STRATFORD PUBLIC SCHOOLS
Stratford, Connecticut

"Tantum eruditi sunt liberi"
Only The Educated Are Free

Chemistry 1

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DISTRICT MISSION STATEMENT

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The mission of the Stratford school community is to ensure that all students acquire the knowledge, character, and 21st century skills to succeed through high quality learning experiences and community partnerships within a culture of diversity and respect.

Portrait of a Stratford Graduate

- Responsible and Involved Citizen
    - Participate in and contribute with empathy and respect to the community.
    - Demonstrate knowledge of and respect for diverse cultures, identities, and perspectives.
    - Practice responsible digital and in person citizenship as a member of a community.
- Creative and Practical Problem-Solver
    - Define and analyze a problem/problems.
    - Select, evaluate, and apply appropriate resources/strategies necessary to find/generate a solution(s) for problems.
    - Generate and critically evaluate the effectiveness of a solution.
- Informed and Integrative Thinker
    - Apply knowledge from various disciplines and contexts to real life situations.
    - Analyze, evaluate, and synthesize information from multiple and diverse sources to build on and utilize knowledge.
    - Use evidence and reasoning to justify claims/solutions.
- Clear and Effective Communicator
    - Select and use communication strategies (questioning, clarifying, verifying, and challenging ideas) and interpersonal skills to collaborate with others (peers, teachers, community members, families) within a diverse community.
    - Demonstrate, adapt, and articulate thoughts and ideas effectively using/including oral, written, multimedia, non-verbal, and/or a performance appropriate for a particular audience.
    - Receive, understand and process information effectively and with consideration for others through active speaking and listening.
- Self-Directed and Lifelong Learner
    - Apply knowledge to set goals, make decisions, and assess new opportunities.
    - Demonstrates initiative, reliability and concern for quality results/solutions/resources/information within time constraints as applicable.
    - Demonstrate flexibility in thinking/problem-solving/etc. including the ability to incorporate new ideas and revise.

UNIT: WHERE DID THE ELEMENTS COME FROM?

Unit Overview
In this lab-based unit, students investigate an answer to the question: "Where do the elements come from" The ESS1 Disciplinary Core Idea from the NRC Framework is broken down into three sub-ideas: the universe and its stars, Earth and the solar system and the history of planet Earth. In this unit, students examine the processes governing the formation and evolution of stars to come to an understanding of how the matter of our world formed during the Big Bang and within the cores of stars. Through PS1-8, phenomena involving nuclei are examined as they are important to understanding the formation and abundance of the elements and the release of energy from the sun and other stars. The crosscutting concepts of patterns, scale, energy and matter, and structure and function are called out as organizing concepts for these disciplinary core ideas. In these performance expectations, students are expected to demonstrate proficiency in developing and using models, planning and conducting investigations, constructing explanations and designing solutions, engaging in argument, and obtaining, evaluating and communicating information; and to use these practices to demonstrate understanding of the core ideas.

Unit At-a-Glance		
Big Ideas	**Performance Expectations**	**Disciplinary Core Ideas**
Stars over their lifecycle produce elements through fusion	**HS-ESS1-3** **HS-PS1-8**	ESS1.A PS1.C

UNIT: WHERE DID THE ELEMENTS COME FROM?

Big Idea: Stars over their lifecycle produce elements through fusion		
PE #	Performance Expectation	Disciplinary Core Idea
HS-ESS1-3	Communicate scientific ideas about the way stars, over their life cycle, produce elements. [Clarification Statement: Emphasis is on the way nucleosynthesis, and therefore the different elements created, varies as a function of the mass of a star and the stage of its lifetime.] [*Assessment Boundary: Details of the many different nucleosynthesis pathways for stars of different masses are not assessed.*]	ESS1.A Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode.
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.*] ***NOTE: the emphasis in this unit is fusion***	PS1.C 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. ***[NOTE: the emphasis in this unit is fusion]***

	Include basic/simplified nucleosynthesis reactions: ● Hydrogen fuses into helium ● Helium fuses into carbon ● Carbon fuses into oxygen ● Oxygen fuses into silicon ● Silicon fuses into iron	

Observable Features

- Students can identify and communicate the relationships between the life cycle of the stars, the production of elements, and the conservation of the number of protons plus neutrons in stars.

- Students can identify that atoms are not conserved in nuclear fusion, but the total number of protons plus neutrons is conserved.

- Students can describe
    - Helium and a small amount of other light nuclei (i.e., up to lithium) were formed from high-energy collisions starting from protons and neutrons in the early universe before any stars existed.
    - More massive elements, up to iron, are produced in the cores of stars by a chain of processes of nuclear fusion, which also releases energy.
    - Supernova explosions of massive stars are the mechanism by which elements more massive than iron are produced.

- Students can describe the correlation between a star's mass and stage of development and the types of elements it can create during its lifetime.

- From the given model, students can identify and describe the components of the model, including:
    - identification of an element by the number of protons
    - the number of protons and neutrons in the nucleus

- Students can develop a model to illustrate the relationships between components underlying the nuclear processes fusion. Students include the following features, based on evidence:
    - The total number of neutrons plus protons is the same both before and after the nuclear process, although

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the total number of protons and the total number of neutrons may be different before and after
- The scale of energy changes in a nuclear process is much larger (hundreds of thousands or even millions of times larger) than the scale of energy changes in a chemical process.

- Students can 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.

Key Terms
main sequence, nucleosynthesis, nuclear reactions, fusion, nucleons, proton, neutron, atomic number, atomic mass, proton-proton chain, triple-alpha process, gamma rays, neutrinos, red giant, blue giant, white dwarf, supernova, exothermic reactions, endothermic reactions, H-R Diagram.

SAFETY: Demonstrations and Labs may include detergents, balloons, bunsen burners and chemicals. Examples of appropriate chemicals for this course include strong acids (ex. Concentrated Hyrdrochloric acid, concentrated Nitric Acid, strong bases (ex. Sodium hydroxide, Potassium hydroxide), strong oxidizers (ex. Potassium permanganate, manganese dioxide) and organic solvents including acetone and hexane.PPE must be worn and students must follow all safety procedures outlined in the safety handout provided to them for this class.

Suggested Phenomenon

We are Stardust
https://www.sciencenewsforstudents.org/article/we-are-stardust

Solar Flares, Sunspots, and the Solar Cycle
https://thewonderofscience.com/phenomenon/2018/7/8/solar-flares-sunspots-and-the-solar-cycle

Newfound ‘dunes’ is among weirdest of northern lights

https://www.sciencenewsforstudents.org/article/newfound-dunes-is-among-weirdest-of-northern-lights

Additional Resources
Imagine the Universe: Part I: How and Where are Elements Created?
https://imagine.gsfc.nasa.gov/educators/lessons/xray_spectra/spectra_unit.html

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The Life Cycles of Stars: How Supernovae Are Formed
https://imagine.gsfc.nasa.gov/educators/lessons/xray_spectra/background-lifecycles.html

The Life Cycle of a Star - Images and diagrams
https://www.schoolsobservatory.org/learn/astro/stars/cycle

Investigating Nuclear Fusion
https://betterlesson.com/lesson/635377/investigating-nuclear-fusion

HS-ESS1-1 Assessment - The Life of a Star
https://docs.google.com/document/d/1mioIQtFsqJ323U1vQpKOrQWv93JvnFXd6v5-0i0hViM/edit

HS-ESS1-1 Assessment - Why the Sun will die and what happens to Earth?
https://docs.google.com/document/d/1rA5YbHSYgOxyYcFeE_HAk1Up0cQ3cBPaUK5yv71uVYY/edit

ESS1.A: The Universe and Its Stars
https://thewonderofscience.com/videos/2017/12/10/ess1a-the-universe-and-its-stars

The Wonder of Science HS-PS1-8
https://thewonderofscience.com/hsps18

The Lifecycle of Stars
https://betterlesson.com/lesson/640537/the-life-cycle-of-stars?from=cc_lesson

Life Cycle of Stars-Make your model
https://sites.google.com/a/lewistonpublicschools.org/earth-systems-science-website---grade-9/home/1st-semester/energy-and-space/summative-assessment/life-cycle-of-a-star

Star In a Box simulation
https://starinabox.lco.global/#

UNIT: STRUCTURE AND PROPERTIES OF MATTER

Unit Overview
In this lab-based unit, students investigate the properties of matter that can be observed to identify cause and effect relationships between the bulk scale and the atomic scale, and the observable patterns in the periodic table that explain the differences among the elements.

Unit At-a-Glance		
Big Ideas	**Performance Expectations**	**Disciplinary Core Ideas**
The structure of an atom determines its location on the periodic table and its chemical properties	HS-PS1-1 HS-PS1-8	PS1.A PS1.C PS2.B
Molecular-level structure determines the structure and properties of large-scale materials	HS-PS1-3 HS-PS2-6	PS1.A PS2.B

UNIT: STRUCTURE AND PROPERTIES OF MATTER

Big Idea: The structure of an atom determines its location on the periodic table and its chemical properties		
PE #	Performance Expectation	Disciplinary Core Idea
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.*]	PS1.A: Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. PS1.A: The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.
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.*]	PS2.B: 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. PS1.C 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.
Observable Features 1. Select or identify from a collection of periodic table components (periods, groups, etc.), including distractors, the components needed to model the phenomenon.		

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2. Make predictions about the properties of elements based on the number of valence electrons. Predictions can be made by completing illustrations or selecting from lists with distractors. 3. Identify missing components, relationships, or other limitations of the model. (Hydrogen similar to Alkali metals, one valence electron, and Halogens, missing only one valence electron). 4. Describe, select, or identify the relationships among components of the periodic table that describe the properties of valence electrons, or explain the properties of elements.
Key Terms Proton, electron, neutron, valence shell, filled shell, ion, cation, anion, solid, liquid, gas, metal, nonmetal, metalloid, group, period, family, atom, molecule, matter, elements, states of matter, pure substance, physical property, chemical property, atomic number, atomic symbol, atomic weight, chemical formula, ionic bond, covalent bond, s, p, d, f orbitals, electron configuration, core electrons, nucleus, single, double, triple bond(s), molar mass, atomic radius, melting point, boiling point, electronegativity,
SAFETY: Demonstrations and Labs may include detergents, balloons, bunsen burners and chemicals. Examples of appropriate chemicals for this course include strong acids (ex. Concentrated Hyrdrochloric acid, concentrated Nitric Acid, strong bases (ex. Sodium hydroxide, Potassium hydroxide), strong oxidizers (ex. Potassium permanganate, manganese dioxide) and organic solvents including acetone and hexane.PPE must be worn and students must follow all safety procedures outlined in the safety handout provided to them for this class.
Suggested Phenomenon Relevance of the activity series of elements to everyday products (anode rods) https://www.youtube.com/watch?v=2IUNIUZz4Os Using properties of elements to weld together train tracks (Thermite welding). https://www.youtube.com/watch?v=5uxsFglz2ig Potassium chloride (KCl) tastes similar to table salt (sodium chloride (NaCl)) Scientists work with silicate substrates in chambers filled with Argon instead of air. Diamond, graphene, and fullerene are different molecules/materials that are only made of carbon. Making Sodium chloride

https://www.youtube.com/watch?v=rGqI3oKxIss The effect of pressure on the boiling point. https://www.youtube.com/watch?v=JTL4dj3Gx1o Isotopes - the story of Uranium-235 and U-238 https://www.youtube.com/watch?v=cO57Zm-WNmg Strontium-90 The St. Louis Baby Tooth Survey http://beckerexhibits.wustl.edu/dental/articles/babytooth.html
Additional Resources 1. 150th birthday of the periodic table – includes reactions between elements on the periodic table including demonstrations of thermite reactions in a classroom setting. https://www.youtube.com/watch?v=kqe9tEcZkno 2. https://phet.colorado.edu/en/simulation/build-an-atom (Limited to the first 10 elements. Build an atom including isotopes of a given element.) 3. Build a molecule. https://phet.colorado.edu/en/simulation/legacy/build-a-molecule 4. Valence electrons and their role in ionic bonding. https://www.youtube.com/watch?v=PEJsjF4_wIE 5. Interactive testing of understanding of bonding properties http://www.teachchemistry.org/bonding 6. Understanding trends in the periodic table in relation to atomic radius. https://www.ck12.org/chemistry/periodic-trends-atomic-radius/lesson/Periodic-Trends:-Atomic-Radius-CHEM/?referrer=concept_details 7. Demonstrate an understanding of trends in atomic size https://www.ck12.org/assessment/ui/?test/view/practice/chemistry/Periodic-Trends-Atomic-Radius-Practice&ep=https://www.ck12.org/chemistry/periodic-trends-atomic-radius/?referrer=concept_details 8. Potential energy of non-bondng electrons based on the distance of separation https://phet.colorado.edu/sims/html/atomic-interactions/latest/atomic-interactions_en.html * honors chemistry 9. Periodic table war game: students play a card game to apply their knowledge of the periodic trends of the main group elements. https://teachchemistry.org/classroom-resources/periodic-war

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10. **Electron configuration:** Understanding the arrangement of electrons around the nucleus. https://www.youtube.com/watch?v=yADrWdNTWEc&t=25s
11. **Electron configuration:** spdf arrangement of electrons and elements https://www.youtube.com/watch?v=rcKilE9CdaA

12. **ISOTOPES:** Distinguishing between mass number and atomic mass. The concept of weighted averages and percent abundance. https://phet.colorado.edu/sims/html/isotopes-and-atomic-mass/latest/isotopes-and-atomic-mass_en.html
    https://www.youtube.com/watch?v=_pY5HeZpNr8

    Uranium enrichment (Uranium-235) Periodic Science
    https://www.youtube.com/watch?v=69UpMhUnEeY

13. **Nuclear Fission**
    https://www.youtube.com/watch?v=_pY5HeZpNr8

14. Chernobyl
    https://www.youtube.com/watch?v=uvpS2IUHZD8
    https://drive.google.com/file/d/1D-YLTDbW7_AyL45wJGmdxXZXIEqfE1GV/view?usp=sharing
    https://teachchemistry.org/classroom-resources/half-life-investigation-simulation

UNIT: STRUCTURE AND PROPERTIES OF MATTER

Big Idea: Molecular-level structure determines the structure and properties of large-scale materials		
PE #	Performance Expectation	Disciplinary Core Idea
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.*]	PS1.A: Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.
HS-PS2-6	**Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.*** [Clarification Statement: Emphasis is on the attractive and repulsive forces that determine the functioning of the material. Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, and pharmaceuticals are designed to interact with specific receptors.] *[Assessment Boundary: Assessment is limited to*	PS2.B**:** 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.

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	provided molecular structures of specific designed materials.]	

Observable Features

1. Identify from a list, including distractors, the materials/tools needed for an investigation of the physical properties/interactions of atomic and/or molecular substances at the bulk scale to gather evidence about the strengths of the electrostatic attractions between the particles of those substances.
2. Identify the outcome data that should be collected in an investigation of the physical properties/interactions of atomic and/or molecular substances at the bulk scale to gather evidence about the strengths of the electrostatic attractions between the particles of those substances.
3. Evaluate the sufficiency and limitations of collected data about the physical properties/interactions of substances at the bulk scale to explain the phenomenon.
4. Make and/or record observations about the physical properties/interactions of substances at the bulk scale that provide evidence to support inferences about the relative strengths of the electrostatic attractions between the particles of those substances.
5. Interpret, summarize, and/or communicate the data from an investigation concerning the physical properties/interactions of substances at the bulk scale
6. Explain or describe the causal processes that lead to the observed data.
7. Select, describe, or illustrate a prediction concerning the physical properties of or interactions between additional substance(s), and/or the strength of electrostatic attractions between the particles of additional substance(s), made by applying the findings from an investigation.
8. Students use at least two different formats (including oral, graphical, textual and mathematical) to communicate scientific and technical information, including fully describing* the structure, properties, and design of the chosen material(s). Students cite the origin of the information as appropriate.
9. Students identify and communicate the evidence for why molecular level structure is important in the functioning of designed materials, including:
    a. How the structure and properties of matter and the types of interactions of matter at the atomic scale determine the function of the chosen designed material(s); and
    b. How the material's properties make it suitable for use in its designed function.
10. Students explicitly identify the molecular structure of the chosen designed material(s) (using a representation appropriate to the specific type of communication — e.g., geometric shapes for drugs and receptors, ball and stick models for long-chained molecules).

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11. Students describe* the intended function of the chosen designed material(s).
12. Students describe* the relationship between the material's function and its macroscopic properties (e.g., material strength, conductivity, reactivity, state of matter, durability) and each of the following:
    a. Molecular level structure of the material;
    b. Intermolecular forces and polarity of molecules; and
    c. The ability of electrons to move relatively freely in metals.
13. Students describe* the effects that attractive and repulsive electrical forces between molecules have on the arrangement (structure) of the chosen designed material(s) of molecules (e.g., solids, liquids, gases, network solid, polymers).
14. Students describe* that, for all materials, electrostatic forces on the atomic and molecular scale results in contact forces (e.g., friction, normal forces, stickiness) on the macroscopic scale.

Key Terms
Nucleus, proton, electron, neutron, electron cloud, intramolecular force, covalent bond/molecule, ionic bond/compound, intermolecular force/attraction, electrostatic force/attraction, electronegativity, electron distribution, polar/polarity, temporary polarity, permanent polarity, polarize, surface area, atomic radius, atomic/molecular weight/mass, solute, solvent, dissolve, macroscopic properties (e.g., material strength, conductivity, reactivity, state of matter, durability)

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Suggested Phenomenon

Thalidomide: How chemical substances can look the same at the atomic level yet have very different macroscopic properties
https://www.youtube.com/watch?v=YOBmga0wcew
How this can be leveraged for disease despite devastating consequences -
https://www.scientificamerican.com/article/new-thalidomide-like-therapy-hijacks-cells-trash-disposal-system/
Advanced reading about the mixture of thalidomide
https://drive.google.com/file/d/18MvjnV8Nm9H95Ara05JitmCoqje86WQn/view?usp=sharing

Laboratory/ demonstrations exploring the impact of intermolecular forces on evaporation of different types of liquids and their

relationship to vapor pressure. Exploring intensive and extensive properties of matter at the molecular level including structure, polarity and intermolecular forces (IMFs).https://drive.google.com/file/d/1MsAEJVZZXA4udF7AyPRMKBTtvPCTr7t7/view?usp=sharing Student activity involving molecular structure, intermolecular forces and their impact on volume. https://www.youtube.com/watch?v=N6jDBqgQnK8 (Intermolecular forces & the impact on volume) Growing crystals - using sodium borate tetrahydrate. https://www.flinnsci.com/borax-crystal-ornaments2/vfm0369/ Excellent lab explaining solubility, the macroscopic properties of crystalline salts and crystal lattice repeating structures. https://drive.google.com/file/d/1Jh9tDZ-a2CLyMAQZAvyR4O0mDfsyoLEI/view?usp=sharing
Additional Resources Calculating the # of layers of atoms on metallic coatings (Layering of Zinc atoms on iron). https://drive.google.com/file/d/1tbGRcYd2AbgPXPrSuovnuhiE0VLjnNPH/view?usp=sharing Associated reading with the lab on metallic coatings - do this after the atomic coatings lab as bimetallic corrosion has the opposite effect of a protective coating. https://drive.google.com/file/d/1fI9Koughe_8mbAs0IVMrLOIYH8nS7WBA/view?usp=sharing

UNIT: MATTER AND ITS INTERACTIONS

Unit Overview
In this lab-based unit, students investigate the relationship of formulas to the number of atoms and the formula weight of a given element or compound. The central concept will be understanding how atoms, molecules and ions are counted by weight. The trends in the periodic table and the electron configuration of the outermost electrons will explain patterns in the formation of chemical bonds, generation of chemical formulas and nomenclature of these recombined atoms and ions.

Unit At-a-Glance		
Big Ideas	**Performance Expectations**	**Disciplinary Core Ideas**
Predicting the formula weight from the chemical formula of ionic and molecular compounds. Using experiments to empirically calculate the number of atoms, molecules and ions present in the given chemical compounds.	**HS-PS1-7**	**PS1.B**
Using patterns in the periodic table to combine atoms and ions into new products, in the correct proportions - consistent with chemistry principles, and generate formulas and names with fidelity, for these new products.	**HS-PS1-2** **HS-PS1-4**	**PS1.A** **ETS1.C**

UNIT: MATTER AND ITS INTERACTIONS

Big Idea: Predicting the formula weight from the chemical formula of ionic and molecular compounds. Using experiments to empirically calculate the number of atoms, molecules and ions present in the given chemical compounds.		
PE #	Performance Expectation	Disciplinary Core Idea
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.]*	**PS1.B** 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.

Observable Features

- Students can calculate the formula weight of an assigned chemical given the chemical formula.
  - Students can calculate the number of moles from an assigned weight of the chemical using gravimetric techniques

- Students can then “count by weighing” using the mole concept to convert between atoms, ions and molecules using Avogadro’s number
- Students can calculate the molar mass (formula weight) from the elemental components of a given chemical formula.
- Students can relate the atomic scale (amu) to the macroscopic scale (grams) in their empirical lab based calculations.
- Students can calculate the quantities of specific elements, ions and chemical functional groups as a subset of the overall chemical formula weight, at both the atomic scale and in grams.

- Students can identify different components of a chemical formula including polyatomic ions, functional groups and other chemical moieties based on their exposure to previous science classes, especially biologically active molecules like amino acids, lipids and electron carriers involved in cellular respiration and photosynthesis.

Key Terms
Atom, valence electrons, protons, neutrons, atomic number, mass number, atomic mass, atomic mass units (amu), atomic symbol, cation, anion, polyatomic ion, charge, molar mass, formula weight, molecular weight, formula units, mole, Avogadro's number, exponentials, gravimetric techniques, tare, significant figures, groups, periods, functional groups, grams, liters, milliliters.

SAFETY: Demonstrations and Labs may include detergents, balloons, bunsen burners and chemicals. Examples of appropriate chemicals for this course include strong acids (ex. Concentrated Hyrdrochloric acid, concentrated Nitric Acid, strong bases (ex. Sodium hydroxide, Potassium hydroxide), strong oxidizers (ex. Potassium permanganate, manganese dioxide) and organic solvents including acetone and hexane.PPE must be worn and students must follow all safety procedures outlined in the safety handout provided to them for this class.

Suggested Phenomenon
Pouring a given volume of orange juice and reading the label calculate the grams of vitamin C present in this solution. Then have students measure out twice that volume, using water (distilled if available), and have them calculate how much ascorbic acid needs to be added to the water to get the same concentration of vitamin C, in grams per liter. Provide students with the chemical formula of ascorbic acid. Have students write down their observations of what happens when ascorbic acid is added to water.

UNIT: MATTER AND ITS INTERACTIONS

Provide students with a certain weight copper sulfate pentahydrate and have them calculate the molar mass. Then have the students gently heat the provided chemical and calculate the subsequent molar mass of the anhydrous chemical. Have them then calculate the water content of hydrated salt. Repeat this experiment with aluminum sulfate octadecahydrate. Vinegar & Baking soda demonstration/ lab activity to introduce the concept of molar mass for reactions https://thewonderofscience.com/assessment-project/2017/12/12/baking-soda-conservation?rq=baking%20soda Defining the mole https://www.youtube.com/watch?v=keaDplIV49M (National Physical Laboratory) https://www.youtube.com/watch?v=TEl4jeETVmg (TED talk)
Additional Resources Introduction to moles (Tyler DeWitt) https://www.youtube.com/watch?v=wI56mHUDJgQ Counting Atoms (Tyler DeWitt) https://www.youtube.com/watch?v=hY7IzRByISk Calculating Molar Mass (Tyler DeWitt) https://www.youtube.com/watch?v=Qflq48Foh2w Converting between atoms, moles and molecules (Tyler DeWitt) https://www.youtube.com/watch?v=HMAOrGpkTsQ Moles Lab - excellent lab to introduce and reinforce skills to calculate moles - Target lab with a grading scale. https://drive.google.com/file/d/1I6XfRVkeY5r_IqyoR-0NknoOQXViyaUE/view?usp=sharing Hydrate lab - teaches students basic lab skills and introduces students to the concept of hydration https://drive.google.com/file/d/10D6H3i_BTJtDS35LzMcW0IPHRWngc9X-/view?usp=sharing

UNIT: MATTER AND ITS INTERACTIONS

Big Idea: Using patterns in the periodic table to combine atoms and ions into new products, in the correct proportions - consistent with patterns in the periodic table, and generate formulas and names with fidelity, for these new products.		
PE #	Performance Expectation	Disciplinary Core Idea
HS-PS1-2 **HS-PS1-4**	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.]* 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*	**PS1.A** The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. (HS-PS1-1),(HS-PS1-2)The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (HS-PS1-3),(secondary to HS-PS2-6) **ETS1.C** 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)

	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.]	

Observable Features

- Students can 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 in a given chemical formula.
- Students can identify different components of a chemical formula including polyatomic ions, functional groups and other chemical moieties.
- Students can associate many everyday chemicals with formulas and names.
- Students can identify and describe the evidence used to construct the explanations for compound type and formulas, including:
    - Identification of compound type, including their chemical formulas and the arrangement of the outermost (valence) electrons within the structure.
    - Identification of the number of the atoms, the elements, and process of accounting for this in the nomenclature of chemical formulas (i.e. sodium chloride vs. octane)
    - Identification of the chemical name and formula from a given structural formula
- The patterns of reactivity (e.g., the high reactivity of alkali metals and halogens) at the macroscopic level as chemical compounds are formed and the rearrangement of atoms in lattice structures in ionic compounds and allotropes.

Key Terms

Atom, valence electrons, protons, neutrons, atomic number, mass number, atomic mass, atomic mass units (amu), atomic symbol, elements, allotropes, cation, anion, polyatomic ion, charge, molar mass, formula weight, molecular weight, formula units, mole, Avogadro's number, exponentials, gravimetric techniques, tare, significant figures, groups, periods, functional groups, grams, liters, milliliters, mono, di, tri, tetra,penta, hexa, hepta, octa, nona, deca, methane, ethane, propane, butane, hexane,heptane,octane, benzene, polyatomic ions from provided list, organic compounds,molecular compounds

UNIT: MATTER AND ITS INTERACTIONS

SAFETY: Demonstrations and Labs may include detergents, balloons, bunsen burners and chemicals. Examples of appropriate chemicals for this course include strong acids (ex. Concentrated Hydrochloric acid, concentrated Nitric Acid, strong bases (ex. Sodium hydroxide, Potassium hydroxide), strong oxidizers (ex. Potassium permanganate, manganese dioxide) and organic solvents including acetone and hexane. PPE must be worn and students must follow all safety procedures outlined in the safety handout provided to them for this class.
Suggested Phenomenon Why do formulas matter: Lyrica advertisement: structure that brings in $3.5 billion in sales last year https://www.ispot.tv/ad/w9A2/lyrica-most-people How much does the ad cost Pfizer https://www.fiercepharma.com/marketing/goodbye-to-lyrica-ads-typical-big-tv-ad-spender-drops-off-top-10-october What does the patent for this structure look like? https://drive.google.com/file/d/17boivA5it9sfW6itLgS5cKIhX2GOUFjr/view?usp=sharing How elements and compounds interact - visual alchemy with ferrofluids. https://www.youtube.com/watch?v=uLAeHVRxhAU Intro to patterns on the periodic table with a specific reference to magnesium hydroxide https://www.youtube.com/watch?v=FKoNE_hzQm0 Milk of Magnesia - what happens when you add an acid based drain cleaner https://www.youtube.com/watch?v=6Fy0sTMDFuw Combining elements into new compounds with different properties (amalgams of mercury) https://www.youtube.com/watch?v=ZiWlthrtneU https://www.youtube.com/watch?v=qZZf9PMOfjU (alkali metals and halogens) https://www.youtube.com/watch?v=PKA4CZwbZWU (introduction to ionic vs. molecular (covalent) compounds). Explaining the process of generating formulas and the names of ionic compounds https://www.youtube.com/watch?v=TQKIbJIqLeA https://www.youtube.com/watch?v=URc75hoKGLY&t=108s

https://www.youtube.com/watch?v=Rq0A-AHdB74 with transition metals Explaining the process of generating formulas and the names for molecular compounds https://www.youtube.com/watch?v=DejkvR4pvRw https://www.youtube.com/watch?v=nijb6UMvZuE&t=209s
Additional Resources Matter & its interactions https://www.ck12.org/ngss/high-school-physical-sciences/matter-and-its-interactions Anion formation https://www.ck12.org/chemistry/anion-formation/ Cation formation https://www.ck12.org/chemistry/cation-formation/ Practice being able to name ionic compounds (binary and polyatomic) https://drive.google.com/file/d/15O1iF4jVdmCSYUUYC8l4XmepY02wXTmT/view?usp=sharing Ion formula chart https://drive.google.com/file/d/1RWv5B1IBk2zyMbw2XK0_kD4CFVq5Mh86/view?usp=sharing Practice with names and formulas https://drive.google.com/file/d/1SPDUvof0LpEamLFyfL97ImmedpeY9y09/view?usp=sharing Differentiating between ionic and molecular compounds https://betterlesson.com/lesson/619488/bonding-inquiry?from=cc_lesson

UNIT: CHEMICAL REACTIONS

Unit Overview
In this lab-based unit, students investigate answers to the questions: "How do substances combine or change (react) to make new substances? How does one characterize and explain these reactions and make predictions about them?" Chemical reactions, including rates of reactions and energy changes, are understood by students at this level in terms of the collisions of molecules and the rearrangements of atoms. The crosscutting concepts of patterns, energy and matter, and stability and change are called out as organizing concepts as students investigate how they can predict and explain the outcomes of chemical reactions. In these performance expectations, students are expected to demonstrate proficiency in developing and using models, using mathematical thinking, constructing explanations, and designing solutions; and to use these practices to demonstrate understanding of the core ideas about chemical reactions

Unit At-a-Glance		
Big Ideas	**Performance Expectations**	**Disciplinary Core Ideas**
Predictable patterns and conservation of mass can be used to explain the outcome of a simple chemical reaction	HS-PS1-2 HS-PS1-7	PS1.A PS1.B
Chemical reaction rates and whether energy stored or released in chemical processes can be understood in terms of the rearrangements of atoms	HS-PS1-4 HS-PS1-5	PS1.A PS1.B
Changes in a system in chemical equilibrium can affect the amounts of products and reactants in a chemical reaction	HS-PS1-6	PS1.B ETS1.C

UNIT: CHEMICAL REACTIONS

Big Idea: Predictable patterns and conservation of mass can be used to explain the outcome of a simple chemical reaction		
PE #	Performance Expectation	Disciplinary Core Idea
HS-PS1-2 **HS-PS1-7**	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.] 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	**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.

	complex chemical reactions.] **Content Limits** Assessment is limited to main group elements and does not include quantitative understanding of ionization energy beyond relative trends. Assessment does not include complex chemical reactions. Students do not need to know: Properties of individual elements, names of groups, or anomalous electron configurations (Chromium and Copper)	

Observable Features

- Students can construct an explanation of the outcome of a given reaction, including:
  - The idea that the total number of atoms of each element in the reactant and products is the same
  - The numbers and types of bonds (i.e., ionic, covalent) that each atom forms, as determined by the outermost (valence) electron states and the electronegativity
  - The outermost (valence) electron state of the atoms that make up both the reactants and the products of the reaction is based on their position in the periodic table
  - A discussion of how the patterns of attraction allow the prediction of the type of reaction that occurs (e.g., formation of ionic compounds, combustion of hydrocarbons)

- Students can identify and describe the evidence used to construct the above explanation, including:
  - Identification of the products and reactants, including their chemical formulas and the arrangement of their outermost (valence) electrons
  - Identification that the number and types of atoms are the same both before and after a reaction
  - Identification of the numbers and types of bonds (i.e., ionic, covalent) in both the reactants and the products
  - The patterns of reactivity (e.g., the high reactivity of alkali metals) at the macroscopic level as determined by using the periodic table

    - The outermost (valence) electron configuration and the relative electronegativity of the atoms that make up both the reactants and the products of the reaction based on their position in the periodic table.

- Students can 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.

- Students can 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.

- Students can **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).

- Students can use the mole to convert between the atomic and macroscopic scale in the analysis.

- Students can identify and describe the relevant components in a mathematical representation of a chemical reaction:
    - 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)

- Students can **describe** how the mathematical representations (e.g. stoichiometric calculations) support the claim that atoms, and therefore mass, are conserved during a chemical reaction.

- Students can use the mathematical representation of a chemical reaction to:
    - Predict the relative number of atoms in the reactants versus the products at the atomic molecular scale
    - Calculate the mass of any component of a reaction, given any other component.

Key Terms

Proton, electron, neutron, valence shell, filled shell, ion, cation, anion, metal, nonmetal, metalloid, group, period, family, pure substance, atomic number, atomic symbol, atomic weight, ionic bond, covalent bond, s, p, d, f orbitals, electron configuration, core electrons, nucleus, single, double, triple bond(s), molar mass, atomic radius, electronegativity, mole, molar ratio, molar mass, limiting reactant, excess reactant, yield(s), theoretical yield, actual yield, concentration, conversion, reversible

UNIT: CHEMICAL REACTIONS

*Note: For NGSS students are NOT expected to know the following terms: Dimensional analysis, stoichiometry, dynamic equilibrium, oxidation state, oxidation-reduction reaction, decomposition, single replacement reaction, double replacement reaction, synthesis reaction, combustion reaction, precipitate, solvent, solute, reaction rate, recombination of chemical elements HOWEVER - familiarity of these vocabulary terms is necessary at the honors level as preparation for AP Chemistry

SAFETY: Demonstrations and Labs may include detergents, balloons, bunsen burners and chemicals. Examples of appropriate chemicals for this course include strong acids (ex. Concentrated Hyrdrochloric acid, concentrated Nitric Acid, strong bases (ex. Sodium hydroxide, Potassium hydroxide), strong oxidizers (ex. Potassium permanganate, manganese dioxide) and organic solvents including acetone and hexane.PPE must be worn and students must follow all safety procedures outlined in the safety handout provided to them for this class.

Suggested Phenomenon

- **HS-PS1-2:** Two metals are placed in water. One bubbles and fizzes, while the other gives off a yellow flame and white smoke.
- **Video: Balloon Race Limiting Reactant Demo**
- **HS-PS1-7:** The history of Apollo 13- the main reaction that had to occur in this instance was the only thing that kept these astronauts alive. https://www.youtube.com/watch?v=i8BsEmyswaY&t=4s
- **The formation of rust**
- Methane gas flows into a Bunsen burner. When a spark is applied, methane gas reacts with oxygen in the air to produce a blue flame. The flame gets larger as the oxygen valve is turned to allow more oxygen to mix with methane. https://www.youtube.com/watch?v=7uGjDsN8JGM

Additional Resources

The Wonder of Science HS-PS1-2 site: https://thewonderofscience.com/hsps12

The Wonder of Science HS-PS1-7 site: https://thewonderofscience.com/hsps17

CK-12 HS-PS1-2 site: https://www.ck12.org/ngss/high-school-physical-sciences/matter-and-its-interactions

CK-12 HS-PS1-7 site: https://www.ck12.org/ngss/high-school-physical-sciences/matter-and-its-interactions

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An Alternative way to Inflate Balloons

The Chemistry of Apollo-13: https://www.shmoop.com/stoichiometry/history.html

PhET Simulation: Balancing Chemical Equations (HTML5)
Use mathematics and visual representations to balance chemical equations.

PhET Simulation: Reactions & Rates (Java)
See that atoms are conserved in an equilibrium situation where there are unreacted particles.

PhET Simulation: Reactions & Rates (Java)
Provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.

Great School Partnership: Why do chemical reactions occur?
https://www.greatschoolspartnership.org › wp-content › uploads › 2017/03
Two-week unit that uses the periodic table to determine the properties of elements (HS-PS1-1) and use that knowledge to predict the outcome of simple chemical reactions and explain why they occur.

Bonding Inquiry: https://betterlesson.com/lesson/619488/bonding-inquiry?from=cc_lesson
Students will be able to differentiate between ionic and covalent compounds by performing eight different tests. Big Idea: Ionic and covalent compounds have different chemical and physical properties.

Ionic, Covalent, and Metallic Bonds https://betterlesson.com/lesson/619489/ionic-covalent-and-metallic-bonds?from=cc_lesson
Students will be able to differentiate between ionic, covalent, and metallic bonds by analyzing a reading and performing a lab. Big Idea: Ionic, covalent, and metallic compounds have specific chemical and physical properties.

Bonding Inquiry Activity
https://betterlesson.com/lesson/630220/bonding-inquiry-activity?from=cc_lesson
SWBAT differentiate between metals and nonmetals with regard to number of valence electrons, electron behavior and ability to become an anion or cation. Big Idea: Ionic and covalent bonds result from the gain, loss or sharing of electrons.

LA + B --> L + AB: https://betterlesson.com/lesson/636418/la-b-l-ab?from=cc_lesson

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SWBAT work in the lab to identify single and double replacement reactions. Big Idea: Knowing the type of reaction helps in predicting the outcome.

Limiting Reactant, Theoretical Yield, and Percent Yield
https://betterlesson.com/lesson/619508/limiting-reactant-theoretical-yield-and-percent-yield?from=cc_lesson
Students will be able to distinguish limiting versus excess reactants in a chemical reaction as well as calculate percent yield as demonstrated by doing an activity, taking notes, and performing practice questions. Big Idea:
In chemical reactions a limiting recant causes a reaction to stop, while an excess reactant is leftover. Additionally one can calculate percent yield using the experimental value from performing a lab and the theoretical value from calculations.

Mole Ratios https://betterlesson.com/lesson/635201/mole-ratios?from=cc_lesson
Students will be able to calculate the number of moles produced or needed in a chemical reaction using a balanced chemical equation. Big Idea: The mole provides chemists with a bridge between the microscopic and the macroscopic world. Mole ratios are used to predict the amount of product formed or reactants needed.

Conservation of Mass Lab https://betterlesson.com/lesson/636075/conservation-of-mass-lab?from=cc_lesson
SWBAT model, identify and balance chemical reactions demonstrating the Law of Conservation of Mass.
Big Idea: Students conduct an investigation that shows mass is conserved during the chemical reaction between sulfuric acid and steel wool (iron).

Baking Soda and Vinegar Reactions: http://labsci.stanford.edu/images/Stoichiometry-T.pdf (*suggested for Chem H.)

How Elements Form Compounds: This is a video excerpt showing how sodium reacts with chlorine to form salt. It is accompanied by discussion questions for engagement.
https://cptv.pbslearningmedia.org/resource/nvhe.sci.chemistry.compounds/how-elements-form-compounds/

Boiling Point Lab: http://www.chsd.us/~tthompson/assignments/trimester3/Physical%20Science/boiling%20point%20lab.pdf

Observing and Modeling Chemical Reactions

Argument Driven Inquiry in Chemistry - Lab 7. Periodic trends: Which properties of the elements follow a periodic trend?

Argument Driven Inquiry in Chemistry - Lab 10. Identification of an unknown based on physical properties: what type of solution

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is the unknown liquid? **Argument Driven Inquiry in Chemistry -** Lab 24. Identification of reaction products: what are the products of the chemical reaction? **Argument Driven Inquiry in Chemistry -** Lab 27. Stoichiometry and chemical reactions: which balanced chemical equation best represents the thermal decomposition of sodium bicarbonate?

Big Idea: Chemical reaction rates and whether energy stored or released in chemical processes can be understood in terms of the rearrangements of atoms		
PE #	Performance Expectation	Disciplinary Core Idea
HS-PS1-4 **HS-PS1-5**	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.] Apply scientific principles and evidence to provide an explanation about the effects of	**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.

	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.] NOTE: Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawing and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved. Emphasis is on student reasoning that focuses on the number and energy of collisions between molecules. **Content Limits:** Assessment does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products. It 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.	

Observable Features

- Students can use evidence to develop a model in which they identify and describe the relevant components,

including:
  - The chemical reaction, the system, and the surroundings under study
  - The bonds that are formed/broken 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
  - The relative potential energies of the reactants and the products.

- In the model, students can include and describe the relationships between components, including:
  - The net change of energy within the system is the result of bonds that are broken and formed during the reaction (Note: This does not include calculating the total bond energy changes.)
  - The energy transfer between system and surroundings by molecular collisions
  - The release or absorption of energy depends on whether the relative potential energies of the reactants and products decrease or increase.

- Students can use the developed model to illustrate
  - The energy change within the system is accounted for by the change in the bond energies of the reactants and products. (Note: This does not include calculating the total bond energy changes.)
  - 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.
  - The relative total potential energies of the reactants and products can be accounted for by the changes in bond energy.

- Students can 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.

- Students can identify and describe evidence (e.g., from a table of data) of a pattern that increases in concentration (e.g., a change in one concentration while the other concentration is held constant) increases the reaction rate, and vice versa, and evidence of a pattern that increases in temperature usually increases the reaction rate, and vice

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versa.

- Students use and describe the following chain of reasoning that integrates evidence, facts, and scientific principles to construct the explanation:
    - Molecules that collide can break bonds and form new bonds, producing new molecules.
    - The probability of bonds breaking in the collision depends on the kinetic energy of the collision being sufficient to break the bond, since bond breaking requires energy.
    - Since temperature is a measure of average kinetic energy, a higher temperature means that molecular collisions will, on average, be more likely to break bonds and form new bonds.
    - At a fixed concentration, molecules that are moving faster also collide more frequently, so molecules with higher kinetic energy are likely to collide more often.
    - 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.

Key Terms
Transfer, heat energy, atomic arrangement, stored energy, conversion, bond energy, release of energy, endothermic, exothermic, stored energy, conversion, concentration, reaction rate, activation energy, catalyst, enzyme, equilibrium

Note: For NGSS students are NOT expected to know the following terms:
Recombination of chemical elements, stable, chemical system, rate laws, rate constant, zero order reactions, first order reactions, stepwise reactions, rate-determining step, steady state, half-life, free radicals, entropy, Gibb's free energy

SAFETY: Demonstrations and Labs may include detergents, balloons, bunsen burners and chemicals. Examples of appropriate chemicals for this course include strong acids (ex. Concentrated Hyrdrochloric acid, concentrated Nitric Acid, strong bases (ex. Sodium hydroxide, Potassium hydroxide), strong oxidizers (ex. Potassium permanganate, manganese dioxide) and organic solvents including acetone and hexane.PPE must be worn and students must follow all safety procedures outlined in the safety handout provided to them for this class.

Suggested Phenomenon
- The light in a sparkler
- Lightstick Reaction Rates versus Temperature
- Hawaii volcano eruption also demonstrating gas production
- Video: **Elephant Toothpaste**

- Video: **Reaction in a Bag**

Additional Resources

The Wonder of Science HS-PS1-4 site: https://thewonderofscience.com/hsps14

The Wonder of Science HS-PS1-5 site: https://thewonderofscience.com/hsps15

CK-12 HS-PS1-4 site: https://www.ck12.org/ngss/high-school-physical-sciences/matter-and-its-interactions

CK-12 HS-PS1-5 site: https://www.ck12.org/ngss/high-school-physical-sciences/matter-and-its-interactions

Storyline Unit: Why do some things get colder (or hotter) when they react?

Chemicals in the Kitchen

Chemical Reactions and Stoichiometry In this activity, students explore reactions in which chemical bonds are formed and broken. Students experiment with changing the temperature and the concentration of the atoms in order to see how these affect reaction rates. They also learn how to communicate what happens during a chemical reaction by writing the ratios of reactants and products, known as stoichiometry.

Chemical Reaction Rates: Inquiry on Affecting Factors This lesson focuses on having students examine the effect of different factors on the rate of a chemical reaction, including: temperature, concentration of particles, surface area of reactants, and the presence of catalysts.

Alka Seltzer and Factors that Affect Reaction Rates: In this lesson students have a chance to practice what they learned about reaction rates through performing a lab activity. Students will be able to explain the factors that affect the rate of a reaction as evidenced by performing a lab activity.

Reaction Rates through Performance Assessment: This folder contains lab activities on reaction rates

Lesson 3: Investigating Energy in Chemical Reactions

UNIT: CHEMICAL REACTIONS

Lesson 1: Investigating Reaction Rates **HS-PS1-4 Performance Assessment** - **Total Bond Energy Change in Chemical Reactions** **Argument Driven Inquiry in Chemistry** - Lab 5. Temperature changes due to evaporation: which of the available substances has the strongest intramolecular forces? **Argument Driven Inquiry in Chemistry** - Lab 21. Reaction rates: why do changes in temperature and reactant concentration affect the rate of a reaction? **Argument Driven Inquiry in Chemistry** - Lab 28. Designing a cold pack: which salt should be used to make an effective but economical cold pack?

Big Idea: Changes in a system in chemical equilibrium can affect the amounts of products and reactants in a chemical reaction		
PE #	Performance Expectation	Disciplinary Core Idea
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	**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. **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)

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	Boundary: Assessment is limited to specifying the change in only one variable at a time. Assessment does not include calculating equilibrium constants and concentrations] NOTE: 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. **Content Limits:** Assessment is limited to specifying the change in only one variable at a time. Assessment does not include calculating equilibrium constants and concentrations.	

Observable Features

- Students can identify and describe potential changes in a component of a given chemical reaction system that will increase the amounts of particular species at equilibrium. Students 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;
  - 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.

- Students can describe the prioritized criteria and constraints, and quantify each when appropriate. Examples of constraints to be considered are cost, energy required to produce a product, hazardous nature and chemical properties of reactants and products, and availability of resources.

UNIT: CHEMICAL REACTIONS

- Students can systematically evaluate the proposed refinements to the design of the given chemical system. The potential refinements are evaluated by comparing the redesign to the list of criteria (i.e., increased product) and constraints (e.g., energy required, availability of resources).

- Students can refine the given designed system by making tradeoffs that would optimize the designed system to increase the amount of product, and describe the reasoning behind design decisions.

Key Terms
Surface area of reactants, dynamic, thermal energy, heat energy, atomic arrangement, equilibrium, bond energy, endothermic, exothermic, catalyst, chemical bond, mole, element, compound, concentration, Le Chatelier's principle

SAFETY: Demonstrations and Labs may include detergents, balloons, bunsen burners and chemicals. Examples of appropriate chemicals for this course include strong acids (ex. Concentrated Hyrdrochloric acid, concentrated Nitric Acid, strong bases (ex. Sodium hydroxide, Potassium hydroxide), strong oxidizers (ex. Potassium permanganate, manganese dioxide) and organic solvents including acetone and hexane.PPE must be worn and students must follow all safety procedures outlined in the safety handout provided to them for this class.

Suggested Phenomenon

- **Video: Indestructible Coating - Polyurea**
- **Reusable Heat Packs**
- **Bailing Beakers Equilibrium:** https://www.youtube.com/watch?v=CMs2WhGY3NE

Additional Resources

The Wonder of Science HS-PS1-6 site: https://thewonderofscience.com/hsps16

CK-12 HS-PS1-6 site: https://www.ck12.org/ngss/high-school-physical-sciences/matter-and-its-interactions

PhET Simulation: Reactions & Rates (Java)

UNIT: CHEMICAL REACTIONS

Change concentrations, energy of reactions, temperatures, types of reactions and see changing concentrations

PhET Simulation: PhET Reversible Reactions
Watch a reaction proceed over time. How does total energy affect a reaction rate? Vary temperature, barrier height, and potential energies. Record concentrations and time in order to extract rate coefficients.

Equilibrium and Le Chatelier's Principle:
https://betterlesson.com/lesson/638816/equilibrium-and-le-chatelier-s-principle?from=cc_lesson
Students will be able to define chemical equilibrium and use Le Chatelier's Principle to predict how changes in pressure, concentration, and temperature affect systems in equilibrium through doing an activity, taking notes, watching videos, and performing practice questions. Big Idea: Equilibrium occurs when the rates of the forward and reverse reactions are equal. Le Chatelier's Principle can be used to predict how changes in concentration, pressure, and heat affect these equilibrium systems.

Lesson 2: Exploring Chemical Equilibrium During the lesson "Exploring Chemical Equilibrium," students will identify how a change in conditions, such as concentration, temperature, or pressure, may affect the amounts of products and reactants in a system at chemical equilibrium. They will also explore acid-base equilibrium systems.

Lesson 3: Analyzing Chemical Systems During the lesson "Analyzing Chemical Systems," students will revisit systems and explore real-world chemical reactions and processes in designed and natural systems.

Reaction Exposed: The Big Chill!

At What Point is a Reversible Reaction Completed?:
https://d3jc3ahdjad7x7.cloudfront.net/avhWLtXhUoF4WQx87XlwdZ6rnAC33Itn6uQoRvxU6BG6FyuA.pdf

Reversible Reactions: https://betterlesson.com/lesson/639906/reversible-reactions?from=cc_lesson
Use computer models (PhET Reversible Reactions) to understand reversible reactions, and that one side -- reactants or products -- of the reaction may be favored. Big Idea: Students can visualize reversible reactions using computer simulations.

Fracking Explained - Video about the impact of pressure on production of natural gas.

Exploring Enzymes Lab - The impact of temperature on biological & chemical systems and product formation

UNIT: CHEMICAL REACTIONS

Argument Driven Inquiry in Chemistry Lab 17. Limiting reactants: why does mixing reactants in different mole ratios affect the amount of the product and the amount of each reactant that is left over?

Argument Driven Inquiry in Chemistry Lab 22. Chemical equilibrium: why do changes in temperature, reactant concentration, and product concentration affect the equilibrium point of a reaction?

Argument Driven Inquiry in Chemistry Lab 30. Equilibrium constant and temperature: how does a change in temperature affect the value of the equilibrium constant for an exothermic reaction?