Robbinsville High School CP Chemistry Curriculum

Unit 1: Alchemy – An Introduction to Chemistry
Instructional Days: 6

Stage 1 – Desired Results

Unit Rationale:

During this unit students will be introduced to laboratory equipment used throughout the course along with the safety precautions one must take while using such items. Students will be given a "gold" coin at the start of the unit which they will need to determine if it's chemical or physical properties match that of elemental gold. To do so, students will explore intrinsic and extrinsic properties, including density. This unit will serve as a foundation for the course as students learn essential laboratory and mathematical skills that will be repeated often throughout the year.

Performance Expectations:

HS-PS1-7: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. [Clarification Statement: Emphasis is on using mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and the products, and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale. Emphasis is on assessing students' use of mathematical thinking and not on memorization and rote application of problem-solving techniques.] [Assessment Boundary: Assessment does not include complex chemical reactions.]

HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

Related Problems:

- Were the alchemists successful in turning cheap metals into valuable gold?

Standards

NGSS	**English Language Arts/Literacy**	**Mathematics**
• HS-PS1-7 • HS-ETS1-2	• RST.9-10.7 • WHST.11.12.8 • WHST.9-12.2	• HSN-Q.A.1 • HSN-Q.A.3

Enduring Understandings	Essential Questions
Students will understand that: • Laboratory equipment must be used properly in order to conduct sound experiments and prevent accidents • Matter can be identified using intrinsic properties	• What type equipment is used to study chemistry? How are these tools used properly and safely? What information can I obtain from these tools? • How are the metric system and dimensional analysis used in chemistry? • How can matter be classified and identified?

Science & Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematics and Computational Thinking Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. • Use mathematical representations of phenomena to support claims. **Constructing Explanations and Designing Solutions** Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles and theories. • Design a solution to a complex real-world problem based on scientific knowledge, student-generated sources of evidence, prioritized criteria,	**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	**Energy and Matter** The total amount of energy and matter in closed systems is conserved.

Stage 2 – Assessment Evidence

Performance Task(s)

A performance task for this unit could include the following criteria:

- Identification of the claim that atoms are conserved during a chemical reaction.
- Mathematically represent that atoms are conserved using numerical calculations, graphs, or other pictorial depictions of quantitative information.
- Students restate the original complex problem into a finite set of two or more sub-problems (in writing or as a diagram or flow chart).
- Students describe how solutions to sub-problems are interconnected to solve all or part of the larger problem

Other Evidence:

- Laboratory equipment group presentation
- Fool's Gold CER, including peer review, revision, then teacher feedback
- Unit test
- Formative assessments: Do nows, clicker questions, exit tickets, etc. will be given so that the teacher can monitor student learning, provide feedback, and assist in remediating student understandings

Stage 3 – Learning Plan

Suggested activities for this unit include:

- "Importance of Goggles" demonstration
- "Tools of the Trade" scavenger hunt and group presentations
- "Whatsa Matter?" card sort activity
- "Intrinsic & Extrinsic Properties" investigation
- "A Penny for Your Thoughts" experiment
- "Fool's Gold" investigation with CER report

Technology and the Nature of Science:

- **Assumes an Order and Consistency in Natural Systems**
  Science assumes the universe is a vast single system in which basic laws are consistent.

Possible Preconceptions/Misconceptions:

- There is only one correct way to solve a problem or investigate a problem
- Experimental error is due to personal mistakes or faulty equipment
- Substances that have the share similar properties must be classified the same way

How do I reinforce or build literacy or mathematics skills?

- CER writing
- Density practice problems; connection to similar equations (ie. F = ma)
- Identifying relevant evidence or information needed to solve a problem or support a claim

Unit 2: A Periodic Puzzle
Instructional Days: 7

Stage 1 – Desired Results

Unit Rationale:

The organization of the periodic table plays a critical role in understanding atomic and molecular structures, and subsequently, the properties of matter. This unit provides the framework students need in order to analyze and predict the structures and properties of matter.

Performance Expectations:

HS-PS1-1. **Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.** [Clarification Statement: Examples of properties that could be predicted from patterns could include reactivity of metals, types of bonds formed, numbers of bonds formed, and reactions with oxygen.] [*Assessment Boundary: Assessment is limited to main group elements. Assessment does not include quantitative understanding of ionization energy beyond relative trends.*]

HS-ETS1-3. **Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.**

Related Problems:

- What material is most energy and cost efficient for use in solar panels?

Standards

NGSS	**English Language Arts/Literacy**	**Mathematics**
• HS-PS1-1 • HS-ETS1-3	• RST.9-10.7 • RST.11-12.7 • RST.11-12.8 • RST.11-12.9	• MP.2 • MP.4 • HSN-QA.1 • HSN-QA.3

Enduring Understandings	**Essential Questions**
Students will understand that: • The periodic table is highly organized with repeating patterns both vertically and horizontally • The properties of matter can be predicted using the periodic table	• How can the properties of matter be predicted using the periodic table? • What factors play a role in the design and manufacturing of materials?

Science & Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s). • Use a model to predict the relationships between systems or between components of a system. **Constructing Explanations and Designing Solutions** Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles and theories. • Evaluate a solution to a complex real world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.	**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. • 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. **ETS1.B: Developing Possible Solutions** • When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.	**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.

Stage 2 – Assessment Evidence

Performance Task(s)

A performance task for this unit could include the following criteria:

- Identify and describe the components of a model that are relevant to predict the arrangement of elements on the periodic table
- Predict the properties of an element based upon its location on the periodic table
- Provide an evidence-based decision of which solution to a complex real-world problem is optimum, based on prioritized criteria, analysis of the strengths and weaknesses (costs and benefits) of each solution, and barriers to be overcome

Other Evidence:

- "Create a Table" poster
- "Properties of the Elements" CER
- "Solar Panel Design" project
- Unit test
- Formative assessments: Do nows, clicker questions, exit tickets, etc. will be given so that the teacher can monitor student learning, provide feedback, and assist in remediating student understandings

Stage 3 – Learning Plan

Suggested activities for this unit include:

- "Create a Table" card sort activity
- "Properties of the Periodic Table" investigation
- "The Modern Periodic Table" POGIL
- Solar panel research and design proposal project

Technology and the Nature of Science:

Influence of Science, Engineering, and Technology on Society and the Natural World
New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology

Possible Preconceptions/Misconceptions:

- All metal elements are solid which means all nonmetals must be liquids or gases

How do I reinforce or build literacy or mathematics skills?

- CER writing
- Research methods and analysis of found content
- Identifying relevant evidence or information needed to solve a problem or support a claim

Unit 3: Inside the Nucleus
Instructional Days: 10

Stage 1 – Desired Results

Unit Rationale:

The organization of the periodic table, which was discussed in the prior unit, plays an essential role in determining what the atoms of each element look like. Students will use the periodic table to accurately model atoms of a given element with the number of protons and electrons, as well as the number of neutrons in the most abundant isotope. Using computer simulations, students will observe how nuclear changes can result in either the formation of an isotope or radioactive decay. Students will investigate how radioactivity can be used to determine the age of artifacts and fossils using half-life. During the unit students will also relate the study of fission to the development of nuclear applications, especially nuclear power plants.

Performance Expectations:

HS-PS1-1. **Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.** [Clarification Statement: Examples of properties that could be predicted from patterns could include reactivity of metals, types of bonds formed, numbers of bonds formed, and reactions with oxygen.] [*Assessment Boundary: Assessment is limited to main group elements. Assessment does not include quantitative understanding of ionization energy beyond relative trends.*]

HS-PS1-8. **Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.** [Clarification Statement: Emphasis is on simple qualitative models, such as pictures or diagrams, and on the scale of energy released in nuclear processes relative to other kinds of transformations.] [*Assessment Boundary: Assessment does not include quantitative calculation of energy released. Assessment is limited to alpha, beta, and gamma radioactive decays.*]

Related Problems:

- Should we have nuclear power plants?

Standards

NGSS	**English Language Arts/Literacy**	**Mathematics**
• HS-PS1-1. • HS-PS1-8.	• RST.9-10.7	• MP.4 • HSN-Q.A.1 • HSN-Q.A.2 • HSN-Q.A.3

Enduring Understandings	Essential Questions
Students will understand that: • The model of atomic structure has changed over time as a result of experimental evidence. • The periodic table reveals patterns and relationships between atoms and elements, which can be explained by examining the subatomic arrangements of particles. • Changes occurring in the nucleus of an atom may alter the identity of an atom and often result in large changes in energy.	• How does the structure of an atom determine its properties?

Science & Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s). • Use a model to predict the relationships between systems or between components of a system. • Develop a model based on evidence to illustrate the relationships between systems or between components of a system.	**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. • 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. **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.	**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. **Energy and Matter** • In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.

Stage 2 – Assessment Evidence

Performance Task(s)

A performance task for this unit could include the following criteria:

- Identify and describe the components of the atomic model, including a positively-charged nucleus composed of both protons and neutrons, surrounded by negatively-charged electrons
- Identify and describe the relationships the arrangement of the main groups of the periodic table to the numbers of protons in the nucleus before and after radioactive decay, as well as the identity of the emitted particles (i.e., alpha, beta — both electrons and positrons, and gamma)
- Develop a fusion model that illustrates a process in which two nuclei merge to form a single, larger nucleus with a larger number of protons than were in either of the two original nuclei.
- Develop a fission model that illustrates a process in which a nucleus splits into two or more fragments that each have a smaller number of protons than were in the original nucleus.
- Develop radioactive decay models that illustrate the differences in type of energy (e.g., kinetic energy, electromagnetic radiation) and type of particle (e.g., alpha particle, beta particle) released during alpha, beta, and gamma radioactive decay, and any change from one element to another that can occur due to the process.
- Develop radioactive decay models that describe that alpha particle emission is a type of fission reaction, and that beta and gamma emission are not.

Other Evidence:

- Atomic models timeline
- Band of stability graph
- Uranium-238 Decay Series
- Half-life CER
- Nuclear power plant debate
- Unit test
- Formative assessments: Do nows, clicker questions, exit tickets, etc. will be given so that the teacher can monitor student learning, provide feedback, and assist in remediating student understandings

Stage 3 – Learning Plan

Suggested activities for this unit include:

- "Subatomic Values" POGIL
- "Isotopes and Atomic Mass"
- Modeling the nucleus with cereal
- "Nuclear Fission" PhET computer modeling
- "Personal Radiation Dose" calculations
- Half-life simulation
- "Radioactive Dating" PhET

Possible Preconceptions/Misconceptions:

- The current model of the atom is the "right" model
- Atoms are microscopic versions of elements—hard or soft, liquid or gas, etc.
- Radiation acts like a communicable disease

How do I reinforce or build literacy or mathematics skills?

- CER writing
- Research methods and analysis of found content
- Identifying relevant evidence or information needed to solve a problem or support a claim

Unit 4: Outside the Nucleus
Instructional Days: 8

Stage 1 – Desired Results

Unit Rationale:

In the previous unit, students were introduced to the electrons and their general location being outside of the nucleus. During this unit, students will investigate more specific locations of electrons in relation to the nucleus using the periodic table. Students will also use the distances of the electrons from the nucleus to predict periodic trends in atomic size and rationalize such trends using effective nuclear charges. Students will quantify the energy of an electron by observing the light emitted from excited electrons, the premise behind fireworks.

Performance Expectations:

HS-PS1-1. **Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.** [Clarification Statement: Examples of properties that could be predicted from patterns could include reactivity of metals, types of bonds formed, numbers of bonds formed, and reactions with oxygen.] [*Assessment Boundary: Assessment is limited to main group elements. Assessment does not include quantitative understanding of ionization energy beyond relative trends.*]

HS-PS4-1. **Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.** [Clarification Statement: Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the Earth.] [*Assessment Boundary: Assessment is limited to algebraic relationships and describing those relationships qualitatively.*]

Related Problems:

- What makes fireworks different colors?

Standards

NGSS	**English Language Arts/Literacy**	**Mathematics**
• HS-PS1-1. • HS-PS4-1	• RST.9-10.7 • RST.11-12.7	• MP.2 • MP.4 • HSA-SSE.A.1 • HSA-SSE.B.3 • HSA.CED.A.4

Enduring Understandings	Essential Questions
Students will understand that: • The model of atomic structure has changed over time as a result of experimental evidence. • The periodic table reveals patterns and relationships between atoms and elements, which can be explained by examining the subatomic arrangements of particles. • Interactions of electrons between and within atoms are the primary factors that determine the properties of matter	• How does the structure of an atom determine its properties?

Science & Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s). • Use a model to predict the relationships between systems or between components of a system. **Using Mathematics and Computational Thinking** Mathematical and computational thinking at the 9-12 level builds on K-8 and progresses to using algebraic thinking and analysis; a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms; and computational tools for statistical analysis to analyze, represent and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. • Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations.	**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. • 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. **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.	**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. **Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Stage 2 – Assessment Evidence

Performance Task(s)

A performance task for this unit could include the following criteria:

- Identify and describe the relationships the arrangement of the main groups of the periodic table to the patterns of outermost electrons.
- Predict the following patterns in the relative sizes of atoms both across a row and down a group in the periodic table
- Identify and describe the mathematical values of and relationship between frequency, wavelength, and speed of waves traveling in various specified media.

Other Evidence:

- Electron configuration battleship tournament
- Atomic radii graph
- "Exciting Electrons" CER
- Unit test
- Formative assessments: Do nows, clicker questions, exit tickets, etc. will be given so that the teacher can monitor student learning, provide feedback, and assist in remediating student understandings

Stage 3 – Learning Plan

Suggested activities for this unit include:

- Electron configuration scavenger hunt
- "Effective Nuclear Charge" POGIL
- "Exciting Electrons" investigation

Possible Preconceptions/Misconceptions:

- If electrons, and therefore atoms are moving, they must be "alive"
- Atoms should collapse if the electrons are attracted to the protons

How do I reinforce or build literacy or mathematics skills?

- CER writing
- Solve for a variable in an equation
- Identifying relevant evidence or information needed to solve a problem or support a claim

Unit 5: Atomic Bonding

Instructional Days: 12

Stage 1 – Desired Results

Unit Rationale:

During this unit students will explore how and why atoms form bonds, including ionic and covalent. Students will make connections between the periodic table and atomic bonding, as well as differentiate between ionic and covalent bonds. The unit will serve as framework for upcoming units that will explore properties of molecules and chemical reactions.

Performance Expectations:

HS-PS1-1. **Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.** [Clarification Statement: Examples of properties that could be predicted from patterns could include reactivity of metals, types of bonds formed, numbers of bonds formed, and reactions with oxygen.] [*Assessment Boundary: Assessment is limited to main group elements. Assessment does not include quantitative understanding of ionization energy beyond relative trends.*]

HS-PS1-2. **Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.** [Clarification Statement: Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen.] [*Assessment Boundary: Assessment is limited to chemical reactions involving main group elements and combustion reactions.*]

Related Problems:

- What bonds are essential to human life?

Standards

NGSS	**English Language Arts/Literacy**	**Mathematics**
• HS-PS1-1. • HS-PS1-2.	• RST.9-10.7 • WHST.9-12.2 • WHST.9-12.2	• HSN-Q.A.1 • HSN-Q.A.3

Enduring Understandings	Essential Questions
Students will understand that: • Atomic bonding joins two or more atoms together forming molecules • Atoms form bonds between them to achieve noble gas electron configurations whether through the sharing or transfer of electrons	• How do atoms form molecules?

Science & Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s). • Use a model to predict the relationships between systems or between components of a system. **Constructing Explanations and Designing Solutions** Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. • Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, and 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.	**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. • 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. **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.	**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.

Stage 2 – Assessment Evidence	
Performance Task(s) A performance task for this unit could include the following criteria: • Use the periodic table to predict the patterns of behavior of the elements based on the attraction and repulsion between electrically charged particles and the patterns of outermost electrons that determine the typical reactivity of an atom • Predict the number and types of bonds formed (i.e. ionic, covalent, metallic) by an element and between elements, the number and charges in stable ions that form from atoms in a group of the periodic table, the trend in reactivity and electronegativity of atoms down a group, and across a row in the periodic table, based on attractions of outermost (valence) electrons to the nucleus, and the relative sizes of atoms both across a row and down a group in the periodic table. • Describe their reasoning that connects the evidence, along with the assumption that theories and laws that describe their natural world operate today as they did in the past and will continue to do so in the future, to construct an explanation for how the patterns of outermost electrons and the electronegativity of elements can be used to predict the number and types of bonds each element forms. • Describe the causal relationship between the observable macroscopic patterns of reactivity of elements in the periodic table and the patterns of outermost electrons for each atom and its relative electronegativity	**Other Evidence:** • Electronegativity graph • Molecular models project • Unit quizzes and test • Formative assessments: Do nows, clicker questions, exit tickets, etc. will be given so that the teacher can monitor student learning, provide feedback, and assist in remediating student understandings

Stage 3 – Learning Plan

Suggested activities for this unit include:

- Molecular Polarity PhET
- Forming Ionic Bonds POGIL
- I Got My "Ion" You class activity
- Modeling Covalent Compounds kit activity

Possible Preconceptions/Misconceptions:

- Bonds are "sticks" that hold atoms together

How do I reinforce or build literacy or mathematics skills?

- Graphing
- Addition of positive and negative numbers
- Identifying relevant evidence or information needed to solve a problem or support a claim

Unit 6: Molecular Interactions

Instructional Days: 8

Stage 1 – Desired Results

Unit Rationale:

In this unit students will discover the cause behind molecular properties. Students will expand upon the concept of polarity by constructing three-dimensional models based upon electron pairs. The electric charges generated as a result of polarity will be used to explain how molecules attract via intermolecular forces. Students will experimentally research how the strength of the intermolecular force determines the properties of a compound. In conjunction with the idea of "like dissolves like" students will be introduced to how to determine and express solution concentrations. Additionally, students will explore how the addition of a solute to a solvent impacts the freezing and melting points.

Performance Expectations:

HS-PS1-3. **Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.** [Clarification Statement: Emphasis is on understanding the strengths of forces between particles, not on naming specific intermolecular forces (such as dipole-dipole). Examples of particles could include ions, atoms, molecules, and networked materials (such as graphite). Examples of bulk properties of substances could include the melting point and boiling point, vapor pressure, and surface tension.] [*Assessment Boundary: Assessment does not include Raoult's law calculations of vapor pressure.*]

HS-PS1-5. **Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.** [Clarification Statement: Emphasis is on student reasoning that focuses on the number and energy of collisions between molecules.] [*Assessment Boundary: Assessment is limited to simple reactions in which there are only two reactants; evidence from temperature, concentration, and rate data; and qualitative relationships between rate and temperature.*]

Related Problems:

- How does soap work?
- Why is salt put on the roads in the winter?

Standards

NGSS	English Language Arts/Literacy	Mathematics
• HS-PS1-3. • HS-PS1-5.	• RST.11-12.1 • WHST.9-12.2 • WHST.9-12.7 • WHST.11-12.8 • WHST.9-12.9	• MP.2 • HSN-Q.A.1 • HSN-Q.A.3

Enduring Understandings	**Essential Questions**
Students will understand that: • Molecules are held together by intermolecular force, which are determined by the polarity of the molecules themselves • The intermolecular forces that hold molecules together are responsible for the physical properties of the molecule • The addition of a solute to a solvent forms a solution with a known concentration and causes changes to the properties of the solvent	• What forces hold molecules together? • How does the structure of a compound or molecule determine its properties? • Why is water the universal solvent?

Science & Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Planning and Carrying Out Investigations Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models. • Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. **Constructing Explanations and Designing Solutions** Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. • Apply scientific principles and evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects.	**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. **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.	**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.

Stage 2 – Assessment Evidence

Performance Task(s)

A performance task for this unit could include the following criteria:

- Describe the phenomenon under investigation, which includes the following idea: the relationship between the measurable properties (e.g., melting point, boiling point, vapor pressure, surface tension) of a substance and the strength of the electrical forces between the particles of the substance.
- Develop an investigation plan and describe the data that will be collected and the evidence to be derived from the data, including bulk properties of a substance (e.g., melting point and boiling point, volatility, surface tension) that would allow inferences to be made about the strength of electrical forces between particles.
- Describe why the data about bulk properties would provide information about strength of the electrical forces between the particles of the chosen substances, including the spacing of the particles of the chosen substances can change as a result of the experimental procedure even if the identity of the particles does not change, kinetic energy has an effect on the ability of the electrical attraction between particles to keep the particles close together, and patterns of interactions between particles at the molecular scale are reflected in the patterns of behavior at the macroscopic scale
- Plan an investigation that includes a rationale for the choice of substances to compare and a description of the composition of those substances at the atomic molecular scale and how the data will be collected, the number of trials, and the experimental set up and equipment required.
- Collect and record data — quantitative and/or qualitative — on the bulk properties of substances
- Evaluate their investigation, including assessing the accuracy and precision of the data collected, as well as the limitations of the investigation; and the ability of the data to provide the evidence required
- Use and describe the following chain of reasoning that integrates evidence, facts, and scientific principles to construct the explanation that a high concentration means that there are more molecules in a given volume and thus more particle collisions per unit of time at the same temperature.

Other Evidence:

- You Light Up My Life CER
- Drops on a Penny CER
- Molarity lab calculations
- Water project
- Unit test
- Formative assessments: Do nows, clicker questions, exit tickets, etc. will be given so that the teacher can monitor student learning, provide feedback, and assist in remediating student understandings

Stage 3 – Learning Plan

Suggested activities for this unit include:

- Balloon VSEPR models
- Concord Consortium simulations: Comparing Attractive Forces and Intermolecular Attractions and Boiling Points
- Drops on a Penny investigation
- Mixing Oil and Water POGIL
- Molarity PhET
- Picking Up Ice activity

Possible Preconceptions/Misconceptions:

- Hydrogen bonds hold atoms together as opposed to molecules
- Salt causes ice to melt on the roadways

How do I reinforce or build literacy or mathematics skills?

- Unit conversions
- Fractions (Molarity)
- Identifying relevant evidence or information needed to solve a problem or support a claim

Unit 7: Chemical Reactions

Instructional Days: 12

Stage 1 – Desired Results

Unit Rationale:

This unit will begin by having students explore that a double displacement reaction may happen when two ionic solutes are added to water. Students will then compare and contrast other types of chemical reactions, including synthesis, decomposition, combustion, and single displacement. By writing balanced chemical equations students will come to understand that all chemical changes conserve mass. In addition, students will learn how to predict quantities of reactants and products within the same reaction if one quantity is known using stoichiometry. This information will be used assess how accurately an experiment is conducted by calculating the percent yield.

Performance Expectations:

HS-PS1-7. **Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.** [Clarification Statement: Emphasis is on using mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and the products, and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale. Emphasis is on assessing students' use of mathematical thinking and not on memorization and rote application of problem-solving techniques.] [*Assessment Boundary: Assessment does not include complex chemical reactions.*]

Related Problems:

- Why, and how much, fertilizer is added to soil?

Standards

NGSS	**English Language Arts/Literacy**	**Mathematics**
• HS-PS-1-7	• RST.9-10.7 • WHST.9-12.7	• MP.2 • HSN-Q.A.1 • HSN-Q.A.2 • HSN-Q.A.3

Enduring Understandings	Essential Questions
Students will understand that: • The type of chemical reaction that will occur depends on the reactants provided • The atoms and, therefore the mass, of the reactants used for a chemical reaction are conserved and can be seen within the products • The amount of a substance used or formed in a chemical reaction can be determined using the mole concept and stoichiometry	• What happens to atoms and molecules during a chemical reaction? • How successful was an experiment?

Science & Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematics and Computational Thinking Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. • Use mathematical representations of phenomena to support claims.	**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.	**Energy and Matter** • The total amount of energy and matter in closed systems is conserved.

Stage 2 – Assessment Evidence

Performance Task(s)

A performance task for this unit could include the following criteria:

- Identify and describe the relevant components in the mathematical representations including: the quantities of reactants and products of a chemical reaction in terms of atoms, moles, and mass; molar mass of all components of the reaction; use of balanced chemical equation(s); and identification of the claim that atoms, and therefore mass, are conserved during a chemical reaction.
- Use the mole to convert between the atomic and macroscopic scale in the analysis
- Given a chemical reaction, students use the mathematical representations to predict the relative number of atoms in the reactants versus the products at the atomic molecular scale and calculate the mass of any component of a reaction, given any other component.
- Describe how the mathematical representations (e.g., stoichiometric calculations to show that the number of atoms or number of moles is unchanged after a chemical reaction where a specific mass of reactant is converted to product) support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
- Describe how the mass of a substance can be used to determine the number of atoms, molecules, or ions using moles and mole relationships (e.g., macroscopic to atomic molecular scale conversion using the number of moles and Avogadro's number).

Other Evidence:

- Mass of a Chemical Change CER
- Stop Motion Project
- Careers Using Stoichiometry presentations
- Percent Yield CER
- Unit test
- Formative assessments: Do nows, clicker questions, exit tickets, etc. will be given so that the teacher can monitor student learning, provide feedback, and assist in remediating student understandings

Stage 3 – Learning Plan

Suggested activities for this unit include:

- Solubility Rules investigation
- Classifying Chemical Reactions POGIL
- Types of Chemical Reactions experiment
- Balancing Equations PhET
- Mass of a Chemical Change experiment
- Reactants, Products, and Leftovers PhET

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.

Possible Preconceptions/Misconceptions:

- The atoms that make up the products are a different set of atoms that make up the reactants
- The mass decreases in reactions that produce a gas

How do I reinforce or build literacy or mathematics skills?

- Dimensional analysis
- Percent calculations
- Identifying relevant evidence or information needed to solve a problem or support a claim

Unit 8: Acids & Bases

Instructional Days: 8

Stage 1 – Desired Results

Unit Rationale:

In this unit students will investigate a specific case of a double displacement reaction: acid-base neutralization reactions. Students will take a closer look at what distinguishes an acid from a base, including how to determine pH and use indicators. Throughout the unit students will explore human impact on the oceans by performing a study on ocean acidification.

Performance Expectations:

HS-PS1-2. **Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.** [Clarification Statement: Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen.] [*Assessment Boundary: Assessment is limited to chemical reactions involving main group elements and combustion reactions.*]

HS-ESS3-6. **Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.** [Clarification Statement: Examples of Earth systems to be considered are the hydrosphere, atmosphere, cryosphere, geosphere, and/or biosphere. An example of the far-reaching impacts from a human activity is how an increase in atmospheric carbon dioxide results in an increase in photosynthetic biomass on land and an increase in ocean acidification, with resulting impacts on sea organism health and marine populations.] [*Assessment Boundary: Assessment does not include running computational representations but is limited to using the published results of scientific computational models.*]

Related Problems:

- How do antacids work?
- Why is chloride added to swimming pools? Should we add chloride to the ocean?

Standards

NGSS	**English Language Arts/Literacy**	**Mathematics**
• HS-PS-1-2 • HS-ESS3-6	• WHST.9-12.2 • WHST.9-12.5	• HSN-Q.A.1 • HSN-Q.A.2 • HSN-Q.A.3 • MP.4

Enduring Understandings	**Essential Questions**
Students will understand that: • Neutralization reactions involve an acid and base reacting together to form water • The pH scale and chemical indicators are useful tools in identifying acidic substances from basic substances • While the ocean helps to slow down the process of global warming it gets harmed by doing so	• How can acids and bases be distinguished? • How is human activity affecting the balance of acids and bases in the environment?

Science & Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. • Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, and 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. **Using Mathematics and Computational Thinking** Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. • Use a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations.	**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. **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. **ESS2.D: Weather and Climate** • Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere. (secondary) **ESS3.D: Global Climate Change** • Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities.	**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. **Systems and System Models** • When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.

Stage 2 – Assessment Evidence	
Performance Task(s) A performance task for this unit could include the following criteria: • Construct an explanation of the outcome of the given reaction, including how the patterns of attraction allow the prediction of the type of reaction that occurs • Identify and describe the products and reactants, including their chemical formulas and the arrangement of their outermost (valence) electrons for a chemical reaction • Given new evidence or context, construct a revised or expanded explanation about the outcome of a chemical reaction and justify the revision. • Identify and describe the relevant components of each of the Earth systems modeled in the given computational representation, including system boundaries, initial conditions, inputs and outputs, and relationships that determine the interaction (e.g., the relationship between atmospheric CO_2 and production of photosynthetic biomass and ocean acidification). • Illustrate and describe relationships among at least two of Earth's systems, including how the relevant components in each individual Earth system can drive changes in another, interacting Earth system. • Describe how human activity could affect the relationships between the Earth's systems under consideration.	**Other Evidence:** • Household Acids & Bases CER • Swimming in Acid (Ocean Acidification) project • Unit test • Formative assessments: Do nows, clicker questions, exit tickets, etc. will be given so that the teacher can monitor student learning, provide feedback, and assist in remediating student understandings

Stage 3 – Learning Plan

Suggested activities for this unit include:

- Acids and bases POGIL
- Calculating pH activity
- Making an acid-base indicator activity
- Household acids and bases investigation
- pH and Dilution PhET
- Ocean acidification investigation

Possible Preconceptions/Misconceptions:

- All acids are dangerous
- All water is neutral

How do I reinforce or build literacy or mathematics skills?

- Solving algebraic formulas
- Graphing
- Persuasive essays
- Percent calculations
- Identifying relevant evidence or information needed to solve a problem or support a claim

Unit 9: Energy of Reactions

Instructional Days: 7

Stage 1 – Desired Results

Unit Rationale:

Students begin this unit by performing a series of chemical reactions and measuring the temperature change throughout the course of the reactions. From this introductory activity students will recognize that some reactions experience an increase in temperature, while others have temperatures that decrease. Students will investigate that rationale as to why this is by exploring deeper into the realm of thermodynamics. Within the unit students will learn how to measure heat vs. temperature, as well as determine if a chemical reaction will be exothermic or endothermic. The unit will include a project in which students will design hot and cold packs that are as equally cost effective as they are temperature effective.

Performance Expectations:

HS-PS1-4. **Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.** [Clarification Statement: Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawings and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved.] [*Assessment Boundary: Assessment does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products.*]

HS-ETS1-3. **Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.**

Related Problems:

- How do hot and cold packs work?

Standards

NGSS	English Language Arts/Literacy	Mathematics
• HS-PS1-4. • HS-ETS1-3.	• SL.11-12.5 • RST.11-12.7 • RST.11-12.8 • RST.11-12.9	• MP.2 • MP.4 • HSN-Q.A.1 • HSN-Q.A.2 • HSN-Q.A.3

Enduring Understandings	Essential Questions
Students will understand that: • Energy is neither created nor destroyed, but only transformed from one form to another. • The reorganization of atoms in chemical reactions results in the release or absorption of heat energy.	• How do matter and energy interact? • How is energy transferred in chemical systems?

Science & Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 9–12 builds on K–8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. • Develop a model based on evidence to illustrate the relationships between systems or between components of a system. **Constructing Explanations and Designing Solutions** Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles and theories. • Evaluate a solution to a complex real world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.	**PS1.A: Structure and Properties of Matter** • A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. **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. **ETS1.B: Developing Possible Solutions** • When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.	**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.

Stage 2 – Assessment Evidence

Performance Task(s)

A performance task for this unit could include the following criteria:

- Use evidence to develop a model to identify, describe, and determine relationships between the chemical reaction, the system, and the surroundings under study; the bonds that are broken during the course of the reaction; the bonds that are formed during the course of the reaction; the energy transfer between the systems and their components or the system and surroundings; the transformation of potential energy from the chemical system interactions to kinetic energy in the surroundings (or vice versa) by molecular collisions; and the relative potential energies of the reactants and the products.
- Use the developed model to illustrate how the energy change within the system is accounted for by the change in the bond energies of the reactants and products; breaking bonds requires an input of energy from the system or surroundings, and forming bonds releases energy to the system and the surroundings; the energy transfer between systems and surroundings is the difference in energy between the bond energies of the reactants and the products; the overall energy of the system and surroundings is unchanged (conserved) during the reaction; energy transfer occurs during molecular collisions; and the relative total potential energies of the reactants and products can be accounted for by the changes in bond energy.
- Generate a list of three or more realistic criteria and two or more constraints, including such relevant factors as cost, safety, reliability, and aesthetics that specifies an acceptable solution to a complex real-world problem
- Analyze (quantitatively where appropriate) and describe the strengths and weaknesses of the solution with respect to each criterion and constraint, as well as social and cultural acceptability and environmental impacts
- Provide an evidence-based decision of which solution is optimum, based on prioritized criteria, analysis of the strengths and weaknesses (costs and benefits) of each solution, and barriers to be overcome.
- Describe which parts of the complex real-world problem may remain even if the proposed solution is implemented

Other Evidence:

- Specific Heat CER
- Enthalpy of a Reaction CER
- Hot/cold pack design project
- Unit test
- Formative assessments: Do nows, clicker questions, exit tickets, etc. will be given so that the teacher can monitor student learning, provide feedback, and assist in remediating student understandings

Stage 3 – Learning Plan

Suggested activities for this unit include:

- Energy in Chemical Reactions POGIL
- Identifying an unknown using specific heat experiment
- Exothermic vs. Endothermic laboratory investigation
- Interpreting Potential Energy graphs
- Reversible Reactions PhET
- Standard Heat of Formation calculations
- Hess' Law activity

Connections to Nature of Science

Influence of Science, Engineering, and Technology on Society and the Natural World

- New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.

Possible Preconceptions/Misconceptions:

- Making bonds requires energy and breaking bonds releases energy
- Heat and temperature are synonymous

How do I reinforce or build literacy or mathematics skills?

- Rearranging equations
- Solving algebraic equations
- Reading graphs
- Research methods and analysis of found content
- Identifying relevant evidence or information needed to solve a problem or support a claim

Unit 10: Reaction Rates & Equilibrium
Instructional Days: 8

Stage 1 – Desired Results

Unit Rationale:

In this unit students will continue their investigation of thermodynamics by determining what would happen if heat is added into both endothermic and exothermic systems. To do this, students will begin by investigating reaction rates and the factors that change them by making film canister rockets. Students will then connect the concept of reaction rates to equilibrium. Students will use both paper and computer modeling to determine equilibrium, as well as how equilibrium will respond to different factors according to Le Chatlier's principal, including adding heat to endothermic and exothermic systems. The unit will conclude with students learning how reaction rates and equilibrium play a vital role in the overall health and functioning of their body and the environment.

Performance Expectations:

HS-PS1-5. **Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.** [Clarification Statement: Emphasis is on student reasoning that focuses on the number and energy of collisions between molecules.] [*Assessment Boundary: Assessment is limited to simple reactions in which there are only two reactants; evidence from temperature, concentration, and rate data; and qualitative relationships between rate and temperature.*]

HS-PS1-6. **Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.*** [Clarification Statement: Emphasis is on the application of Le Chatelier's Principle and on refining designs of chemical reaction systems, including descriptions of the connection between changes made at the macroscopic level and what happens at the molecular level. Examples of designs could include different ways to increase product formation including adding reactants or removing products.] [*Assessment Boundary: Assessment is limited to specifying the change in only one variable at a time. Assessment does not include calculating equilibrium constants and concentrations.*]

Related Problems:

- Why do you get light-headed at high altitudes?

Standards

NGSS	**English Language Arts/Literacy**	**Mathematics**
• HS-PS1-5. • HS-PS1-6.	• RST.11-12.1 • WHST.9-12.2 • WHST.9-12.7	• MP.2 • HSN-Q.A.1 • HSN-Q.A.3

Enduring Understandings	Essential Questions
Students will understand that: • Chemical reaction rates are related to how frequently reactant molecules collide Rates of reaction and chemical equilibrium are dynamic processes that are significant in many systems • There is a dynamic balance between the forward reaction and the reverse reaction for many chemical processes	• How are the rates of a chemical reaction and equilibrium position effected by different factors? • How are the quantities of reactants and products in dynamic equilibrium determined?

Science & Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. • Apply scientific principles and evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. • Refine a solution to a complex real world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.	**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. • 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. **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 (tradeoffs) may be needed. (secondary)	**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 **Stability and Change** • Much of science deals with constructing explanations of how things change and how they remain stable.

Stage 2 – Assessment Evidence	
Performance Task(s) A performance task for this unit could include the following criteria: • Construct an explanation that includes the idea that as the kinetic energy of colliding particles increases and the number of collisions increases, the reaction rate increases • Identify and describe evidence to construct the explanation, including: evidence of a pattern that increases in concentration increases the reaction rate, and vice versa; and evidence of a pattern that increases in temperature usually increase the reaction rate, and vice versa • Identify and describe potential changes in a component of the given chemical reaction system that will increase the amounts of particular species at equilibrium. • Use evidence to describe the relative quantities of a product before and after changes to a given chemical reaction system (e.g., concentration increases, decreases, or stays the same), and will explicitly use Le Chatelier's principle, including: how, at a molecular level, a stress involving a change to one component of an equilibrium system affects other components; that changing the concentration of one of the components of the equilibrium system will change the rate of the reaction (forward or backward) in which it is a reactant, until the forward and backward rates are again equal; and a description of a system at equilibrium that includes the idea that both the forward and backward reactions are occurring at the same rate, resulting in a system that appears stable at the macroscopic level	**Other Evidence:** • Pop Rocket Reaction Rates CER • Paper ball equilibrium graphs • Equilibrium in the body project • Unit test • Formative assessments: Do nows, clicker questions, exit tickets, etc. will be given so that the teacher can monitor student learning, provide feedback, and assist in remediating student understandings

Stage 3 – Learning Plan

Suggested activities for this unit include:

- Pop rockets investigation
- Reactions & Rates PhET
- Paper ball class demonstration
- Le Chatlier's Principal POGIL

Possible Preconceptions/Misconceptions:

- The condition of equilibrium means equal concentrations of reactants and products.
- A reaction at equilibrium has stopped.
- Equilibrium can only be approached in the forward direction

How do I reinforce or build literacy or mathematics skills?

- Rearranging equations
- Solving algebraic equations
- Reading and creating graphs
- Research methods and analysis of found content
- Identifying relevant evidence or information needed to solve a problem or support a claim