civilization depends on major technological systems. (HSPS4-2), (HS-PS4-5)

Connections to Nature of Science Scientific Knowledge Assumes an Order and Consistency in Natural Systems:
Science assumes the universe is a vast single system in which basic laws are consistent. (HS-PS1-7)

Career Readiness, Life Literacies, and Key Skills:
SCIENCE, TECHNOLOGY, ENGINEERING & MATHEMATICS (ST)
9.3.ST.1 Apply engineering skills in a project that requires project management, process control and quality assurance.
9.3.ST.3 Describe and follow safety, health and environmental standards related to science, technology, engineering and mathematics (STEM) workplaces.
9.3.ST.6 Demonstrate technical skills needed in a chosen STEM field.

ENGINEERING & TECHNOLOGY CAREER PATHWAY (ST-ET)
9.3.ST-ET.2 Display and communicate STEM information.

SCIENCE & MATHEMATICS CAREER PATHWAY (ST-SM)
9.3.ST-SM.2 Apply science and mathematics concepts to the development of plans, processes and projects that address real world problems.
9.3.ST-SM.3 Analyze the impact that science and mathematics has on society.

Career Ready Practices:
CRP1. Act as a responsible and contributing citizen and employee.
CRP2. Apply appropriate academic and technical skills.
CRP4. Communicate clearly and effectively and with reason.
CRP5. Consider the environmental, social and economic impacts of decisions.
CRP6. Demonstrate creativity and innovation.
CRP7. Employ valid and reliable research strategies.
CRP8. Utilize critical thinking to make sense of problems and persevere in solving them.
CRP9. Model integrity, ethical leadership and effective management.
CRP11. Use technology to enhance productivity.
CRP12. Work productively in teams while using cultural global competence.

Interdisciplinary Connections and 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-PS1-3),(HS-PS1-5)
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),(HS-PS1-6)
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)
Mathematics:
MP.2 Reason abstractly and quantitatively. (HS-PS1-5),(HS-PS1-7)
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-PS1-3),(HS-PS1-4),(HS-PS1-5),(HS-PS1-7),(HS-PS1-8)
HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. (HS-PS1-4),(HS-PS1-7),(HS-PS1-8)
HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS1-2),(HS-PS1-3),(HS-PS1-4),(HS-PS1-5),(HS-PS1-7), (HS-PS1-8)

Computer Science and Design Thinking:
8.1.12.DA.1: Create interactive data visualizations using software tools to help others better understand real world phenomena, including climate change.
8.1.12.DA.5: Create data visualizations from large data sets to summarize, communicate, and support different interpretations of real-world phenomena.
8.1.12.DA.6: Create and refine computational models to better represent the relationships among different elements of data collected from a phenomenon or process.
8.1.12.NI.3: Explain how the needs of users and the sensitivity of data determine the level of security implemented.

NJ SLS Companion Standards: Reading and Writing Standards for History, Social Studies, Science, and Technical Subjects:
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-PS1-5)
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),(HS-PS1-6)
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)

Unit Understandings:

Students will understand that…
- Intermolecular forces can explain the physical properties of a material.
- Matter exists in three states: solid, liquid, and gas, and their differences are influenced by variances in

spacing and motion of the molecules.
- Gas properties are explained macroscopically—using the relationships among pressure, volume, temperature, moles, gas constant—and molecularly by the motion of the gas.
- Interactions between intermolecular forces influence the solubility and separation of mixtures.
- Spectrophotometry can be used as an analytical tool to determine the structure and concentration chemical species in a mixture.

Unit Essential Questions:
- How are physical properties of substances used in the purification of materials?
- How are properties of gases useful in our everyday lives?
- How can we quantify substances in solutions using light?

Knowledge and Skills

Students will know…..
- Molecule classification and explanations for the different types of intermolecular forces of attraction (IMF) between molecules that result: London Dispersion, Dipole-Dipole, Dipole- induced, ion-dipole, hydrogen bonding.
- Differences in physical properties and explanations based on strengths of IMF (vapor pressure and boiling point , melting points) for ionic solids, covalent network solids, molecular, metals, large biomolecules or polymers, crystalline vs. amorphous solids, and solids vs liquids.
- Gas particles behave differently than liquids and solids due to their constant random motion. (Kinetic Energy = ½ mv^2) A.Their frequencies of collision and the average spacing between them are dependent on temperature, pressure, and volume. Because of this constant motion, and minimal effects of forces between particles, a gas has neither a definite volume nor a definite shape. [Kinetic Molecular Theory (KMT)]
- The macroscopic properties of ideal gases are related through the ideal gas law: EQN: PV = nRT. Deviations from the ideal gas law may result from interparticle attractions among gas molecules, particularly at conditions that are close to those resulting in condensation. Deviations may also arise from particle volumes, particularly at extremely high pressures.
- In a sample containing a mixture of ideal gases, the pressure exerted by each component (the partial pressure) is independent of the other components. Therefore, the total pressure of the sample is the sum of the partial pressures. EQN: PA = Ptotal × XA , where XA = moles A/total moles; EQN: Ptotal= PA + PB + PC
- The Maxwell-Boltzmann distribution describes the distribution of the kinetic energies of particles at a given temperature as well as energies/ velocities of particles at a given temperature.
- Solutions can be homogeneous or heterogeneous. The concentration of a homogeneous solution (Molarity EQN: M = n solute/L solution)
- Components in a solution can be separated using chromatography or distillation through application of IMF differences.
- Matter can absorb and emit different amounts of energy in the form of a photon of light (Electromagnetic spectrum). The wavelength of the electromagnetic wave is related to its frequency and the speed of light by the equation EQN: $c = \lambda\nu$. The energy of a photon is related to the frequency of the electromagnetic wave through Planck's equation ($E = h\nu$).
- Beer-Lambert law relates the absorption of light by a solution to three variables according to the equation: EQN: A = Ebc. (molar absorptivity E, cuvette path length b and concentration c are proportional to the number of absorbing species) l. Photspectroscopy applies Beer's Law to determine concentrations of unknown species; the absorbance is proportional only to the concentration of absorbing molecules or ions when b and E are constant.

Students will be able to …
- Explain the relationship between the chemical structures of molecules and the relative strength of their intermolecular forces when: a. The molecules are of the same chemical species; b. The molecules are of

two different chemical species

- Explain the relationship among the macroscopic properties of a substance, the particulate-level structure of the substance, and the interactions between these particles.
- Represent the differences between solid, liquid, and gas phases using a particulate- level model.
- Explain the relationship between the macroscopic properties of a sample of gas or mixture of gases using the Ideal Gas Law and Dalton's Law of Partial Pressure.
- Explain the relationship between the motion of particles and the macroscopic properties of gases with: a. The Kinetic Molecular Theory (KMT); b. A particulate model; c. A graphical representation.
- Explain the relationship among non-ideal behaviors of gases, interparticle forces, and/or volumes.
- Calculate the number of solute particles, volume, or molarity of solutions.
- Using particulate models for mixtures represent concentrations to components and interactions between components.
- Explain the relationship between the solubility of ionic and molecular compounds in aqueous and nonaqueous solvents, and the intermolecular interactions between particles.
- Explain the relationship between a region of the electromagnetic spectrum and the types of molecular or electronic transitions associated with that region.
- Explain the properties of an absorbed or emitted photon in relationship to an electronic transition in an atom or molecule.
- Explain the amount of light absorbed by a solution of molecules or ions in relationship to the

EVIDENCE OF LEARNING

concentration, path length, and molar absorptivity.

Assessment:

What evidence will be collected and deemed acceptable to show that students truly "understand"?

- Students will interpret molecular level understanding to differentiate intermolecular forces and physical properties for various substances.
- Students will apply the Kinetic Molecular Theory, Ideal Gas Law and Dalton's Law of Partial Pressure to explain volume, pressure, temperature, mass or velocity relationships.
- Students will apply an understanding of laboratory scientific measurement, underlying molecular level concepts and physical properties to the separation of substances.
- Students will analyze electromagnetic absorption spectra to identify quantities of analytes in solutions.
- Students will solve conceptual problems and chemistry math –based problems in guided practice, independent practice, and as homework.
- Students will complete AP Classroom assessments as well as a comprehensive exam on the unit, which will be composed of multiple choice, short answer, essay and lab practicum problems.

Learning Activities:

What differentiated learning experiences and instruction will enable all students to achieve the desired results?

- Unit PowerPoint slide class notes and word problem packets.
- AP Classroom videos, formative assessments and progress checks.
- Mini-group peer activities.
- Online and live demonstrations/ activities: intermolecular attractions and physical properties, gas properties and applications, separation techniques using physical properties, properties of light and analytical use.
- Activities and laboratory experiments including: Lab Activities: How do I know what food dye I am eating in M&Ms? How can inert gases be safely used? Collecting Gas Over Water,

Application of Dalton's Law. What is the concentration of blue food dye used in different flavors of Gatorade?

RESOURCES

Teacher Resources:

- Zumdahl, Steven S., et.al. Chemistry, 10th Edition, Boston New York, Cengage Learning, 2018
- AP Chemistry Guided Inquiry Experiments: Applying the Science Practices. 2019.
- Volz, Donald, Smola, Ray. Investigating Chemistry through Inquiry 1st edition. Vernier Software & Technology, 2010.
- AP Chemistry Classroom, College Board web access.

Equipment Needed:

- Computer, projector and laptop connections. Vernier Labquest, calculators.
- Laboratory equipment and chemicals for demonstrations and labs.

RAHWAY PUBLIC SCHOOLS AP CHEMISTRY CURRICULUM

UNIT OVERVIEW

Content Area: AP Chemistry

Unit Title: Unit 4 Chemical Reactions

Target Course/Grade Level: Grade 11, 12

Unit Summary: Chemical changes involve the making and breaking of chemical bonds that allows for the rearrangement of atoms. Classification of chemical reactions allows one to develop balanced equations that explain molecular level changes in the reaction and also provides the basis for quantifying substances. A titration is an analytical tool used to quantify substances in solutions.

Approximate Length of Unit: 14 class periods

LEARNING TARGETS

NJ Student Learning Standards:
HS-PS1-2. Matter and Its Interaction: Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties
HS-PS1-7. Matter and Its Interaction: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
HS-PS2-6. Motion and Stability: Forces and Interactions: Communicate scientific and technical information about why the molecular level structure is important in the functioning of designed materials.

Science and Engineering Practices:
Constructing explanations and designing solutions:

- Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-PS1-2)

Using mathematics and computational thinking:

- Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations. (HS-PS1-7) , (HS-PS4-1)

Obtaining, evaluating, and communicating information:

- 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)

Disciplinary Core Ideas:
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-PS1-1),(HS-PS1-2)

- The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (secondary to HS-PS2-6)

PS1.B: Chemical Reactions:

- The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. (HS-PS1-2),(HS-PS1-7)

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-PS2-6) (secondary to HS-PS1-1),(secondary to HS-PS1-3)

Cross Cutting 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-PS1-2),(HS-PS1-3),(HS-PS1-5)

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 solve a problem. (HS-PS2-6**)**

Energy and Matter:

- The total amount of energy and matter in closed systems is conserved. (HS-PS1-7)

Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems:

- Science assumes the universe is a vast single system in which basic laws are consistent. (HS-PS1-7)

Career Readiness, Life Literacies, and Key Skills:

SCIENCE, TECHNOLOGY, ENGINEERING & MATHEMATICS (ST)

9.3.ST.1 Apply engineering skills in a project that requires project management, process control and quality assurance.

9.3.ST.3 Describe and follow safety, health and environmental standards related to science, technology, engineering and mathematics (STEM) workplaces.

9.3.ST.6 Demonstrate technical skills needed in a chosen STEM field.

ENGINEERING & TECHNOLOGY CAREER PATHWAY (ST-ET)

9.3.ST-ET.2 Display and communicate STEM information.

SCIENCE & MATHEMATICS CAREER PATHWAY (ST-SM)

9.3.ST-SM.2 Apply science and mathematics concepts to the development of plans, processes and projects that address real world problems.

9.3.ST-SM.3 Analyze the impact that science and mathematics has on society.

Career Ready Practices:

CRP1. Act as a responsible and contributing citizen and employee.
CRP2. Apply appropriate academic and technical skills.
CRP4. Communicate clearly and effectively and with reason.
CRP5. Consider the environmental, social and economic impacts of decisions.
CRP6. Demonstrate creativity and innovation.
CRP7. Employ valid and reliable research strategies.
CRP8. Utilize critical thinking to make sense of problems and persevere in solving them.
CRP9. Model integrity, ethical leadership and effective management.
CRP11. Use technology to enhance productivity.
CRP12. Work productively in teams while using cultural global competence.

Interdisciplinary Connections and 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), (HS-PS2-6)
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)
Mathematics:
MP.2 Reason abstractly and quantitatively. (HS-PS1-5),(HS-PS1-7)
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-PS1-3),(HS-PS1-4),(HS-PS1-5),(HS-PS1-7),(HS-PS1-8)
HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. (HS-PS1-4),(HS-PS1-7),(HS-PS1-8)
HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS1-2),(HS-PS1-3),(HS-PS1-4),(HS-PS1-5),(HS-PS1- 7),(HS-PS1-8)

Computer Science and Design Thinking:
8.1.12.DA.1: Create interactive data visualizations using software tools to help others better understand real world phenomena, including climate change.
8.1.12.DA.5: Create data visualizations from large data sets to summarize, communicate, and support different interpretations of real-world phenomena.
8.1.12.DA.6: Create and refine computational models to better represent the relationships among different elements of data collected from a phenomenon or process.
8.1.12.NI.3: Explain how the needs of users and the sensitivity of data determine the level of security implemented.

NJ SLS Companion Standards: Reading and Writing Standards for History, Social Studies, Science, and Technical Subjects:
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), (HS-PS2-6)
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)

Unit Understandings:
Students will understand that…
- A substance that changes its properties, or that changes into a different substance, can be represented by chemical equations.
- When a substance changes into a new substance, or when its properties change, no mass is lost or gained.
- A substance can change into another substance through different processes, and the change itself can be classified by the sort of processes that produced it.

Unit Essential Questions:
- How do we know a chemical reaction has happened?
- How can we use titration to identify quantities of substances?

Knowledge and Skills:

Students will know…..

- Balanced molecular, complete ionic, and net ionic equations are differing symbolic forms used to represent a chemical reaction that occurs when substances are transformed into new substances, due to a rearrangement of atoms. These reactions produce heat or light, formation of a gas, formation of a precipitate, and/or color change.
- Processes that involve the breaking and/or formation of chemical bonds are typically classified as chemical processes. Processes that involve only changes in intermolecular interactions, such as phase changes, are typically classified as physical processes.
- Balanced chemical equations follow the Law of Conservation of Mass by using the mole coefficients. Stoichiometry is applied to quantitatively determine substance in chemical reactions.
- Acid-base reactions involve the transfer of a proton based on Brønsted-Lowry theory. These reactions can be written to convey the conjugate acid-base pairs. Acid-Base titrations may be used to determine the concentration of an analyte in solution based on the application of the equivalence point and stoichiometric calculations.
- Oxidation-reduction reactions involve transfer of one or more electrons between chemical species where one element is oxidized and the other is reduced. Combustion, synthesis, decomposition and single displacement reactions often undergo oxidation reduction.
- Precipitation reactions frequently involve mixing ions in aqueous solution and typically are not oxidation-reduction.

Students will be able to ...

- Identify evidence of chemical and physical changes in matter.
- Represent changes in matter with a balanced chemical or net ionic equation: a. For physical changes; b. For given information about the identity of the reactants and/or products; c. For ions in a given chemical reaction.
- Represent a given chemical reaction or physical process with a consistent particulate model.
- Explain the relationship between macroscopic characteristics and bond interactions for a chemical or physical process.
- Explain changes in the amounts of reactants and products based on the balanced reaction equation for a chemical process.
- Identify the equivalence point in a titration based on the amounts of the titrant and analyte, assuming the titration reaction goes to completion.
- Identify a reaction as acid- base, oxidation-reduction, or precipitation.
- Identify species as Brønsted- Lowry acids, bases, and/or conjugate acid-base pairs, based on proton-transfer involving those species.
- Represent a balanced redox reaction equation using half-reactions.

EVIDENCE OF LEARNING

Assessment:

What evidence will be collected and deemed acceptable to show that students truly "understand"?

- Students will classify chemical reactions based on processes and molecular level understanding to identify reactant species, write balanced chemical equations, and quantify substances in the reactions.

- Students will investigate acid base and REDOX reactions to determine the amount of analyte in solutions by applying titration techniques and stoichiometry.
- Students will solve conceptual problems and chemistry math –based problems in guided practice, independent practice, and as homework.
- Students will complete AP Classroom assessments as well as a comprehensive exam on the unit, which will be composed of multiple choice, short answer, essay and lab practicum problems.

Learning Activities:

What differentiated learning experiences and instruction will enable all students to achieve the desired results?

- Unit PowerPoint slide class notes and word problem packets.
- AP Classroom videos, formative assessments and progress checks.
- Mini-group peer activities.
- Online and live demonstrations/ activities: combustion, synthesis, decomposition, single and double displacement reactions with conceptual explanation of molecular processes and quantification of reaction substances.
- Activities and laboratory experiments including: Lab Activities: Determination of Hard water. What is the identity of the acid? What is the % H_2O_2 in an over the counter product?

RESOURCES

Teacher Resources:

- Zumdahl, Steven S., et.al. Chemistry, 10th Edition, Boston New York, Cengage Learning, 2018
- AP Chemistry Guided Inquiry Experiments: Applying the Science Practices. 2019.
- Volz, Donald, Smola, Ray. Investigating Chemistry through Inquiry 1st edition. Vernier Software & Technology, 2010.
- AP Chemistry Classroom, College Board web access.

Equipment Needed:

- Computer, projector and laptop connections. Vernier Labquest, calculators.
- Laboratory equipment and chemicals for demonstrations and labs.

RAHWAY PUBLIC SCHOOLS AP CHEMISTRY CURRICULUM

UNIT OVERVIEW

Content Area: AP Chemistry

Unit Title: Unit 5 Kinetics

Target Course/Grade Level: Grade 11, 12

Unit Summary: The rates at which chemical changes occur and the factors that influence the rates will be explored. Chemical changes are represented by chemical reactions, and the rates of chemical reactions are determined by the details of the molecular collisions. Experimental data of change of concentration as a function of time is used to determine rates of reactions. These chemical processes may be observed in a variety of ways and often involve changes in energy as well.

LEARNING TARGETS

Approximate Length of Unit: 14 class periods

NJ Student Learning Standards:
H.S.PS1-5. Matter and Its Interaction: Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration on the reacting particles on the rate at which a reaction will occur.
H.S.PS1-8. Matter and Its Interaction: Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during a chemical reaction.
HS-PS3-1. Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.

Science and Engineering Practices:
Developing and using models
- Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS1-4),(HS-PS1-8)

Using mathematics and computational thinking:
- Create a computational model or simulation of a phenomenon, designed device, process, or system. (HS-PS3-1)

Constructing explanations and designing solutions:
- Apply scientific principles and evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. (HS-PS1-5)

Disciplinary Core Ideas:
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)

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)

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. There is a single quantity called energy 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)

PS3.B: 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. (HS-PS3-1), (HS-PS3-4)
- Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. (HS-PS3-1)
- The availability of energy limits what can occur in any system. (HS-PS3-1)

Cross Cutting 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-PS1-2),(HS-PS1-3),(HS-PS1-5)

Energy and Matter:

- In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (HS-PS1-8)

Systems and System Models:

- 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)

Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems:

- Science assumes the universe is a vast single system in which basic laws are consistent. (HS-PS3-1)

Career Readiness, Life Literacies, and Key Skills:

SCIENCE, TECHNOLOGY, ENGINEERING & MATHEMATICS (ST)

9.3.ST.1 Apply engineering skills in a project that requires project management, process control and quality assurance.

9.3.ST.3 Describe and follow safety, health and environmental standards related to science, technology, engineering and mathematics (STEM) workplaces.

9.3.ST.6 Demonstrate technical skills needed in a chosen STEM field. ENGINEERING & TECHNOLOGY CAREER PATHWAY (ST-ET)

9.3.ST-ET.2 Display and communicate STEM information. SCIENCE & MATHEMATICS CAREER PATHWAY (ST-SM)

9.3.ST-SM.2 Apply science and mathematics concepts to the development of plans, processes and projects that address real world problems.

9.3.ST-SM.3 Analyze the impact that science and mathematics has on society.

Career Ready Practices:

CRP1. Act as a responsible and contributing citizen and employee.
CRP2. Apply appropriate academic and technical skills.
CRP4. Communicate clearly and effectively and with reason.
CRP5. Consider the environmental, social and economic impacts of decisions.
CRP6. Demonstrate creativity and innovation.
CRP7. Employ valid and reliable research strategies.
CRP8. Utilize critical thinking to make sense of problems and persevere in solving them.
CRP9. Model integrity, ethical leadership and effective management.
CRP11. Use technology to enhance productivity.

CRP12. Work productively in teams while using cultural global competence.

Interdisciplinary Connections and Standards:
ELA Literacy:
RST.11-21.1 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-PS1-5)
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)
Mathematics:
MP.2 Reason abstractly and quantitatively. (HS-PS3-1)
MP.4 Model with mathematics. (HS-PS1-8),(HS-PS3-1)
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-PS1-3),(HS-PS1-4),(HS-PS1-5),(HS-PS1-7),(HS-PS1-8)
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)

Computer Science and Design Thinking:
8.1.12.DA.1: Create interactive data visualizations using software tools to help others better understand real world phenomena, including climate change.
8.1.12.DA.5: Create data visualizations from large data sets to summarize, communicate, and support different interpretations of real-world phenomena.
8.1.12.DA.6: Create and refine computational models to better represent the relationships among different elements of data collected from a phenomenon or process.
8.1.12.NI.3: Explain how the needs of users and the sensitivity of data determine the level of security implemented.

NJ SLS Companion Standards: Reading and Writing Standards for History, Social Studies, Science, and Technical Subjects:
RST.11-21.1 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-PS1-5)
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)

Unit Understandings:
Students will understand that…
- Some reactions happen quickly, while others happen more slowly and depend on reactant concentrations and temperature.
- There is a relationship between the speed of a reaction and the collision frequency of particle collisions.
- Many chemical reactions occur through a series of elementary reactions. These elementary reactions when combined form a chemical equation.
- The speed at which a reaction occurs can be influenced by a catalyst.

Unit Essential Questions:
- What influences and determines rates of reactions?
- How do elementary step reactions explain overall reaction rates?

Knowledge and Skills:

Students will know…..

- Kinetics is the rate at which an amount of reactants is converted to products per unit of time and influenced by reactant concentrations, temperature, surface area, catalysts, which can be monitored experimentally.
- Experimental data determines
- The rate law expresses the rate of a reaction as proportional to the concentration of each reactant raised to a power. The power of each reactant in the rate law is the order of the reaction with respect to that reactant. The sum of the powers of the reactant concentrations in the rate law is the overall order of the reaction. The proportionality constant in the rate law is called the rate constant. The value of this constant is temperature dependent and the units reflect the overall reaction order. Comparing initial rates of a reaction is a method to determine the order with respect to each reactant.
- If a reaction is first order with respect to a reactant being monitored, a plot of the natural log (ln) of the reactant concentration as a function of time will be linear. If a reaction is second order with respect to a reactant being monitored, a plot of the reciprocal of the concentration of that reactant versus time will be linear. The slopes of the concentration versus time data for zeroth, first, and second order reactions can be used to determine the rate constant for the reaction. Zeroth order:EQN: $[A]_t - [A]_0 = -kt$; First order: EQN: $\ln[A]_t - \ln[A]_0 = -kt$ Second order: EQN: $1/[A]_t - 1/[A]_0 = kt$
- Half-life is a critical parameter for first order reactions because the half-life is constant and related to the rate constant for the reaction by the equation: EQN: $t_{1/2} = 0.693$. Radioactive decay processes provide an important illustration of first order kinetics.
- The rate law of an elementary reaction can be inferred from the stoichiometry of the molecules participating in a collision, and successful collisions have both sufficient energy to overcome energy barriers and orientations that allow the bonds to rearrange in the required manner. A collision is necessary to initiate bond-breaking and bond- making events.
- Maxwell-Boltzmann distribution curve describes the distribution of particle energies; this distribution can be used to gain a qualitative estimate of the fraction of collisions with sufficient energy to lead to a reaction, and also how that fraction depends on temperature.
- The reaction coordinate is the axis along which the complex set of motions involved in rearranging reactants to form products can be plotted. The energy profile gives the energy along the reaction coordinate, which typically proceeds from reactants, through a transition state, to products. The energy difference between the reactants and the transition state is the activation energy for the forward reaction.
- The Arrhenius equation relates the temperature dependence of the rate of an elementary reaction to the activation energy needed by molecular collisions to reach the transition state.
- A reaction mechanism consists of a series of elementary reactions, or steps, that occur in sequence. The components may include reactants, intermediates, products, and catalysts. The elementary steps when combined should align with the overall balanced equation of a chemical reaction, eliminating a reaction intermediate that is produced and consumed.
- For reaction mechanisms in which each elementary step is irreversible, or in which the first step is rate limiting, the rate law of the reaction is set by the molecularity of the slowest elementary step (i.e., the rate-limiting step). This elementary step determines the overall rate of reaction.
- In order for a catalyst to increase the rate of a reaction, the addition of the catalyst must increase the number of effective collisions and/ or provide a reaction path with a lower activation energy relative to the original reaction coordinate.
- In a reaction mechanism containing a catalyst, the net concentration of the catalyst is constant. However, the catalyst will frequently be consumed in the rate-determining step of the reaction, only to be regenerated in a subsequent step in the mechanism. Catalysts include enzymes, acid-base, and surface.

Students will be able to …

- Explain the relationship between the rate of a chemical reaction and experimental parameters.
- Represent experimental data with a consistent rate law expression.
- Identify the rate law expression of a chemical reaction using data that show how the concentrations of reaction species change over time.
- Represent an elementary reaction as a rate law expression using stoichiometry.
- Explain the relationship between the rate of an elementary reaction and the frequency, energy, and orientation of molecular collisions.
- Represent the activation energy and overall energy change in an elementary reaction using a reaction energy profile.
- Identify the components of a reaction mechanism.
- Identify the rate law for a reaction from a mechanism in which the first step is rate limiting.
- Identify the rate law for a reaction from a mechanism in which the first step is not rate limiting.
- Represent the activation energy and overall energy change in a multistep reaction with a reaction Explain the relationship between the effect of a catalyst on a reaction and changes in the reaction mechanism.

EVIDENCE OF LEARNING

Assessment:

What evidence will be collected and deemed acceptable to show that students truly "understand"?

- Students will apply stoichiometry of a substance's reaction rate to determine rates for other substances in a reaction.
- Students will apply experimental data to the determination of reaction rates and to rate order for reactions by analyzing mathematically and/ or graphical representations of concentration vs. time variables measured in the lab. Students will analyze and combine elementary step reactions eliminating intermediates and catalysts to develop molecular reactions, interpret elementary steps to derive the rate law .
- Students will interpret energy diagrams to explain the activation energy and the effect of catalysts.
- Students will solve conceptual problems and chemistry math –based problems in guided practice, independent practice, and as homework.
- Students will complete AP Classroom assessments as well as a comprehensive exam on the unit, which will be composed of multiple choice, short answer, essay and lab practicum problems.

Learning Activities:

What differentiated learning experiences and instruction will enable all students to achieve the desired results?

- Unit PowerPoint slide class notes and word problem packets.
- AP Classroom videos, formative assessments and progress checks.
- Mini-group peer activities.
- Online and live demonstrations/ activities:
- Activities and laboratory experiments including: How does concentration, temperature or a catalyst affect reaction rate and determine reaction order? How does the degradation of blue light using a spectrophotometer provide data to create plots of rate laws for rate law determination?

RESOURCES

Teacher Resources:

- Zumdahl, Steven S., et.al. Chemistry, 10th Edition, Boston New York, Cengage Learning, 2018
- AP Chemistry Guided Inquiry Experiments: Applying the Science Practices. 2019.
- Volz, Donald, Smola, Ray. Investigating Chemistry through Inquiry 1st edition. Vernier Software & Technology, 2010.
- AP Chemistry Classroom, College Board web access.

Equipment Needed:

- Computer, projector and laptop connections. Vernier Labquest, calculators.
- Laboratory equipment and chemicals for demonstrations and labs.

RAHWAY PUBLIC SCHOOLS AP CHEMISTRY CURRICULUM

UNIT OVERVIEW

Content Area: AP Chemistry

Unit Title: Unit 6 Thermodynamics

Target Course/Grade Level: Graded 11,12

Unit Summary: The First Law of Thermodynamics describes the essential role of energy, its conservation and transfer in the form of heat and work. Breaking chemical bonds requires energy, an endothermic process, making chemical bonds releases energy, an exothermic process. Overall energy transfer in reactions depends on this bond breaking and making process.

Approximate Length of Unit: 10 class periods

LEARNING TARGETS

NJ Student Learning Standards:
H.S.PS1-7. Matter and Its Interaction: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
HS-PS3-1. Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.
HS-PS3-2. Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects).
HS-PS3-4. Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperatures are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).

Science and Engineering Practices:
Developing and using models
- 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:
- 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:
- Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations. (HS-PS1-7) , (HS-PS4-1)
- Create a computational model or simulation of a phenomenon, designed device, process, or system. (HS-PS3-1)

Disciplinary Core Ideas:
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. There is a single quantity called energy 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)
- These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. (HS-PS3-2)

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)
- Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. (HS-PS3-1)
- 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)

Cross Cutting Concepts:

Systems and 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:
- The total amount of energy and matter in closed systems is conserved. (HS-PS1-7)
- 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)

Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems:
- Science assumes the universe is a vast single system in which basic laws are consistent. (HS-PS1-7),(HS-PS3-1)

Career Readiness, Life Literacies, and Key Skills:

SCIENCE, TECHNOLOGY, ENGINEERING & MATHEMATICS (ST)

9.3.ST.1 Apply engineering skills in a project that requires project management, process control and quality assurance.

9.3.ST.3 Describe and follow safety, health and environmental standards related to science, technology, engineering and mathematics (STEM) workplaces.

9.3.ST.6 Demonstrate technical skills needed in a chosen STEM field. ENGINEERING & TECHNOLOGY CAREER PATHWAY (ST-ET)

9.3.ST-ET.2 Display and communicate STEM information. SCIENCE & MATHEMATICS CAREER PATHWAY (ST-SM)

9.3.ST-SM.2 Apply science and mathematics concepts to the development of plans, processes and projects that address real world problems.
9.3.ST-SM.3 Analyze the impact that science and mathematics has on society.

Career Ready Practices:
CRP1. Act as a responsible and contributing citizen and employee.
CRP2. Apply appropriate academic and technical skills.
CRP4. Communicate clearly and effectively and with reason.
CRP5. Consider the environmental, social and economic impacts of decisions.
CRP6. Demonstrate creativity and innovation.
CRP7. Employ valid and reliable research strategies.
CRP8. Utilize critical thinking to make sense of problems and persevere in solving them.
CRP9. Model integrity, ethical leadership and effective management.
CRP11. Use technology to enhance productivity.
CRP12. Work productively in teams while using cultural global competence.

I**nterdisciplinary Connections and 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)
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-PS1-5),(HS-PS1-7)
MP.4 Model with mathematics. (HS-PS1-4),(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-PS1-2),(HS-PS1-3),(HS-PS1-4),(HS-PS1-5),(HS-PS1-7),(HS-PS1-8)
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)

Computer Science and Design Thinking:
8.1.12.DA.1: Create interactive data visualizations using software tools to help others better understand real world phenomena, including climate change.
8.1.12.DA.5: Create data visualizations from large data sets to summarize, communicate, and support different interpretations of real-world phenomena.
8.1.12.DA.6: Create and refine computational models to better represent the relationships among different elements of data collected from a phenomenon or process.
8.1.12.NI.3: Explain how the needs of users and the sensitivity of data determine the level of security implemented.

NJ SLS Companion Standards: Reading and Writing Standards for History, Social Studies, Science, and Technical Subjects:
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)
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)

Unit Understandings:
Students will understand that…
.
- Changes in a substance's properties or change into a different substance requires an exchange of energy.
- The energy exchanged in a chemical transformation is required to break and form bonds.

Unit Essential Questions:
- How is energy transferred?
- How is energy transformed in chemical reactions?

Knowledge and Skills:
Students will know…..

- Energy transfer can release heat (exothermic) or gain heat (endothermic) from the system to the surrounding in processes such as the heating or cooling of a substance, phase changes, solution formation, or chemical transformations. In these processes energy is conserved.
- A physical or chemical process can be described with an energy diagram that shows the endothermic or exothermic nature of that process.
- Particles in a warmer body have a greater average kinetic energy than those in a cooler body. Collisions between particles in thermal contact can result in the transfer of energy in the form of heat. Eventually, thermal equilibrium is reached as the particles continue to collide.
- The heating of a cool body by a warmer body is an important form of energy transfer between two systems. The amount of heat transferred between two bodies may be quantified by the heat transfer equation: EQN: $q = mc\Delta T$. Calorimetry experiments are used to measure the transfer of heat.
- The enthalpy change of a reaction gives the amount of heat energy per mole of a substance released (for negative values) or absorbed (for positive values) by a chemical reaction at constant pressure. EQN: $\Delta H= q/n$.
- During a chemical reaction, bonds are broken and/or formed, and these events change the potential energy of the system.

Students will be able to …
- Explain the relationship between experimental observations and energy changes associated with a

chemical or physical transformation.

- Represent a chemical or physical transformation with an energy diagram.
- Explain the relationship between the transfer of thermal energy and molecular collisions.
- Calculate the heat q absorbed or released by a system undergoing heating/ cooling based on the amount of the substance, the heat capacity, and the change in temperature.
- Explain changes in the heat q absorbed or released by a system undergoing a phase transition based on the amount of the substance in moles and the molar enthalpy of the phase transition.
- Calculate the heat q absorbed or released by a system undergoing a chemical reaction in relationship to the amount of the reacting substance in moles and the molar enthalpy of reaction.
- Calculate the enthalpy change of a reaction based on the average bond energies of bonds broken and formed in the reaction.
- Calculate the enthalpy change for a chemical or physical process based on the standard enthalpies of formation.
- Represent a chemical or physical process as a sequence of steps.
- Explain the relationship between the enthalpy of a chemical or physical process and the sum of the enthalpies of the individual steps.

EVIDENCE OF LEARNING

Assessment:

What evidence will be collected and deemed acceptable to show that students truly "understand"?

- Students can "speak the language of energy transfer" being able to create a model and representation of energy transfer for physical and chemical transformations.
- Students can carry out energy transfer reactions in the lab and translate this information to calculate heat (q) and enthalpy (ΔH) to create thermochemical equations and write energy diagrams for processes such as heating or cooling of a substance, physical change, solutions formation, chemical transformation.
- Students will apply knowledge of endothermic, bond breaking, and exothermic, bond making, processes to calculate the enthalpy of reactions and write thermochemical equations and energy diagrams.
- Students can carry out elementary step thermochemical reactions in the lab and combine these reaction steps to write overall thermochemical reactions.
- Students will solve conceptual problems and chemistry math –based problems in guided practice, independent practice, and as homework.
- Students will complete AP Classroom assessments as well as a comprehensive exam on the unit, which will be composed of multiple choice, short answer, essay and lab practicum problems.

Learning Activities:

What differentiated learning experiences and instruction will enable all students to achieve the desired results?

- Unit PowerPoint slide class notes and word problem packets.
- AP Classroom videos, formative assessments and progress checks.
- Mini-group peer activities.
- Online and live calorimetry demonstrations/ activities.
- Activities and laboratory experiments including: Optimizing a Hand Warmer; and Hess' Law Lab Application.

RESOURCES

Teacher Resources:

- Zumdahl, Steven S., et.al. Chemistry, 10th Edition, Boston New York, Cengage Learning, 2018
- AP Chemistry Guided Inquiry Experiments: Applying the Science Practices. 2019.
- Volz, Donald, Smola, Ray. Investigating Chemistry through Inquiry 1st edition. Vernier Software & Technology, 2010.
- AP Chemistry Classroom, College Board web access.

Equipment Needed:

- Computer, projector and laptop connections. Vernier Labquest, calculators.
- Laboratory equipment and chemicals for demonstrations and labs.

RAHWAY PUBLIC SCHOOLS AP CHEMISTRY CURRICULUM

UNIT OVERVIEW

Content Area:

Unit Title: Unit 7 Chemical Equilibrium

Target Course/Grade Level: Grade 11, 12

Unit Summary: Chemical equilibrium is a dynamic state in which opposing processes occur at the same rate. In this unit, students learn that any bond or intermolecular attraction that can be formed can be broken. These two processes are in a dynamic competition, sensitive to initial conditions and external perturbations. A change in conditions, such as addition of a chemical species, change in temperature, or change in volume, can cause the rate of the forward and reverse reactions to fall out of balance. Le Châtelier's principle provides a means to reason qualitatively about the direction of the shift in an equilibrium system resulting from various possible stresses. The expression for the equilibrium constant, K, is a mathematical expression that describes the equilibrium state associated with a chemical change. An analogous expression for the reaction quotient, Q, describes a chemical reaction at any point, enabling a comparison to the equilibrium state.

Approximate Length of Unit: 15 class periods

LEARNING TARGETS

NJ Student Learning Standards:
H.S.PS1-6. Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.
H.S.PS1 -7. Matter and Its Interaction: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.

Science and Engineering Practices:
Using mathematical and computational thinking:

- Use mathematical representations of phenomena to support claims. (HS-PS1-7)

Constructing explanations and Designing Solutions:

- Refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade off considerations. (HS-PS1-6)

Disciplinary Core Ideas:
PS1.B: Chemical Reactions:

- 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)

Cross Cutting Concepts:
Energy and Matter:

- The total amount of energy and matter in closed systems is conserved. (HS-PS1-7)

Stability and Change:

- Much of science deals with constructing explanations of how things change and how they remain stable. (HS-PS1-6)

Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems:

- Science assumes the universe is a vast single system in which basic laws are consistent. (HS-PS1-7)

Career Readiness, Life Literacies, and Key Skills:

SCIENCE, TECHNOLOGY, ENGINEERING & MATHEMATICS (ST)
9.3.ST.1 Apply engineering skills in a project that requires project management, process control and quality assurance.
9.3.ST.3 Describe and follow safety, health and environmental standards related to science, technology, engineering and mathematics (STEM) workplaces.
9.3.ST.6 Demonstrate technical skills needed in a chosen STEM field. ENGINEERING & TECHNOLOGY CAREER PATHWAY (ST-ET)
9.3.ST-ET.2 Display and communicate STEM information. SCIENCE & MATHEMATICS CAREER PATHWAY (ST-SM)
9.3.ST-SM.2 Apply science and mathematics concepts to the development of plans, processes and projects that address real world problems.
9.3.ST-SM.3 Analyze the impact that science and mathematics has on society.

Career Ready Practices:

CRP1. Act as a responsible and contributing citizen and employee.
CRP2. Apply appropriate academic and technical skills.
CRP4. Communicate clearly and effectively and with reason.
CRP5. Consider the environmental, social and economic impacts of decisions.
CRP6. Demonstrate creativity and innovation.
CRP7. Employ valid and reliable research strategies.
CRP8. Utilize critical thinking to make sense of problems and persevere in solving them.
CRP9. Model integrity, ethical leadership and effective management.
CRP11. Use technology to enhance productivity.
CRP12. Work productively in teams while using cultural global competence.

Interdisciplinary Connections and Standards:

ELA Literacy:

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. (HSPS1-3),(HS-PS1-6)

Mathematics:

MP.2 Reason abstractly and quantitatively. (HS-PS1-5),(HS-PS1-7)
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-PS1-3),(HS-PS1-4),(HS-PS1-5),(HS-PS1-7),(HS-PS1-8)
HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. (HS-PS1-4),(HS-PS1-7),(HS-PS1-8)
HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS1-2),(HS-PS1-3),(HS-PS1-4),(HS-PS1-5),(HS-PS1- 7),(HS-PS1-8)

Computer Science and Design Thinking:

8.1.12.DA.1: Create interactive data visualizations using software tools to help others better understand real world phenomena, including climate change.
8.1.12.DA.5: Create data visualizations from large data sets to summarize, communicate, and support different interpretations of real-world phenomena.
8.1.12.DA.6: Create and refine computational models to better represent the relationships among different elements of data collected from a phenomenon or process.
8.1.12.NI.3: Explain how the needs of users and the sensitivity of data determine the level of security implemented.

NJ SLS Companion Standards: Reading and Writing Standards for History, Social Studies, Science, and Technical Subjects:
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),(HS-PS1-6)

Unit Understandings:
Students will understand that…
- Some reactions can occur in both forward and reverse directions, sometimes proceeding in each direction simultaneously.
- A system at equilibrium depends on the relationships between concentrations, partial pressures of chemical species, and equilibrium constant K.
- Systems at equilibrium respond to external stresses to offset the effect of the stress. The dissolution of a salt is a reversible process that can be influenced by environmental factors such as pH or other dissolved ions.

Unit Essential Questions:
- How do systems achieve reversible equilibrium reactions?
- How can an equilibrium position be changed?
- How do we interpret the dynamic processes involved in equilibrium positions?

Knowledge and Skills:
Students will know…..

- The equilibrium state is dynamic and often an observable process. The forward and reverse processes continue to occur at equal rates, resulting in no net observable change in the concentrations or partial pressures of all species.
- Graphs of concentration, partial pressure, or rate of reaction versus time for simple chemical reactions can be used to understand the establishment of chemical equilibrium.
- If the rate of the forward reaction is greater than the reverse reaction, then there is a net conversion of reactants to products. If the rate of the reverse reaction is greater than that of the forward reaction, then there is a net conversion of products to reactants. An equilibrium state is reached when these rates are equal.
- The reaction quotient Qc or Qp describes the relative concentrations of reaction species at any time. Equilibrium constants Kc or Kp can be determined from experimental measurements of the concentrations or partial pressures of the reactants and products at equilibrium. When Q=K the system is at equilibrium. K and Q are multiplicative functions.
- The concentrations or partial pressures of species at equilibrium can be predicted given the balanced reaction, initial concentrations, and the appropriate K.
- Le Châtelier's principle can be used to predict the response of a system to stresses such as addition or removal of a chemical species, change in temperature, change in volume/ pressure of a gas-phase

system, or dilution of a reaction system. Le Châtelier’s principle can be used to pH, temperature, and color of a solution.

- The solubility of a substance can be calculated from the Ksp for the dissolution process. This relationship can also be used to predict the relative solubility of different substances and also predict the effect a common ion will have on a system. Le Châtelier’s principle is applied to qualitatively understand these types of systems.

Students will be able to …

- Explain the relationship between the occurrence of a reversible chemical or physical process, and the establishment of equilibrium, to experimental observations.
- Explain the relationship between the direction in which a reversible reaction proceeds and the relative rates of the forward and reverse reactions.
- Represent the reaction quotient Qc or Qp, for a reversible reaction, and the corresponding equilibrium expressions Kc = Qc or Kp = Qp.
- Calculate Kc or Kp based on experimental observations of concentrations or pressures at equilibrium.
- Explain the relationship between very large or very small values of K and the relative concentrations of chemical species at equilibrium.
- Represent a multistep process with an overall equilibrium expression, using the constituent K expressions for each individual reaction.
- Identify the concentrations or partial pressures of chemical species at equilibrium based on the initial conditions and the equilibrium constant.
- Represent a system undergoing a reversible reaction with a particulate model.
- Identify the response of a system at equilibrium to an external stress, using Le Châtelier's principle.
- Explain the relationships between Q, K, and the direction in which a reversible reaction will proceed to reach equilibrium.
- Calculate the solubility of a salt based on the value of Ksp for the salt.
- Identify the solubility of a salt, and/or the value of Ksp for the salt, based on the concentration of a common ion already present in solution.
- Identify the qualitative effect of changes in pH on the solubility of a salt.

EVIDENCE OF LEARNING

Assessment:

What evidence will be collected and deemed acceptable to show that students truly “understand”?

- Students will apply Le Châtelier's principle to predict the impact of stresses on different equilibrium processes.
- Students can analyze and solve equilibrium problems applying the ICE method, the multiplicative function of K, or through the interpretation of Q.
- Students will solve conceptual problems and chemistry math –based problems in guided practice, independent practice, and as homework.
- Students will complete AP Classroom assessments as well as a comprehensive exam on the unit, which will be composed of multiple choice, short answer, essay and lab practicum problems.

Learning Activities:

What differentiated learning experiences and instruction will enable all students to achieve the desired results?

- Unit PowerPoint slide class notes and word problem packets.
- AP Classroom videos, formative assessments and progress checks.

- Mini-group peer activities.
- Online and live demonstrations/ activities using the application of Le Châtelier's principle ; determining concentrations of substances and/or the value of K, the application of Q versus K.
- Activities and laboratory experiments including: Applying Le Châtelier's principle. Determining the Kc value of FeSCN. Determining the Ksp for $Ca(OH)_2$.

RESOURCES

Teacher Resources:

- Zumdahl, Steven S., et.al. Chemistry, 10th Edition, Boston New York, Cengage Learning, 2018
- AP Chemistry Guided Inquiry Experiments: Applying the Science Practices. 2019.
- Volz, Donald, Smola, Ray. Investigating Chemistry through Inquiry 1st edition. Vernier Software & Technology, 2010.
- AP Chemistry Classroom, College Board web access.

Equipment Needed:

- Computer, projector and laptop connections. Vernier Labquest, calculators.
- Laboratory equipment and chemicals for demonstrations and labs.

RAHWAY PUBLIC SCHOOLS AP CHEMISTRY CURRICULUM

UNIT OVERVIEW

Content Area: AP Chemistry

Unit Title: Unit 8 Acid-Base Chemistry and Equilibrium

Target Course/Grade Level: Grade 11, 12

Unit Summary: Chemical equilibrium plays an important role in acid-base chemistry and solubility. The proton-exchange reactions of acid-base chemistry are reversible reactions that reach equilibrium and can also be understood by applying the principles of chemical equilibrium

Approximate Length of Unit: 15 class periods

LEARNING TARGETS

NJ Student Learning Standards:
H.S.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.
H.S.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
H.S.PS1-6. Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.
H.S.PS1 -7. Matter and Its Interaction: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.

Science and Engineering Practices:
Developing and using models
- Use a model to predict the relationships between systems or between components of a system. (HS-PS1-1)

Using mathematical and computational thinking:
- Use mathematical representations of phenomena to support claims. (HS-PS1-7)

Constructing explanations and Designing Solutions:
- Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (HS-PS1-2)
- Refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade off considerations. (HS-PS1-6)

Disciplinary Core Ideas:
PS1.B: Chemical Reactions:
- 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)

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-PS2-6) (secondary to HS-PS1-1),(secondary to HS-PS1-3)

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-PS1-6)

Cross Cutting 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-PS1-2),(HS-PS1-3),(HS-PS1-5)

Energy and Matter:

- The total amount of energy and matter in closed systems is conserved. (HS-PS1-7)

Stability and Change:

- Much of science deals with constructing explanations of how things change and how they remain stable. (HS-PS1-6)

Connections to Nature of Science

Scientific Knowledge Assumes an Order and Consistency in Natural Systems:

- Science assumes the universe is a vast single system in which basic laws are consistent. (HS-PS1-7)

Career Readiness, Life Literacies, and Key Skills:

SCIENCE, TECHNOLOGY, ENGINEERING & MATHEMATICS (ST)

9.3.ST.1 Apply engineering skills in a project that requires project management, process control and quality assurance.

9.3.ST.3 Describe and follow safety, health and environmental standards related to science, technology, engineering and mathematics (STEM) workplaces.

9.3.ST.6 Demonstrate technical skills needed in a chosen STEM field. ENGINEERING & TECHNOLOGY CAREER PATHWAY (ST-ET)

9.3.ST-ET.2 Display and communicate STEM information. SCIENCE & MATHEMATICS CAREER PATHWAY (ST-SM)

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Career Ready Practices:

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CRP6. Demonstrate creativity and innovation.
CRP7. Employ valid and reliable research strategies.
CRP8. Utilize critical thinking to make sense of problems and persevere in solving them.
CRP9. Model integrity, ethical leadership and effective management.
CRP11. Use technology to enhance productivity.
CRP12. Work productively in teams while using cultural global competence.

I**nterdisciplinary Connections and 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)
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-PS1-3),(HS-PS1-6)

Mathematics:
MP.2 Reason abstractly and quantitatively. (HS-PS1-5),(HS-PS1-7)
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-PS1-3),(HS-PS1-4),(HS-PS1-5),(HS-PS1-7),(HS-PS1-8)
HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. (HS-PS1-4),(HS-PS1-7),(HS-PS1-8)
HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS1-2),(HS-PS1-3),(HS-PS1-4),(HS-PS1-5),(HS-PS1- 7),(HS-PS1-8)

Computer Science and Design Thinking:
8.1.12.DA.1: Create interactive data visualizations using software tools to help others better understand real world phenomena, including climate change.
8.1.12.DA.5: Create data visualizations from large data sets to summarize, communicate, and support different interpretations of real-world phenomena.
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Unit Understandings:
Students will understand that…
- The chemistry of acids and bases involves reversible proton-transfer reactions, with equilibrium concentrations being related to the strength of the acids and bases involved.
- A buffered solution resists changes to its pH when small amounts of acid or base are added.

Unit Essential Questions:
- What makes a solution acidic, basic or neutral?
- How do acids and bases achieve equilibrium?
- How are titrations used to understand acid base reactions?
- How do buffers work?

Knowledge and Skills:
Students will know…..

- The pH, pOH, acidity or basicity of solutions is based on the ratio of [H_3O+]: [OH−], and derived from the equilibrium equation for the dissociation of water EQN: Kw = [H_3O+][OH−] = 1.0×10^{-14} at 25°C. With the following derived equations: 1. EQN: pH = −log[H_3O+] EQN: pOH = −log[OH−] ;2. pH = pOH is called a neutral solution. At 25°C, pKw = 14.0 and thus pH = pOH = 7.0. EQN: pKw= pKa * pKb; 3. EQN: 14 = pH + pOH at 25°C.
- Strong acid and bases completely dissociate in water to make 100% [H_3O+] or [OH−] so pH for an acid = = −log[H_3O+], and pOH for a base = −log[OH−].
- For weak acids and weak bases only a small percent of the molecule is ionized in water so the solution comes to equilibrium between the un-ionized and ionized particles. The equilibrium constant for a weak acid reaction is Ka, often reported as pKa. The pH of a weak acid solution can be determined from the initial acid concentration and the pKa. EQN: Ka = [H_3O^+][HA]
EQN: pKa = −log Ka. [A^-]
- The equilibrium constant for this reaction is Kb, often reported as pKb. The pH of a weak base solution can be determined from the initial base concentration and the pKb.
EQN: Kb = [OH−][HB] EQN: pKb = −log Kb [B^-]

- Acid- Base titration produces different quantities of either equimolar substances or limiting and excess reactants requiring the application of stoichiometry to solve for quantities of substances in solution that are affecting the pH/pOH and the systems can be represented and analyzed using a titration curve.
- Buffers can be prepared using weak acid : HA(aq) + OH−(aq) A−(aq) H2O(l) and / or weak base B(aq) + H_3O+(aq)⇆ HB+(aq) + H_2O(l) systems and the pH can be determined from the Henderson-Hasselbalch equation.
- For titrations of weak acids/bases, it is useful to consider the point halfway to the equivalence point, that is, the half-equivalence point. At this point, there are equal concentrations of each species in the conjugate acid-base pair, for example, for a weak acid [HA] = [A−]. Because pH = pKa when the conjugate acid and base have equal concentrations, the pKa can be determined from the pH at the half-equivalence point in a titration.
- For polyprotic acids, titration curves can be used to determine the number of acidic protons. In doing so, the major species present at any point along the curve can be identified, along with the pKa associated with each proton in a weak polyprotic acid.
- The protons on a molecule that will participate in acid-base reactions, and the relative strength of these protons, can be inferred from the molecular structure.
- Increasing the concentration of the buffer components (while keeping the ratio of these concentrations constant) keeps the pH of the buffer the same but increases the capacity of the buffer to neutralize added acid or base. When a buffer has more conjugate acid than base, it has a greater buffer capacity for addition of added base than acid. When a buffer has more conjugate base than acid, it has a greater buffer capacity for addition of added acid than base.

Students will be able to …

- Calculate the values of pH and pOH, based on Kw and the concentration of all species present in a neutral solution of water.
- Calculate pH and pOH based on concentrations of all species in a solution of a strong acid or a strong base. Explain the relationship among pH, pOH, and concentrations of all species in a solution of a monoprotic weak acid or weak base.
- Explain the relationship among the concentrations of major species in a mixture of weak and strong acids and bases.
- Explain results from the titration of a mono- or polyprotic acid or base solution, in relation to the

properties of the solution and its components.
- Explain the relationship between the strength of an acid or base and the structure of the molecule or ion.
- Explain the relationship between the predominant form of a weak acid or base in solution at a given pH and the pKa of the conjugate acid or the pKb of the conjugate base.
- Explain the relationship between the ability of a buffer to stabilize pH and the reactions that occur when an acid or a base is added to a buffered solution.
- Identify the pH of a buffer solution based on the identity and concentrations of the conjugate acid-base pair used to create the buffer.
- Explain the relationship between the buffer capacity of a solution and the relative concentrations of the conjugate acid and conjugate base components of the solution.

EVIDENCE OF LEARNING

Assessment:
What evidence will be collected and deemed acceptable to show that students truly "understand"?

- Students will apply experimental data to the determination of concentrations of analytes, pH and pOH in different acid base systems.
- Students will analyze titration data and curves to determine concentrations of analytes, pH and pOH in different acid base systems.
- Students will apply an understanding of structures, chemical acid base reactions to explaining equilibrium and nonequilibrium acid base systems.
- Students will analyze and explain buffering systems and determine their buffering capacity.
- Students will solve conceptual problems and chemistry math –based problems in guided practice, independent practice, and as homework.
- Students will complete AP Classroom assessments as well as a comprehensive exam on the unit, which will be composed of multiple choice, short answer, essay and lab practicum problems.

Learning Activities:
What differentiated learning experiences and instruction will enable all students to achieve the desired results?

- Unit PowerPoint slide class notes and word problem packets.
- AP Classroom videos, formative assessments and progress checks.
- Mini-group peer activities.
- Online and live demonstrations/ activities acid base systems, buffers and reactions using titrations.
- Activities and laboratory experiments including:
  - Use titration to determine the molar mass of a monoprotic acid.
  - Build titration curves and analyze end points for different acid/base systems.
  - Use titration to the effect of buffers and no-buffering systems on pH.
  - Create a HH buffering system and test its buffering capacity.

RESOURCES

Teacher Resources:
- Zumdahl, Steven S., et.al. Chemistry, 10th Edition, Boston New York, Cengage Learning, 2018
- AP Chemistry Guided Inquiry Experiments: Applying the Science Practices. 2019.

- Volz, Donald, Smola, Ray. Investigating Chemistry through Inquiry 1st edition. Vernier Software & Technology, 2010.
- AP Chemistry Classroom, College Board web access.

Equipment Needed:

- Computer, projector and laptop connections. Vernier Labquest, calculators.
- Laboratory equipment and chemicals for demonstrations and labs.

RAHWAY PUBLIC SCHOOLS AP CHEMISTRY CURRICULUM

UNIT OVERVIEW

Content Area: AP Chemistry

Unit Title: Unit 9 Application of Thermodynamics and Electrochemistry

Target Course/Grade Level: Grade 11, 12

Unit Summary: The thermodynamics of a chemical reaction is connected to both the structural aspects of the reaction and the macroscopic outcomes of the reaction. All changes in matter involve some form of energy change. One key determinant of chemical transformations is the change in potential energy that results from changes in electrostatic forces. Chemical systems undergo three main processes that change their energy: heating/cooling, phase transitions, and chemical reactions. Applying the laws of thermodynamics will allow students to describe the essential role of energy and explain and predict the direction of changes in matter.

Approximate Length of Unit: 15 class periods

LEARNING TARGETS

NJ Student Learning Standards:
H.S.PS1-7. Matter and Its Interaction: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
HS-PS3-1. Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.
HS-PS3-2. Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects).
HS-PS3-3. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.
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).

Science and Engineering Practices:
Developing and using models
- 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:
- 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:
- Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations. (HS-PS1-7) , (HS-PS4-1)
- Create a computational model or simulation of a phenomenon, designed device, process, or system. (HS-

PS3-1)

Constructing explanations and designing solutions:

- Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade off considerations. (HS-PS3-3)

Disciplinary Core Ideas:

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. There is a single quantity called energy 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)
- These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. (HS-PS3-2)

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)
- Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g. relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. (HS-PS3-1)
- 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)

Cross Cutting 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 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:

- 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-PS3-3)
- 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)

Connections to Engineering, Technology, and Applications of Science
Connections to Nature of Science
Scientific Knowledge Assumes an Order and Consistency in Natural Systems:
- Science assumes the universe is a vast single system in which basic laws are consistent. (HS-PS1-7), (HS-PS3-1)

Influence of Science, Engineering, and Technology on Society and the Natural World
- Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (HS-PS3-3)

Career Readiness, Life Literacies, and Key Skills:
SCIENCE, TECHNOLOGY, ENGINEERING & MATHEMATICS (ST)
9.3.ST.1 Apply engineering skills in a project that requires project management, process control and quality assurance.
9.3.ST.3 Describe and follow safety, health and environmental standards related to science, technology, engineering and mathematics (STEM) workplaces.
9.3.ST.6 Demonstrate technical skills needed in a chosen STEM field. ENGINEERING & TECHNOLOGY CAREER PATHWAY (ST-ET)
9.3.ST-ET.2 Display and communicate STEM information. SCIENCE & MATHEMATICS CAREER PATHWAY (ST-SM)
9.3.ST-SM.2 Apply science and mathematics concepts to the development of plans, processes and projects that address real world problems.
9.3.ST-SM.3 Analyze the impact that science and mathematics has on society.

Career Ready Practices:
CRP1. Act as a responsible and contributing citizen and employee.
CRP2. Apply appropriate academic and technical skills.
CRP4. Communicate clearly and effectively and with reason.
CRP5. Consider the environmental, social and economic impacts of decisions.
CRP6. Demonstrate creativity and innovation.
CRP7. Employ valid and reliable research strategies.
CRP8. Utilize critical thinking to make sense of problems and persevere in solving them.
CRP9. Model integrity, ethical leadership and effective management.
CRP11. Use technology to enhance productivity.
CRP12. Work productively in teams while using cultural global competence.

I**nterdisciplinary Connections and 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)

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),(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-PS1-2),(HS-PS1-3),(HS-PS1-4),(HS-PS1-5),(HS-PS1-7),(HS-PS1-8)

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)

Computer Science and Design Thinking:

8.1.12.DA.1: Create interactive data visualizations using software tools to help others better understand real world phenomena, including climate change.

8.1.12.DA.5: Create data visualizations from large data sets to summarize, communicate, and support different interpretations of real-world phenomena.

8.1.12.DA.6: Create and refine computational models to better represent the relationships among different elements of data collected from a phenomenon or process.

8.1.12.NI.3: Explain how the needs of users and the sensitivity of data determine the level of security implemented.

NJ SLS Companion Standards: Reading and Writing Standards for History, Social Studies, Science, and Technical Subjects:

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)

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)

Unit Understandings:

Students will understand that…

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- Some chemical or physical processes cannot occur without intervention.
- The relationship between $\Delta G°$ and K can be used to determine favorability of a chemical or physical transformation.
- Electrical energy can be generated by chemical reactions.

Unit Essential Questions:

- What makes reactions happen spontaneously versus non-spontaneously?
- How do thermodynamically favored systems operate?

Knowledge and Skills:

Students will know…..

- Entropy increases when matter or energy becomes more dispersed. The entropy change for a process can be calculated from the absolute entropies of the species involved before and after the process occurs. EQN: ΔS^o reaction = ΣS^o products − ΣS^o reactants.
- The standard Gibbs free energy change for a chemical or physical process is a measure of thermodynamic favorability. When ΔG^o.< 0 for the process, it is said to be thermodynamically favored. $\Delta G^\circ_{\text{reaction}} = \Sigma \Delta G^o_{\text{f products}} - \Sigma \Delta G^o_{\text{f reactants}}$ OR EQN: $\Delta G^\circ = \Delta H^\circ - T\,\Delta S^\circ$
- Processes that are thermodynamically favored, but do not proceed at a measurable rate, are under "kinetic control." High activation energy is a common reason for a process to be under kinetic control.
- The phrase "thermodynamically favored" ($\Delta G^o < 0$) at equilibrium ($K > 1$). The equilibrium constant is related to free energy by the equations EQN: K = e−ΔG°/RT and EQN: $\Delta G^\circ = -RT \ln K$. Processes with $\Delta G^\circ < 0$ favor products (i.e., $K > 1$) and those with $\Delta G^\circ > 0$ favor reactants (i.e., $K < 1$).
- An external source of energy can be used to make a thermodynamically unfavorable process occur. Examples include: a. Electrical energy to drive an electrolytic cell or charge a battery. b. Light to drive the overall conversion of carbon dioxide to glucose in photosynthesis
- A desired product can be formed by coupling a thermodynamically unfavorable reaction that produces that product to a favorable reaction (e.g., the conversion of ATP to ADP in biological systems). The sum of the individual reactions produces an overall reaction that achieves the desired outcome and has $\Delta G^\circ <$ 0.
- Each component of an electrochemical cell (electrodes, solutions in the half-cells, salt bridge, voltage/current measuring device) plays a specific role in the overall functioning of the cell. The operational characteristics of the cell (galvanic vs. electrolytic, direction of electron flow, reactions occurring in each half-cell, change in electrode mass, evolution of a gas at an electrode, ion flow through the salt bridge) can be described at both the macroscopic and particulate level. Galvanic, sometimes called voltaic, cells involve a thermodynamically favored reaction, whereas electrolytic cells involve a thermodynamically not favored reaction.
- ENE-6.A.3 For all electrochemical cells, oxidation occurs at the anode and reduction occurs at the cathode. The standard cell potential of electrochemical cells can be calculated by identifying the oxidation and reduction half-reactions and their respective standard reduction potentials. ΔG° (standard Gibbs free energy change) is proportional to the negative of the cell potential using the equation EQN: $\Delta G^o = -nFE^o$
- The cell potential is a driving force toward equilibrium; the farther the reaction is from equilibrium, the greater the magnitude of the cell potential.
- The effects of concentration on cell potential can be derived from conceptual reasoning and qualitative use of the Nernst equation: EQN: $E = E^o - (RT/nF) \ln Q$.
- Faraday's laws can be used to determine the stoichiometry of the redox reaction occurring in an electrochemical cell EQN: $I = q/t$

Students will be able to …

- Identify the sign and relative magnitude of the entropy change associated with chemical or physical processes.
- Calculate the entropy change for a chemical or physical process based on the absolute entropies of the species involved in the process.
- Explain whether a physical or chemical process is thermodynamically favored based on an evaluation of ΔG^o.
- Explain, in terms of kinetics, why a thermodynamically favored reaction might not occur at a measurable rate.
- Explain whether a process is thermodynamically favored using the relationships between K, ΔG^o, and T.
- Explain the relationship between external sources of energy or coupled reactions and their ability to drive thermodynamically unfavorable processes.
- Explain the relationship between the physical components of an electrochemical cell and the overall operational principles of the cell.

- Explain whether an electrochemical cell is thermodynamically favored, based on its standard cell potential and the constituent half-reactions within the cell.
- Explain the relationship between deviations from standard cell conditions and changes in the cell potential.
- Calculate the amount of charge flow based on changes in the amounts of reactants and products in an electrochemical cell.

EVIDENCE OF LEARNING

Assessment:

What evidence will be collected and deemed acceptable to show that students truly "understand"?

- Students will analyze, compute and interpret standard data to determine the thermodynamic favorability of reactions and processes.
- Students will build a voltaic cell (and a series of cells) and explain the components of the cell, the reactions, the transfer of energy, and the cell voltage and thermodynamic favorability.
- Students will carry out laboratory and classroom exercises for non-standard cells and explain the difference between standard and non-standard cells by applying the Nernst equation.
- Students will compute the charge flow of electrolytic cells.
- Students will solve conceptual problems and chemistry math –based problems in guided practice, independent practice, and as homework.
- Students will complete AP Classroom assessments as well as a comprehensive exam on the unit, which will be composed of multiple choice, short answer, essay and lab practicum problems.

Learning Activities:

What differentiated learning experiences and instruction will enable all students to achieve the desired results?

- Unit PowerPoint slide class notes and word problem packets.
- AP Classroom videos.
- Mini-group peer activities.
- Online and live demonstrations/ activities of thermodynamically favored reactions and or processes such as voltaic cells (battery operation), electrolytic cells, solar cells, series of voltaic cells converting energy from chemical to electrical to light or mechanical energy.
- Activities and laboratory experiments including:
  - Gibbs Free Energy lab $\Delta G° = \Delta H° - T\ \Delta S°$
  - How can you build a battery to make a toy car run?
  - Aluminum air cell battery operation and energy conversion to light a diode or run a 1.5 V motor.

RESOURCES

Teacher Resources:

- Zumdahl, Steven S., et.al. Chemistry, 10th Edition, Boston New York, Cengage Learning, 2018
- AP Chemistry Guided Inquiry Experiments: Applying the Science Practices. 2019.
- Volz, Donald, Smola, Ray. Investigating Chemistry through Inquiry 1st edition. Vernier Software & Technology, 2010.
- AP Chemistry Classroom, College Board web access.

Equipment Needed:

- Computer, projector and laptop connections. Vernier Labquest, calculators.
- Laboratory equipment and chemicals for demonstrations and labs.