CTECS

CONNECTICUT TECHNICAL EDUCATION AND CAREER SYSTEM

Grade 11

Chemistry/Honors Chemistry

SC610/SC615

Connecticut Technical High School System
39 Woodland Street
Hartford, Connecticut 06105

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CTECS - Vision of a Graduate

The Vision of a Graduate (VoG) at the Connecticut Technical Education and Career System (CTECS) embodies our commitment to preparing students for success in Connecticut's workforce.

Developed in collaboration with students, parents, staff, and employers, the VoG ensures that CTECS students are not only job-ready but also equipped to lead, innovate, and adapt in a dynamic world.

As educators, we are dedicated to developing these qualities by providing a comprehensive education that empowers our students to achieve their fullest potential and make meaningful contributions to society.

A Problem Solver

Problem solvers tackle challenges by identifying root causes of issues, brainstorming solutions, implementing effective strategies, and demonstrating adaptability.

- ➔ Engage students with open-ended, creative thinking tasks that require both conventional and innovative solutions.
- ➔ Facilitate group discussions and collaborative projects.
- ➔ Use real-world scenarios and hands-on activities.
- ➔ Highlight the importance of effort, persistence, and continuous learning.
- ➔ Provide regular feedback and encourage reflection.

Work Ready

To be work-ready includes a combination of technical expertise, soft skills, and personal qualities that ensure a graduate can effectively contribute to the workplace from day one.

- ➔ Set high standards for punctuality, responsibility, professionalism, and task completion.
- ➔ Use project-based learning and collaborative assignments.
- ➔ Emphasize clear written and verbal communication.
- ➔ Offer practical exercises like mock interviews and resume workshops.
- ➔ Integrate technology and teach digital literacy.

Respectful

Graduates who embody respectfulness emphasize the importance of treating others with dignity, valuing diversity, and fostering an inclusive and positive environment, both personally and professionally.

- ➔ Demonstrate personal, interpersonal, and professional skills.
- ➔ Show respect for diversity.
- ➔ Model respect through active listening and empathy.
- ➔ Set clear expectations for respectful interactions.
- ➔ Promote collaboration and group discussions.
- ➔ Celebrate respectful behavior.
- ➔ Address disrespect promptly and constructively.

Skilled Socially

Graduates who are skilled socially are equipped to navigate social environments, build relationships, and contribute positively to their communities and workplaces.

- ➔ Show awareness of global responsibility to others and the environment.
- ➔ Participate in community involvement.
- ➔ Design cooperative group projects and team activities
- ➔ Set expectations for respect and give regular feedback.
- ➔ Facilitate discussions on inclusivity, kindness, and respect.
- ➔ Model positive interactions and recognize strong social skills.

A Critical Thinker

Critical thinkers approach problems systematically by analyzing, evaluating, and synthesizing information to make well-informed decisions and contribute to innovative solutions.

- ➔ Encourage critical thinking individually and collaboratively.
- ➔ Design lessons that challenge assumptions and explore diverse viewpoints.
- ➔ Use open-ended questions, rigorous activities, and cross-curricular projects.
- ➔ Integrate project-based learning and real-world problem-solving.
- ➔ Offer reflective opportunities like journaling and discussions.
- ➔ Cultivate an environment that values curiosity and inquiry.

An Effective Communicator

Effective communicators convey ideas, information, and emotions accurately and persuasively, fostering understanding and collaboration.

- ➔ Communicate effectively using oral, written, visual, artistic, and technical modes.
- ➔ Include group discussions, presentations, and peer reviews.
- ➔ Promote active listening and thoughtful responses.
- ➔ Offer clear guidelines and constructive feedback.
- ➔ Stress clear, respectful, and purposeful communication.

CTECS Instructional Model

CTECS uses the Marzano Compendium to guide research-based instructional strategies that differentiate learning and promote access, engagement, and success for all students. Teachers apply these strategies to support diverse learners (including multilingual learners, students with disabilities, and students with varied academic or technical backgrounds) through scaffolds, modeling, guided practice, and multiple ways to participate and show understanding. This approach ensures every student can work toward proficiency in the Priority Standards and the competencies outlined in the CTECS Vision of a Graduate.

Curriculum Introduction

This curriculum document outlines the essential learning for this academic program and provides a clear structure for planning, instruction, and assessment. It includes the components required by NEASC Standard 2.2a, along with elements that reflect the unique nature of CTECS academic programs. The curriculum is organized to show what students learn in each course, how learning progresses across grade levels, and how instruction supports both technical skill development and the CTECS Vision of a Graduate.

Teachers should use this document to:

- Understand the overall structure and expectations of the course sequence
- Reference the Course Map to see the scope and sequence of Priority Standards
- Use the Priority Standards and Units of Study to guide daily, weekly, and cycle-based planning
- Integrate Big Ideas, Essential Questions, Skills/Learning Outcomes, vocabulary, and resources during lesson design
- Plan and implement formative assessments to monitor progress and guide instruction
- Prepare students for the District Summative Assessments, ensuring alignment with the Course Map
- Maintain consistency of instruction across campuses while adapting to student needs

Curriculum Components

Course Map

A Course Map serves as the scope and sequence for this course by outlining the progression of instructional units and the standards that guide teaching and assessment. While each campus will have individual student needs, cycle schedules, and industry-based opportunities, all instructors are expected to teach the standards outlined in the Course Map. Using the Course Map below, teachers will intentionally plan learning experiences that prepare students to meet the identified standards within the designated assessment windows.

Priority Standards (Units of Study)

Priority Standards identify the most essential learning in the trade program. They reflect the core technical competencies, safety practices, and industry-aligned skills that require the greatest instructional focus and appear on program assessments. In CTE programs, each Priority Standard also functions as a Unit of Study, because it includes the required components such as big ideas, essential questions, content topics, and skills/learning outcomes aligned to assessments.

Learning Outcomes

Learning outcomes are what students will know (Concepts) and be able to do (Skills). Concepts identify the major content topics within the Priority Standard (Unit of Study). They appear in the left column of the Learning Outcomes table and follow a similar coding structure as the Priority Standard. Skills are learning objectives that describe the measurable actions students must be able to perform to demonstrate proficiency. They appear in the right column of the Learning Outcomes table and show the progression of learning evidence in the Priority Standard.

Resources

Resources include the tools, equipment, texts, materials, and digital tools that support learning within each unit and reflect industry standards.

Assessment Practices

Teachers use ongoing formative assessments—such as questioning, checks for understanding, performance demonstrations, reflections, and teacher observation—to monitor progress, guide instruction, and support all learners in mastering the Priority Standards.

Vocabulary

Essential vocabulary includes the technical and academic terms students must understand and use accurately to engage in scientific learning and demonstrate proficiency on assessments. Vocabulary is foundational to safety, precision, and communication, and should be a primary initial focus within each unit and taught explicitly through modeling, demonstration, and repeated application.

Chemistry - Grade 11 or 12

Description of the Course

(1 credit) This lab course builds on knowledge developed in the previous integrated science courses. Students will be introduced to chemistry topics such as: atomic structure, chemical bonding, energy changes, stoichiometry, periodicity, and nuclear processes. Students will investigate the properties, composition, and structure of matter and the laws that govern the combination of elements and reaction of substances. The application of scientific concepts to trade experiences reinforces the curriculum. Students will apply their knowledge of chemistry to various problem-solving activities with the use of science-specific technologies and standard laboratory tools.

Honors Chemistry is an accelerated course. Students are expected to complete several inquiry-based projects over the course of the year, in addition to meeting additional, more challenging objectives. **Additional performance expectations for honors students are shaded in the curriculum chart. These performance expectations may also be integrated into the regular curriculum as appropriate.**

CTECS Science Assessment & Instruction Guidelines

The grade-level **SEP (Science and Engineering Practices) Summative Assessments** for grades 9 through 11 and the **Basic Skills Assessment** for grade 12 are designed to measure mastery of the *science and engineering practices* identified by the NGSS (Next Generation and Science Standards). The practices describe behaviors that scientists engage in as they investigate and build models and theories about the natural world and the key set of engineering practices that engineers use as they design and build models and systems.

The SEPs are:

- **Asking Questions and Defining Problems**: A practice of science is to ask and refine questions that lead to descriptions and explanations of how the natural and designed world works and which can be empirically tested.
- **Developing and Using Models**: A practice of both science and engineering is to use and construct models as helpful tools for representing ideas and explanations. These tools include diagrams, drawings, physical replicas, mathematical representations, analogies, and computer simulations.
- **Planning and Carrying Out Investigations**: Scientists and engineers plan and carry out investigations in the field or laboratory, working collaboratively as well as individually. Their investigations are systematic and require clarifying what counts as data and identifying variables or parameters.
- **Analyzing and Interpreting Data**: Scientific investigations produce data that must be analyzed in order to derive meaning. Because data patterns and trends are not always obvious, scientists use a range of tools—including tabulation, graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in the data. Scientists identify sources of error in the investigations and calculate the degree of certainty in the results. Modern technology makes the collection of large data sets much easier, providing secondary sources for analysis.
- **Using Mathematics and Computational Thinking**: In both science and engineering, mathematics and computation are fundamental tools for representing physical variables and their relationships. They are used for a range of tasks such as constructing simulations; statistically analyzing data; and recognizing, expressing, and applying quantitative relationships.

- **Constructing Explanations and Designing Solutions**: The products of science are explanations and the products of engineering are solutions.
- **Engaging in Argument from Evidence**: Argumentation is the process by which explanations and solutions are reached.
- **Obtaining, Evaluating, and Communicating Information**: Scientists and engineers must be able to communicate clearly and persuasively the ideas and methods they generate. Critiquing and communicating ideas individually and in groups is a critical professional activity.

Each grade-level SEP Summative Assessment is designed to assess mastery of specific practices. The expectation is that students should demonstrate mastery as outlined below in preparation for the NGSS Assessment in 11th grade. Cross-cutting concepts are incorporated across all courses.

Grade Level	**Science Engineering and Practices (SEPs) to be Mastered**
9 General Science	Asking Questions and Defining Problems
	Planning and Carrying Out Investigations
	Analyzing and Interpreting Data
10 Biology	Developing and Using Models
	Engaging in Argument from Evidence
	Obtaining, Evaluating, and Communicating Information
11 Chemistry Advanced Topics Physics	Using Mathematics and Computational Thinking
	Constructing Explanations and Designing Solutions

Cross-Cutting Concepts (incorporated into all courses)
Cause and Effect
Structure and Function
Systems and System Models
Scale, Proportion, and Quantity
Stability and Change
Energy and Matter
Patterns

Instruction, Grading, and Assessment Considerations

The manner and pedagogy used to teach the Disciplinary Core Ideas (DCIs) is at the discretion of the instructors. They are, however, expected to support their students in demonstrating mastery of the SEPs on the common summative assessments by the end of the course, in unit order.

Instruction:

- Keeping in mind that all DCIs should be covered by the end of the school year for each course, instructors are encouraged to engage students in learning tasks that consider relevance, interest, school trades, and available materials and supplies.
- The instructional focus should be on the SEPs and the Cross-Cutting Concepts (CCCs) as identified by the NGSS.
- Instruction can be linear or spiraling and be designed around anchoring phenomena and/or storylines.
- Interim-Based Assessment:
    - 11th Grade Chemistry: Students will be exposed to NGSS-style questions through the NGSS Practice Assessments. Skills of focus include: Test-Taking Skills, Navigating Multi-Select Questions, Desmos Calculator, Highlighting, Online Graphing.
    - Minimum of 1 Interim-Based Assessment practice session per quarter during Junior year.

Grading:

- As mandated by the District, Mandated Grading Categories are:
    - Assessment 40%
    - Labs/Projects 30%
    - Classwork/Homework 30%

Assessment (Summative and Formative):

- Three-dimensional district-wide unit assessments will measure mastery of Science and Engineering Practices (SEPs) in alignment with Cross-Cutting Concepts (CCCs) and Disciplinary Core Ideas (DCIs).
- Claim Evidence Reasoning: CERs will measure a student's ability to use data, critical thinking, and scientific reasoning to form and support an argument.

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Course Map - Chemistry

Unit	Cycles	Big Ideas	Standards	Interim Assessments

Unit 1: Big Bang and Periodic Trends	**1-3**	• Understanding of atomic structure through nuclear processes.
		• Nuclear fusion (stars)
		• The arrangement of elements in the periodic table, properties of chemicals and reactivity
		• Periodic trends
			• **HS-PS1-8**
			  ○ **HS-ESS1-1**
			  ○ **HS-ESS1-2**
			• **HS-PS1-1**
				HS-ESS1-2
				HS-PS1-1

Unit 2: Bulk Scale Properties and Reactions	**4-6**	• Bonding • Intermolecular forces dictate state/phase, conductivity, solubility • The Law of Conservation of Mass and Matter • The Mole • Factors that influence the formation of different types of chemical reactions	• **HS-PS1-2** • **HS-PS1-3** • **HS-PS1-7** • **HS-PS2-6 (HONORS ONLY)**	**HS-PS1-2**
Unit 3: Rate of Reactions and Equilibrium	**7-8**	• Collision Theory/Bond Energy • Le Chatelier's Principle	• **HS-PS1-4** • **HS-PS1-5** • **HS-PS1-6**	**HS-PS1-5** **HS-PS1-6**
Unit 4 Chemistry Topics	**9-10**	**Choices:** • Acid/Base Chemistry • Organic Chemistry • Gas Laws		

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Unit 1: Big Bang and Periodic Trends

Priority Standard (Performance Expectation): HS-PS1-8
Structure and Properties of Matter

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.)

Big Idea(s):
- While chemical reactions rearrange the world, nuclear reactions create it, releasing energy on a scale that dwarfs any other process on Earth.
- While the number of atoms of a specific element is not conserved, the total mass of all particles is conserved.

Essential Question(s):
- If atoms are the building blocks of matter, what 'factory' in the universe is responsible for building the atoms themselves?
- How do humans use the concept of nuclear reactions in society?

Examples of Engaging Phenomenon:
- Rocks from the Tuna Creek area of the Grand Canyon were tested and found to contain less lead (Pb) and more uranium (U) than rocks from the Elves Chasm area of the Grand Canyon. https://www.grandcanyontrust.org/grand-canyon-uranium/
- Mousetrap Fission https://www.youtube.com/watch?v=vjqIJW_Qr3c
- Atomic Bomb https://inquirygroup.org/history-lessons/atomic-bomb
- "Nuclear Energy: Is Fission the Future?" https://www.youtube.com/watch?v=vp3YyFy4p8c
- Nuclear Fission Animation https://www.dailymotion.com/video/x282sg
- "Plasmas are hot, fusion is cool." https://www.youtube.com/watch?v=wQYKAoNSz8g

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● US Navy Nuclear Power Program- Recruiter may come in to do a presentation ● Radiocarbon Dating https://www.youtube.com/watch?v=phZeE7Att_s ● Half- Life Gizmo ● Nuclear Decay Gizmo ● Personal Radiation Assessment https://www.epa.gov/radiation/calculate-your-radiation-dose ● Dominion Energy Millstone (Nuclear) Power Station produces 33% of Connecticut's electricity as of 2023 https://www.eia.gov/state/?sid=CT#tabs-3 ● Radiac beeping near a banana https://www.youtube.com/watch?v=z9LgUlKNGFg ● The Manhattan Project https://thewonderofscience.com/phenomenon/2018/7/7/the-manhattan-project ● Chernobyl Nuclear Meltdown https://www.georgiascienceteacher.org/phenomena/ https://www.youtube.com/watch?v=phZeE7Att_s https://www.youtube.com/watch?v=uvpS2lUHZD8

Students will know: (Disciplinary Core Ideas) HIghlights are ETTS1-1	As evidenced by: (Science & Engineering Practices)
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. ***DCI OBJECTIVES:*** ● Nuclear processes (reactions) such as fusion, fission, and radioactive decay can be modeled by nuclear equations, which show how particles and energy are conserved in these reactions. ● In nuclear processes, the number of atoms is not conserved, but the total number of protons plus neutrons is conserved. (Conservation of Matter/Mass/Energy).	**Using Mathematics and Computational Thinking** **Constructing Explanations and Designing Solutions** **Developing and Using Models** ● Develop models in which they identify and describe the relevant components of the models including Identification of an element by the number of protons; the number of protons and neutrons in the nucleus before and after the decay; the identity of the emitted particles (i.e., alpha, beta — both electrons and positrons, and gamma); and the scale of energy changes associated with nuclear processes, relative to the scale of energy changes associated with chemical processes. ● Develop five distinct models to illustrate the relationships between components underlying the nuclear processes of fission, fusion, and

● Nuclear fusion reactions power the Sun and other stars. In a fusion reaction, two light nuclei merge to form a single heavier nucleus. The process releases energy because the total mass of the resulting single nucleus is less than the mass of the two original nuclei. The leftover mass becomes energy. This process is being studied by scientists on Earth. Fusion is dependent on extreme conditions. ● Einstein's Mass-Energy Equivalence Equation, $e=mc^2$, explains mathematically how a small amount of mass can be transformed into a large amount of energy. ● Fission is a splitting of atoms where a tremendous amount of energy is released, along with neutrons that initiate a chain reaction. ● Isotopes of an element contain the same number of protons but differing numbers of neutrons. All isotopes of an element possess similar chemical properties, however physical properties including melting/boiling points, density, and nuclear decay properties may vary. Some specific isotopes are more useful than others in nuclear reactions. ● Three main types of radioactive decay are alpha decay, beta decay, and gamma decay. ● Radioactive decay is the process in which a radioactive atom spontaneously gives off radiation in the form of energy or particles to reach a more stable state. ● A half-life is the time taken for the radioactivity of a specified isotope to fall to half its original value.	three distinct types of radioactive decay. Include the following features, based on evidence, in all five models: the total number of neutrons plus protons is the same both before and after the nuclear process, although the total number of protons and the total number of neutrons may be different before and after and 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. ● 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. In both the fission and fusion models, illustrate that these processes may release energy and may require initial energy for the reaction to take place. 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.

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• A decay curve is a graph that shows the amount or percentage of the remaining radioactive substance compared to elapsed time. Each radioactive isotope produces its own unique decay curve. • All living creatures are exposed to natural radiation sources including the Sun, ground, and food sources. All living creatures are adapted to certain levels of radiation to reduce harm. Humans may be exposed to man-made radiation sources through medical tests such as x-rays and CT/CAT scans, air travel, and various consumer products including smoke detectors. High levels of radiation can cause health issues to all organisms. **(TRADE CONCEPT)** • Fusion/fission/decay equations can be balanced to account for number of particles and total energy (Conservation of Matter/Mass/Energy). This balancing process may vary greatly in complexity. • Energy release and scale difference between nuclear reactions and chemical reactions are magnitudes different. • Nuclear energy can be generated in power plants and transmitted as electricity. This public policy issue can be controversial as there are significant pros and cons. Debate on the topic should be civil and supported by factual evidence and data.	
Cross Cutting Concepts: **Energy and Matter** • Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems. Prompts for integrating cross-cutting concepts Graphic organizers for cross-cutting concepts	

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Academic Vocabulary: - Science vocabulary students ARE expected to know: Proton, Neutron, Atomic Number, Atomic Mass, Atom, Nuclear Reaction, Nucleus, Fission, Fusion, Decay Rate, Unstable, Half-life, Radioactive, Radiation, Alpha Decay, Beta Decay, Gamma Decay, Decay Curve, Isotope, Radioactive Decay - Additional tier 2 words that students should be familiar with: Transformation, Alpha Particle, Beta Particle, Gamma Radiation, Beta Emission Science vocabulary students are NOT expected to know: - Nucleon(s), radioisotopes, positron, positron emission, electron capture, radioactive series, nuclear disintegration series, magic numbers, nuclear transmutations, particle accelerators, transuranium elements, radiometric dating, becquerel (Bq) unit, curie (Ci) unit, Geiger counter, radiotracer, critical mass, supercritical mass, nuclear reactor, ionizing radiation, nonionizing radiation, target nucleus, bombarding particle, nuclear process, nuclear stability, particle emission, rate of nuclear decay, spontaneous nuclear reaction
Resources: NGSS Phenomenon Master List

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**** The following standard is to be integrated into instruction of HS-PS1-8 Structure and Properties of Matter to deepen student understanding. Due to time limitations, it does NOT need to be developed as in-depth as the main chemistry standards.****

Priority Standard (Performance Expectation): HS-ESS1-1 **Earth's Place in the Universe** Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy that eventually reaches Earth in the form of radiation.
[Clarification Statement: (Clarification Statement: Emphasis is on the energy transfer mechanisms that allow energy from nuclear fusion in the sun's core to reach Earth. Examples of evidence for the model include observations of the masses and lifetimes of other stars, as well as the ways that the sun's radiation varies due to sudden solar flares ("space weather"), the 11-year sunspot cycle, and non-cyclic variations over centuries.) (Assessment Boundary: Assessment does not include details of the atomic and subatomic processes involved with the sun's nuclear fusion.)
Big Idea(s): ● The Sun is not an eternal fire, but a cosmic engine with a finite fuel supply that dictates the past, present, and future of every system on our planet. ● The Sun's energy is produced by its core, where fusion occurs. This energy is released as electromagnetic radiation and emitted into space.
Essential Question(s): ● If the Sun is the 'battery' for all life on Earth, how can we use its current behavior to predict its eventual 'expiration date'? ● What are the implications of the sun's life span and the energy it releases for the Earth and its systems?
Examples of Engaging Phenomenon: ● Solar Flares, Sunspots, and the Solar Cycle https://thewonderofscience.com/phenomenon/2018/7/8/solar-flares-sunspots-and-the-solar-cycle https://www.youtube.com/watch?v=rx9m6H6GeLs&ab_channel=NASAGoddard https://www.youtube.com/watch?v=Z0uIcLZ5rh8&ab_channel=NASAGoddard ● Why do we sunburn? https://www.epa.gov/radtown/ultraviolet-uv-radiation-and-sun-exposure ● Chemosynthesis- Exception to the Rule https://timesofmalta.com/article/Myth-debunked-Does-all-life-on-earth-depend-on-the-sun.672339#:

~:text=.uvic.ca/-,Although%20it%20is%20true%20that%20nearly%20every%20organism%20on%20earth,simple%20sugars%20as%20food%20source.

- What happens if the Sun dies?
  https://www.youtube.com/watch?app=desktop&v=duCdi8eSK6Y&ab_channel=MakeItEasyEducation

- Aurora Borealis (Northern Lights) and Aurora Australis (Southern Lights)
  https://www.space.com/15139-northern-lights-auroras-earth-facts-sdcmp.html
  https://www.swpc.noaa.gov/products/aurora-viewline-tonight-and-tomorrow-night-experimental
  https://www.youtube.com/watch?v=EMw4OPjRnTo

Students will know: (Disciplinary Core Ideas)	As evidenced by: (Science & Engineering Practices)
ESS1.A: The Universe and Its Stars • The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years. **PS3.D: Energy in Chemical Processes and Everyday Life** • Nuclear fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation. ***<u>DCI OBJECTIVES:</u>*** • Our Sun is a yellow dwarf star following a relatively stable life cycle. It begins as a main sequence star, fusing hydrogen into helium in its core for billions of years. Eventually, the hydrogen fuel will be exhausted, leading to the star expanding and becoming a red giant. After shedding its outer layers, the core will cool and become a white dwarf. It will then gradually cool further and fade into a black dwarf. This process takes place over billions of years. • All life on Earth depends on energy. Almost all of that energy comes from the Sun where nuclear fusion releases it to travel as radiation throughout the solar system.	**Using Mathematics and Computational Thinking** **Constructing Explanations and Designing Solutions** **Developing and Using Models** • Develop a model that identifies and describes the relevant components, including: i. Hydrogen as the sun's fuel; ii. Helium and energy as the products of fusion processes in the sun; and iii. That the sun, like all stars, has a life span based primarily on its initial mass, and that the sun's lifespan is about 10 billion years. • Describe relationships between the components, including a description of the process of radiation, and how energy released by the sun reaches Earth's system. • Predict how the relative proportions of hydrogen to helium change as the sun ages.Qualitatively describe the scale of the energy released by the fusion process as being much larger than the scale of the energy released by chemical processes. Identify that chemical processes are unable to produce the amount of energy flowing out of the sun over long periods of time, thus requiring fusion processes as the mechanism for energy release in the sun.

● The Sun's radiation output varies due to solar flares, the sunspot cycle, and noncyclic variations. ● Solar flares, often called "space weather," are sudden, intense releases of energy from the Sun's atmosphere, often accompanied by coronal mass ejections, large temporary emissions of solar material. They release radiation across the electromagnetic spectrum, including X-rays and UV radiation, that can impact Earth's upper atmosphere and ionosphere. ● The Sun follows an 11-year sunspot cycle. It has variations in the number of sunspots (cooler, darker areas on the Sun's surface). During periods of high activity (solar maximum), the Sun emits slightly more electromagnetic radiation than during periods of low activity (solar minimum). ● Over centuries, the Sun's radiation can also vary in a non-cyclic way.	

Cross Cutting Concepts:
Scale, Proportion, and Quantity

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

Academic Vocabulary:

- Science vocabulary students ARE expected to know: Sun, Nuclear Fusion, Core, Energy, Radiation, Electromagnetic Spectrum, Solar Wind, Solar Flares, Life Span, Sunspot, Solar Cycle, Life Cycle, Yellow Dwarf, Main Sequence Star, Red Giant, White Dwarf, Black Dwarf, Model, Evidence, Convection

- Additional tier 2 words that students should be familiar with: Stellar Evolution, Thermonuclear Reactions, Space Weather, UV Radiation, Atmosphere, Ionosphere, Solar Maximum, Solar Minimum, Photosynthesis, Chemosynthesis, Coronal Mass Ejections, Photosphere

Science vocabulary students are NOT expected to know: photosphere, chromosphere, corona, coronal mass ejections

Resources: NGSS Phenomenon Master List

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**** The following standard is to be integrated into instruction of HS-PS1-8 Structure and Properties of Matter to deepen student understanding. Due to time limitations, it does NOT need to be developed as in-depth as the main chemistry standards.****

Priority Standard (Performance Expectation): HS-ESS1-2
Earth's Place in the Universe

Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.

(Clarification Statement: Emphasis is on the astronomical evidence of the redshift of light from galaxies as an indication that the universe is currently expanding, the cosmic microwave background as the remnant radiation from the Big Bang, and the observed composition of ordinary matter of the universe, primarily found in stars and interstellar gasses (from the spectra of electromagnetic radiation from stars), which matches that predicted by the Big Bang theory (3/4 hydrogen and 1/4 helium).

Big Idea(s):
- The universe is an expanding "history book," where light arriving from distant galaxies serves as evidence that everything we see emerged from a single, hot, dense beginning.
- Stars act as massive nuclear furnaces, producing elements through nuclear fusion, such as hydrogen and helium into larger elements, all the way up to iron (Fe). The elements produced depend heavily on the mass of the star and its stage in its life cycle and elements that are heavier than iron are produced during the supernova stage of stars.

Essential Question(s):
- How can we use light from billions of miles away to reconstruct the story of how the universe began?

Examples of Engaging Phenomenon:
- Why is Space Black?
  https://thewonderofscience.com/phenomenon/2018/5/3/why-is-space-black
- Gravitational Waves
  https://thewonderofscience.com/phenomenon/2018/7/9/gravitational-waves-and-ligo
- Mystery of the Universe's Expansion Rate Widens with New Hubble Data
  Mystery of the Universe's Expansion Rate Widens with New Hubble Data - NASA Science
- James Webb Telescope and the Cosmic Web
  NASA's Webb Identifies the Earliest Strands of the Cosmic Web - NASA
- Our Universe is Expanding

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Tom Whyntie: The beginning of the universe for beginners | TED Talk Sajan Saini: What is the universe expanding into? | TED Talk ● Big Bang Theory Hubble's Law Gizmo	
Students will know: (Disciplinary Core Ideas)	As evidenced by: (Science & Engineering Practices)
ESS1.A: The Universe and Its Stars ● The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. ● The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe. ● 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. **PS4.B: Electromagnetic Radiation** ● Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identification of the presence of an element, even in microscopic quantities. ***DCI OBJECTIVES:*** ● The Big Bang Theory is the most widely accepted explanation for the origin of the universe. According to this theory, the universe began as an infinitely small, hot, and dense point that rapidly expanded and continued to expand over 13.7 billion years. This initial period of rapid inflation set the stage for the vast and still-growing cosmos we observe today. ● The existence of cosmic microwave background radiation	**Using Mathematics and Computational Thinking** **Constructing Explanations and Designing Solutions** ● Construct an explanation that includes a description of how astronomical evidence from numerous sources is used collectively to support the Big Bang Theory, which states that the universe is expanding and that thus it was hotter and denser in the past, and that the entire visible universe emerged from a very tiny region and expanded. ● Identify and describe the evidence to construct the explanation, including: i. The composition (hydrogen, helium and heavier elements) of stars; ii. The hydrogen-helium ratio of stars and interstellar gases; iii. The redshift of the majority of galaxies and the redshift vs. distance relationship; and iv. The existence of cosmic background radiation. Use a variety of valid and reliable sources for the evidence, which may include investigations, theories, simulations, and peer review. Describe the source of the evidence and the technology used to obtain that evidence. ● Connect evidence using reasoning, along with 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, to construct the explanation for the early universe (the Big Bang theory). Describe the following chain of reasoning for their explanation: i. Redshifts indicate that an object is moving away from the observer, thus the observed redshift for most galaxies and the redshift vs. distance relationship is evidence that the universe is expanding. ii. The observed background cosmic radiation and the ratio of hydrogen to helium have been shown to be consistent with a universe that was very dense and hot a long time ago and that

(CMB), a faint "echo" of the universe's early expansion that scientists can study in detail. The changes they have identified imply a hot, dense early universe that cooled as it expanded. ● The overall composition of matter in the universe since it matches the Big Bang Theory's prediction of approximately 74% hydrogen and 26% helium. ● The motion of galaxies. Light arriving from far-off galleries has been "red-shifted," indicating that they are moving further away and the universe is expanding. ● Each element emits a distinct frequency of light. A spectroscope can divide light into its component wavelengths. Thus, the spectra can be used to identify the elements. When a star emits a light spectra, the spectra along with the star's brightness can be analyzed to determine the star's composition and distance from Earth. These spectra are also evidence in support of the Big Bang Theory.	evolved through different stages as it expanded and cooled (e.g., the formation of nuclei from colliding protons and neutrons predicts the hydrogen-helium ratio [numbers not expected from students], later formation of atoms from nuclei plus electrons, background radiation was a relic from that time). iii. An expanding universe must have been smaller in the past and can be extrapolated back in time to a tiny size from which it expanded.

Cross Cutting Concepts:
Energy and Matter
Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems.

Academic Vocabulary:

- Science vocabulary students ARE expected to know: Galaxy, Universe, Primordial Radiation, Cosmic Microwave Background (CMB) Radiation, Electromagnetic Energy, Emit, Absorb, Frequency, Wavelength, Light, Dense, Expand, Motion, Red-Shift, Big Bang Theory, Spectra, Matter, Nucleosynthesis

- Additional tier 2 words that students should be familiar with: Dark Matter, Dark Energy, Singularity, Construct, Explanation, Composition Astronomical Evidence, Observable universe

Science vocabulary students are NOT expected to know:

- Cosmological redshift, Hubble Law, photometric redshift, spectroscopy

Resources: NGSS Phenomenon Master List

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Priority Standard (Performance Expectation): HS-PS1-1
Matter and its Interactions
Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.

(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.)

Big Idea(s):
- The periodic table is a master key; by understanding the repeating patterns of protons and electrons, we can unlock an element's "personality" and predict its behavior without ever touching it.
- Patterns of valence electrons and electron shells determine chemical reactivity and bonding behaviors.

Essential Question(s):
- If the Periodic Table is a 'map' of the elements, how can we use it to predict the behavior of substances we've never even seen?
- How does the number and arrangement of subatomic particles determine the properties and behavior of the element?

Examples of Engaging Phenomenon:
- Potassium chloride (KCl) tastes similar to table salt (sodium chloride, NaCl) https://www.youtube.com/watch?v=LVfcmIxTZO4
- Balloons are filled with helium gas instead of hydrogen gas https://chemed.chem.purdue.edu/demos/demosheets/10.1.html
- Argon gas is used when welding metals to reduce oxidation/reactivity https://penflex.com/weld-purging-with-argon-gas/
- Burning Steel Wool https://thewonderofscience.com/phenomenon/2018/7/8/burning-steel-wool
- Limiting Reactant https://thewonderofscience.com/phenomenon/2017/10/8/ps1-matter-and-its-interactions
- CSI unknown white powder https://www.georgiascienceteacher.org/phenomena/
- Volatile Elements Needed for Health https://www.georgiascienceteacher.org/phenomena/
- Element Builder Gizmo

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● Electron Configuration Gizmo ● Diamond, graphene, and fullerene are different molecules/materials that are only made of Carbon https://www.youtube.com/watch?v=BNAZO1FplaQ	
Students will know: (Disciplinary Core Ideas) HIghlights are ETTS1-1	As evidenced by: (Science & Engineering Practices)
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. ***DCI OBJECTIVES:*** ● Atoms consist of a small central region called the nucleus made of positively-charged protons (represented by atomic number) and neutral neutrons (represented as atomic mass when added to protons; isotopic average). The nucleus is surrounded by a larger region called the electron cloud that contains negatively-charged electrons. Atoms also contain other subatomic particles in addition to these basic three, including quarks, neutrinos, bosons, and leptons. ● The periodic table is designed to illustrate properties of all known elements. It orders elements in rows called periods by electron shell numbers. Elements are grouped in vertical columns called groups or families, that represent the number of valence electrons they possess (excluding transition metals). Metal reactivity decreases from left to right across periods and increases down groups. ● Alternative arrangements of the Periodic Table do exist, each having positive and negative attributes.	**Using Mathematics and Computational Thinking** **Constructing Explanations and Designing Solutions** **Developing and Using Models** ● Identify and describe the components of the model that are relevant for their predictions, including: elements and their arrangement in the periodic table; a positively-charged nucleus composed of both protons and neutrons, surrounded by negatively-charged electrons; electrons in the outermost energy level of atoms (i.e., valence electrons); and the number of protons in each element. ● Identify and describe the following relationships between components in the given model, including: the arrangement of the main groups of the periodic table reflects the patterns of outermost electrons, and elements in the periodic table are arranged by the numbers of protons in atoms. ● Predict, using the periodic table, 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 following patterns of properties: 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

• Nonmetal reactivity increases from left to right and decreases down groups. • Valence electrons are the electrons in the outermost shell, or energy level, of an atom. They influence how the atom will form bonds. • The Octet Rule is that an atom will be most stable when surrounded by 8 electrons in the valence shell. An atom that does not have eight electrons will bond with other atoms to have eight electrons. (Hydrogen and Helium are exceptions since they are so small; they are stable with only two valence electrons.) • Electrons fill the innermost shell first before moving on to the second shell, and then the third, etc. The first orbital can hold a maximum of 2 electrons, then 8 in the second orbital, 18 in the third orbital, and 32 in the fourth orbital. More advanced electron configuration also includes quantum numbers and orbital shapes (s, p, d, f).	the periodic table.

Cross Cutting Concepts: Patterns

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

Academic Vocabulary:

- Science vocabulary students ARE expected to know: Periodic Table, Element, Properties, Proton, Electron, Neutron, Periods, Groups/ Families, Valence Shell/ Energy Level, Metal, Nonmetal, Metalloid/ Semimetal, Pure Substance, Atomic Number, Atomic Symbol, Nucleus, Reactivity, Atomic Radius, Electronegativity, Molar Mass, Electronegativity, Ionization Energy

- Additional tier 2 words that students should be familiar with: Electron Configuration, s/p/d/f Orbitals, Ion, Cation, Anion

Science vocabulary students are NOT expected to know: Oxidation state, diatomic, polyatomic ions, empirical formulas, molecular formulas, quantum, photon, Heisenberg Uncertainty Principle, Hund's Rule, Pauli Exclusion Principle

Resources: NGSS Phenomenon Master List

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Unit 2: Bulk Scale Properties and Reactions

Priority Standard (Performance Expectation): HS-PS1-2
Matter and Its Interactions

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.)

Big Idea(s):

- Chemical reactions are not random; they are governed by the sharing and transfer of valence electrons as atoms strive to find their most stable configuration.
- In any chemical reaction, the number and types of atoms are conserved; they are rearranged into new products, not created or destroyed.

Essential Question(s):

- How does the 'secret code' of an atom's identity—its outermost electrons—dictate every chemical partnership it will ever make?
- How does the electronegativity of the elements involved determine the type of bonds they will form, and thus the outcome of the chemical reaction?

Examples of Engaging Phenomenon:

- Alkali metals reactivity
  https://www.bbc.co.uk/bitesize/guides/zdykw6f/revision/2
- Sodium metal (Na) combines with chlorine gas (Cl_2) to make sodium chloride (NaCl), otherwise known as table salt
  https://chem.libretexts.org/Bookshelves/Introductory_Chemistry/Chemistry_for_Changing_Times_(Hill_and_McCreary)/04%3A_Chemical_Bonds/4.03%3A_The_Reaction_of_Sodium_with_Chlorine
- Cleaning pennies
  https://kids.usmint.gov/resources/coin-activities/clean-or-green-pennies
- Carbon monoxide (CO) formation
  https://www.sciencedirect.com/topics/chemistry/carbon-monoxide
- Periodic Trends Gizmo
- Ionic Bonds Gizmo

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• Covalent Bonds Gizmo • Polarity and Intermolecular Forces Gizmo	
Students will know: (Disciplinary Core Ideas)	As evidenced by: (Science & Engineering Practices)
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. ***DCI OBJECTIVES:*** • The arrangement of the elements on the periodic table can predict the electronegativity, ionization energy, and atomic radius for all elements. These are known as [periodic trends](#). • Electronegativity can be used to determine the type of bond formed between two elements: [metallic, ionic, polar covalent, or nonpolar covalent bonds](#). • It is possible to predict outcomes of chemical reactions based upon the patterns of reactivity within the periodic table. • Ionic bonding = metal bonded to nonmetal; transfer of electrons (creates [ions](#)) • Polar covalent bonding = nonmetal bonded to nonmetal; unequal sharing of pairs of electrons • Nonpolar covalent bonding = nonmetal bonded to nonmetal; equal shared pairs of electrons • Metallic bonding = metal bonded to metal; shared/delocalized electrons • Hydrogen bonding = Hydrogen and a more electronegative atom (often oxygen or nitrogen); weaker bond	**Using Mathematics and Computational Thinking** **Constructing Explanations and Designing Solutions** • Construct an explanation of the outcome of the 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; and 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). • Identify and describe the evidence to construct the 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; and 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. • 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

● Lewis dot structures are used to show valence electrons surrounding individual atoms and the bonding of elements along with lone pairs of electrons. ● Covalent bonds can have single, double, or triple bonds. ● Noble gases do not react with other elements due to the Octet Rule. ● The chemical properties of the elements involved can be used to describe and predict chemical bonds. ● A chemical change results in a change in the elemental composition of a substance, while a physical change only changes the appearance, smell, or other superficial characteristics of a substance. Evidence of a chemical change occurring includes color change, temperature change, gas production, and precipitate formation. ● For a given compound it is possible to identify the numbers and types of bonds (i.e., ionic, covalent). ● Five basic types of chemical reactions are synthesis, decomposition, combustion, single replacement, and double replacement. These reactions are used in careers and daily life. **(TRADE CONCEPT)** ● Combustion reactions release carbon dioxide, CO_2, that is a factor in global climate change. Strategies and alternatives could reduce its increased release into the atmosphere, slowing down the rate of change of the process. ● Chemical reactions are notated as chemical equations that can be balanced to ensure Conservation of Matter. This balancing process may vary greatly in complexity.	used to predict the number and types of bonds each element forms. In the explanation, 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. ● Construct a revised or expanded explanation about the outcome of a chemical reaction and justify the revision.

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• The outcome of a simple chemical reaction can be predicted using only the reactants and their valence electrons.	

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

Academic Vocabulary:
- Science vocabulary students ARE expected to know: Trend, Electronegativity, Ionization Energy, Atomic Radius, Chemical Bond, Ionic Bond, Covalent Bond, Polar Bond, Nonpolar Bond, Single Bond, Double Bond, Triple Bond, Lewis Dot Structure, Lone Pairs, Ion, Energy Level, Octet Rule, Chemical Change, Physical Change, Synthesis, Decomposition, Combustion, Single Replacement, Double Replacement, Valence Electron

- Additional tier 2 words that students should be familiar with: Electron Sharing, Electron Transfer, Noble Gas, Metallic Bond, Hydrogen Bond

Science vocabulary students are NOT expected to know: Molecular orbital diagram, multiplicity, antibonding orbitals, rearrangement, by-product, oxidation-reduction reaction, decomposition, single replacement reaction, double replacement
reaction, synthesis reaction, precipitate

Resources: NGSS Phenomenon Master List

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Priority Standard (Performance Expectation): HS-PS1-3
Matter and Its Interactions

Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.

(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.)

Big Idea(s):

- The physical properties of materials (i.e. state at STP, conductivity, melting point) are due to the arrangement and attraction of particles (ions, molecules)
- The strength of electrical forces between particles dictate macroscopic behavior.
- Bulk-scale properties (i.e. high vs. low melting points) can be explained by the strength of attraction between similar particles.

Essential Question(s):

- Why does water support life as a liquid while similar molecules exist only as gases, and how does this 'invisible' stickiness shape our world?
- How do the properties of one molecule affect its interaction with other molecules of the same type OR different molecules?

Examples of Engaging Phenomenon:

- Panning for gold works because of density. https://www.youtube.com/watch?v=dzEndIo-X8A&ab_channel=EdReeves
- Milk and Soap Experiment https://thewonderofscience.com/phenomenon/2018/7/11/milk-and-soap-experiment
- Ice Cube Spikes https://thewonderofscience.com/phenomenon/2018/6/10/ice-cube-spikes
- Gecko Feet https://thewonderofscience.com/phenomenon/2018/5/3/gecko-feet
- Floating Whiteboard Ink https://thewonderofscience.com/phenomenon/2017/10/16/floating-whiteboard-ink
- Water and Oil Don't Mix https://web.fscj.edu/Milczanowski/psc/lect/Ch10/slide10.htm#:~:text=Liquid%20water%20is%20held%20together,stay%20separate%20from%20the%20water.
- Melting Points Gizmo

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• Colligative Properties Gizmo • Density Gizmo • Density by Comparison Gizmo	
Students will know: (Disciplinary Core Ideas)	As evidenced by: (Science & Engineering Practices)
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. **PS2.B Types of Interactions** • Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformation of matter, as well as the contact forces between material objects. ***<u>DCI OBJECTIVES:</u>*** • The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms (e.g., melting point and boiling point, solubility, vapor pressure, volatility, surface tension, density, viscosity, conductivity). Honors students should examine more of these properties than students in the regular course. • 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. • Intermolecular forces are forces between two or more molecules that determine properties of a specific substance including flammability, conductivity, melting point, and boiling point. Intramolecular forces are forces that hold each individual molecule together.	**Using Mathematics and Computational Thinking** **Constructing Explanations and Designing Solutions** **Planning and Carrying Out Investigations** • 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 following descriptions: 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 (e.g., when water is boiled the molecules are still present but further apart); thermal (kinetic) energy has an effect on the ability of the electrical attraction between particles to keep the particles close together. Thus, as more energy is added to the system, the forces of attraction between the particles can no longer keep the particles close together; the patterns of interactions between particles at the molecular scale are reflected in the patterns of behavior at the macroscopic scale; and together, patterns observed at multiple scales can provide evidence of the causal relationships between the

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• Bulk scale properties are readily applicable to real-life situations and trade scenarios, along with improvements in trade systems. **(TRADE CONCEPT)**	strength of the electrical forces between particles and the structure of substances at the bulk scale. • Construct a rationale for the choice of substances to compare and a description of the composition of those substances at the atomic molecular scale; a description of 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 evaluation of: 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. If necessary, refine the plan to produce more accurate, precise, and useful data.

Cross Cutting Concepts:
Patterns

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

Academic Vocabulary:

- Science vocabulary students ARE expected to know: Interaction, Matter, Electrical Forces, Melting Point, Boiling Point, Solubility, Vapor Pressure, Volatility, Surface Tension, Density, Viscosity, Conductivity, Attraction, Repulsion, Intramolecular Force, Intermolecular Force, Flammability, Polarity

- Additional tier 2 words that students should be familiar with: Electronegativity, Dissolve, Solute, Solvent, Networked Material

Science vocabulary students are NOT expected to know: Dipole, induced dipole, dipole moment, delta, Coulomb's law, dipole-dipole, London forces, Van der
Waals forces, ion-dipole, hydrogen bonding, pi-electron cloud, pi stacking, colligative properties,
electron shielding.

Resources: NGSS Phenomenon Master List

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Priority Standard (Performance Expectation): HS-PS1-7
Matter and its Interactions

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.

Big Idea(s):
- The number of atoms of reactants and products remains the same through chemical reactions; total mass remains constant.
- The mole acts as a bridge between microscopic interactions and macroscopic measurements.
- Chemical equations provide proportional, stoichiometric relationships to predict the amount of product formed OR reactants needed.

Essential Question(s):
- How do chemists use math to 'count' particles that are too small to be seen, and why is this 'accounting' essential for every modern industry?
- What evidence can we show that mass is conserved in a chemical reaction?

Examples of Engaging Phenomenon:
- Alka Seltzer and Water inflates a balloon
  https://uwaterloo.ca/chem13-news-magazine/october-2017/activities/chemistry-alka-seltzer
  https://www.science-sparks.com/alka-seltzer-balloon/
- Inflate a balloon
  https://learning.sciencemuseumgroup.org.uk/resources/blow-up-balloon/
- Burning Steel Wool
  https://thewonderofscience.com/phenomenon/2018/7/8/burning-steel-wool
- Slime
  https://thewonderofscience.com/phenomenon/2018/5/13/slime
- Elephant Toothpaste
  https://thewonderofscience.com/phenomenon/2018/5/13/elephant-toothpaste
- Limiting Reactant
  https://thewonderofscience.com/phenomenon/2017/10/8/ps1-matter-and-its-interactions
- Sugar-Sulfuric Acid Chemical Reaction
  https://www.georgiascienceteacher.org/phenomena/

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Students will know: (Disciplinary Core Ideas)	As evidenced by: (Science & Engineering Practices)
PS1.B: Chemical Reactions ● The fact that atoms are conserved, together with knowledge of the elements involved, can be used to describe and predict chemical reactions. ***DCI OBJECTIVES:*** ● Atoms (therefore mass) are conserved in a chemical reaction in conjunction with properties of matter based on elements involved. ● The Law of Conservation of Mass states that matter cannot be created nor destroyed, but may change form. Thus, the types of elements and the number of atoms of each must be equal for the reactants and the products in a reaction. ● The relationship between masses of atoms in the reactants to masses of atoms in the products can be calculated and compared by using stoichiometry. In addition, moles of reactants and moles of products can be calculated and compared.This calculation process may vary greatly in complexity. ● A mole is an important unit of measurement that chemists use. A mole consists of 6.022 x 10^23 particles, Avogadro's Number. ● A relative mathematical relationship in moles exists between the reactants and products of a balanced chemical equation. ● Stoichiometric calculations can determine the macroscopic quantities of reactants and products of a chemical reaction in a closed system. These calculations may vary greatly in complexity.	**Using Mathematics and Computational Thinking** ● Explain and provide mathematical evidence that atoms and mass are conserved during a chemical reaction. **Constructing Explanations and Designing Solutions** ● Identify and describe the relevant components in the mathematical representations: 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. The mathematical representations may include numerical calculations, graphs, or other pictorial depictions of quantitative information. Identify the claim to be supported: that atoms, and therefore mass, are conserved during a chemical reaction. ● Convert, using the mole, between the atomic and macroscopic scale in the analysis. ● Predict, given a chemical reaction using the mathematical representations to, 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

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	Avogadro's number).

Cross Cutting Concepts:
Energy and Matter

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

Academic Vocabulary:

- Science vocabulary students ARE expected to know: Conserve, Law of Conservation of Mass/Matter, Create, Destroy, Change Form, Balanced Equation, Unbalanced Equation, Reactant, Product, Coefficient, Subscript, Mole, Molar Mass, Avogadro's Number

- Additional tier 2 words that students should be familiar with: Limiting Reactant, Excess Reactant, Theoretical Yield, Closed System, Stoichiometry

Science vocabulary students are NOT expected to know:

- Dimensional analysis, stoichiometry, (dynamic) equilibrium, La Chatlier's Principle, oxidation state, diatomic, polyatomic ion, empirical formula, by-product, oxidation-reduction reaction, decomposition, single replacement reaction, double replacement reaction, synthesis reaction, combustion reaction, precipitate, solvent, solute, reaction rate, recombination of chemical elements, stable

Resources: NGSS Phenomenon Master List

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Priority Standard (Performance Expectation): HS-PS2-6 **Motion and Stability: Forces and Interactions** Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.
[Clarification Statement: Emphasis is on the attractive and repulsive forces that determine the functioning of the material. Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long-chained molecules, and pharmaceuticals are designed to interact with specific receptors.) (Assessment Boundary: Assessment is limited to provided molecular structures of specific designed materials.)
Big Idea(s): ● The specific arrangement of atoms and molecules determines chemical properties of a material. ● The macro-level behavior of materials is dictated by attractive and repulsive forces at a molecular level (i.e. metallic bonds as conductors)
Essential Question(s): ● How can we engineer a molecule to behave exactly the way we want, from a drug that targets a disease to a plastic that never breaks?
Examples of Engaging Phenomenon: ● Hydrophobic and hydrophilic fabrics https://www.wptnonwovens.com/blog/hydrophobic-material-vs-hydrophilic/ https://favouritehub.com/hydrophobic-and-hydrophilic-non-woven-materials/ ● A sample of cotton fabric was dyed with two different kinds of dye and then was washed several times to determine how well the dye stayed in the fabric. One dye faded over time; the other did not. https://www.texintel.com/blog/understanding-the-five-basic-fastness-standards-for-printed-textile-fabrics https://www.eysan.com.tw/ultimate-guide-to-color-fastness-of-fabrics/ ● Design Phenomenon: Students are to solve a real-world problem of designing filters that pull out specific soluble and insoluble particles from water sources.

Students will know: (Disciplinary Core Ideas)	As evidenced by: (Science & Engineering Practices)
PS2.B Types of Interactions ● Attraction and repulsion between electric charges at the	**Using Mathematics and Computational Thinking** **Constructing Explanations and Designing Solutions**

atomic scale explain the structure, properties, and transformation of matter, as well as the contact forces between material objects. **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. ***DCI OBJECTIVES:*** ● Science and engineering can be used to solve real-world problems. ● -Many varied solutions to a problem may be possible, but each will have strengths and weaknesses. Product testing and iterative improvements can make a product better, but likely none will be perfect. ● 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. ● An attractive force is when objects exert a pull on each other, making them want to move closer together. Particles with different electromagnetic charges attract each other. A repulsive force is when objects push each other away. Particles with the same electromagnetic charge repel each other. ● Intermolecular forces are forces of attraction or repulsion which act between neighboring particles (atoms, molecules or ions). They are weak compared to the intramolecular forces, which keep a molecule together (e.g., covalent and ionic bonding).	**Obtaining, Evaluating, and Communicating Information** ● Communicate, in two different formats, scientific and technical information, including fully describing the structure, properties, and design of the chosen material(s). Cite the origin of the information as appropriate. ● Identify and communicate the evidence for why molecular level structure is important in the functioning of designed materials including: 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 how the material's properties make it suitable for use in its designed function. 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). Describe the intended function of the chosen designed material(s). 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: Molecular level structure of the material; Intermolecular forces and polarity of molecules; and The ability of electrons to move relatively freely in metals. 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). Describe that, for all materials, electrostatic forces on the atomic and molecular scale result in contact forces (e.g., friction, normal forces, stickiness) on the macroscopic scale.

• Electrostatic forces on the atomic and molecular scale result in contact forces (e.g., friction, normal forces, stickiness) on the macroscopic scale. • Different materials have different properties. Some properties of materials include electrical conductivity, flexibility, durability, strength, reactivity, state of matter, chemical structure, and environmental impact. • The properties of a material support its purpose. Materials with common properties can be used to perform similar functions, while materials with different properties are best suited for different functions. • Molecular level structure is important in the functioning of designed materials. 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. The material's properties make it suitable for use in its designed function. • Water has unique properties. Water molecules are polar so they form hydrogen bonds. Water has cohesive (molecules of water stick to other water molecules) and adhesive (molecules of water stick to other types of molecules) properties. It is an excellent solvent (capable of dissolving other polar molecules and ionic compounds). It has a high heat capacity (the amount of heat it must gain or lose in order to change temperature) and a high heat of vaporization (boiling point). It is less dense as a solid than as a liquid, in direct contrast to most other materials. • The ability of electrons to move relatively freely in metals causes unique properties including ductility (ability to be drawn into a thin, long wire) and malleability (ability to be formed into a thin, flat sheet). Metals are also good conductors	

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of heat and electricity and have a high density and high melting point. ● A polymer is any of a class of natural or synthetic substances composed of very large molecules, called macromolecules, which are multiples of simpler chemical units called monomers. Polymers make up many of the materials in living organisms and are the basis of many minerals and man-made materials including plastics. Examples of naturally occurring polymers are silk, wool, DNA, cellulose and proteins. Examples of synthetic polymers include nylon, polyethylene, polyester, Teflon, and epoxy. The monomers in a polymer are arranged in side chains; the specific arrangements determine the properties of the substance including flexibility and durability.	

Cross Cutting Concepts:
Structure and Function

- Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.

Academic Vocabulary:

- Science vocabulary students ARE expected to know: Electrical Conductivity, Criteria, Trade-offs, Polymer, Surface Tension, Reactivity, Charge, Conductor, Insulator, Resistance, Ductile, Malleable, Friction, Material Strength, Reactivity, Stickiness, State of Matter, Polarity, Attractive, Repulsive, Contact Force, Electron Sharing, Electron Transfer, Flexible, Durable, Normal Force, Electrostatic Forces, Environmental Impact, Structure, Function

- Additional tier 2 words that students should be familiar with: Synthetic, Monomer, Network Solid, Iterative Improvement, Long-Chained Molecules, Network Material, Pharmaceuticals, Hydrophobic, Hydrophilic, Soluble

Science vocabulary students are NOT expected to know:

- Electric potential, electromotive force, permeating, quantum property, Laplace force, electrodynamics, magnetic dipole, electrostatic, general relativity, Ampere's Law, Coulomb force, Lorentz force, Van der Waals forces, organic molecules

Resources: NGSS Phenomenon Master List

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Unit 3: Rate of Reactions & Equilibrium

Priority Standard (Performance Expectation): HS-PS1-4 **Matter and its Interactions** Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.
[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.)
Big Idea(s): ● Stable molecules have lower energy than separated atoms; breaking bonds requires energy, while forming new bonds releases it. ● Chemical reactions are systems where the change in total bond energy (reactants vs. products) determines if energy is released (exothermic) or absorbed (endothermic).
Essential Question(s): ● In a chemical reaction, where does the fire actually come from, and why do some reactions 'steal' heat from their surroundings? ● How can the concept of energy release be used in industry/product creation?
Examples of Engaging Phenomenon: ● Hot/cold pack https://www.carolina.com/teacher-resources/Interactive/hot-and-cold-packs-a-thermochemistry-activity/tr29415.tr#:~:text=Many%20instant%20hot%20and%20cold,absorbed%20in%20an%20endothermic%20reaction. ● Indestructible Coating - Polyurea https://thewonderofscience.com/phenomenon/2018/7/9/indestructible-coating-polyurea ● Reusable Heat Packs https://thewonderofscience.com/phenomenon/2018/7/8/reusable-heat-packs ● Elephant Toothpaste https://thewonderofscience.com/phenomenon/2018/5/13/elephant-toothpaste

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- Reaction Energy Gizmo
- Feel the Heat Gizmo

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<tr><td>Students will know: (Disciplinary Core Ideas)</td><td>As evidenced by: (Science & Engineering Practices)</td></tr>
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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

- The fact that atoms are conserved, together with knowledge of the elements involved, can be used to describe and precinct chemical reactions.

DCI OBJECTIVES:

- Reactants and products have different potential energies or total bond energies as a result of the different arrangement of atoms, resulting in a net energy change in the chemical system.
- -Breaking bonds requires an input of energy from the system or surroundings, and forming bonds releases energy to the system and the surroundings.
- The total energy of the system and surroundings is unchanged (conserved) during the reaction.
- Energy transfer occurs after molecular collisions.
- A potential energy diagram can represent a particular endothermic or exothermic reaction based on an observed temperature change in the surroundings.

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Using Mathematics and Computational Thinking

Constructing Explanations and Designing Solutions

Developing and Using Models

- Develop, using evidence, 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 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.
- 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 total energy change of the chemical reaction system is matched by an equal but opposite change of energy in the surroundings (Note: This does not include calculating the total bond energy changes.); and the release or absorption of energy depends on whether the relative potential energies of the reactants and products decrease or increase.
- 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

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● Energy changes predictably when amounts of reactants are increased/decreased. ● Data in graphs or tables can be used to identify whether energy was absorbed (endothermic) or released (exothermic) in a chemical reaction.	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.

Cross Cutting Concepts:
Energy and Matter

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

Academic Vocabulary:

- Science vocabulary students ARE expected to know:
  - Energy, Release, Absorb, Bond Energy, Break, Form, Energy Transfer, Collision, Exothermic, Endothermic, Heat Energy, Atomic Arrangement, Reactant

- Additional tier 2 words that students should be familiar with: Potential Energy Diagram, Increase, Decrease

Science vocabulary students are NOT expected to know:

- Recombination of chemical elements, stable, chemical system, chemical reaction rate

Resources: NGSS Phenomenon Master List

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Priority Standard (Performance Expectation): HS-PS1-5 **Matter and its Interactions** 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.)
Big Idea(s): ● Chemical processes involve the breaking of bonds in reactant molecules and the formation of new bonds to create products. ● Chemical reaction rates depend on frequency and energy of collisions between reacting molecules. ● Chemical reactions either release or absorb energy due to total bond energy differences. ● Patterns observed at the molecular level – effect of temperature change, concentration of reactants – help explain macroscopic phenomena.
Essential Question(s): ● Since reactions do not occur instantaneously, what must be happening in the molecular interactions to cause a reaction to begin AND sustain itself? ● How can we 'rig' a chemical reaction to work on our schedule by manipulating the molecular 'dance' of particles?
Examples of Engaging Phenomenon: ● Reaction in a Bag https://thewonderofscience.com/phenomenon/2018/7/8/reaction-in-a-bag ● Reusable Heat Packs https://thewonderofscience.com/phenomenon/2018/7/8/reusable-heat-packs ● Alka Seltzer Rockets https://www.imaginationstationtoledo.org/educators/diy-activities/alka-seltzer-rockets ● Small particles of granulated sugar react (dissolve) more quickly than larger particles of sugar cubes. Sugar reacts (dissolves) more quickly in hot water than in cold water. https://chem.libretexts.org/Bookshelves/Introductory_Chemistry/Introductory_Chemistry_(CK-12)/16%3A_Solutions/16.02%3A_Rate_of_Dissolving ● Equilibrium and Pressure Gizmo ● Ocean Carbon Equilibrium Gizmo

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Students will know: (Disciplinary Core Ideas)	As evidenced by: (Science & Engineering Practices)
PS1.B: Chemical Reactions ● The fact that atoms are conserved, together with knowledge of the elements involved, can be used to describe and precinct chemical reactions. ***<u>DCI OBJECTIVES:</u>*** ● Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules. ● Changing the conditions of a specific reaction (moles, temperature, pressure), whether reversible or irreversible, can change the rate at which the reaction occurs. ● Activation energy is needed for reactions to occur. Catalysts can be used to achieve this activation energy requirement. ● Chemical reactions can be reversible or irreversible.	**Using Mathematics and Computational Thinking** **Constructing Explanations and Designing Solutions** ● 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 (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) increase the reaction rate, and vice versa; and evidence of a pattern that increases in temperature usually increase the reaction rate, and vice versa. ● 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.

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Cross Cutting Concepts: **Patterns** ● Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.
Academic Vocabulary: - Science vocabulary students ARE expected to know: Catalyst, Chemical Reaction Rate, Concentration, Reversible Reaction, Pressure, Temperature, Concentration, Particle Size - Additional tier 2 words that students should be familiar with: Activation Energy, Collision Theory, Forward/ Reverse Reaction, Phase, Reaction Rate Constant, Reaction Rate Graph Science vocabulary students are NOT expected to know: - Recombination of chemical elements, stable, chemical system, rate laws, Le Chatelier's principle, rate constant, zero order reactions, first order reactions, stepwise reactions, rate-determining step, steady state, half-life, free radicals, entropy, Gibb's free energy
Resources: NGSS Phenomenon Master List

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Priority Standard (Performance Expectation): HS-PS1-6
Matter and its Interactions

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.)

Big Idea(s):

- Systems at equilibrium will shift due to changes in conditions (concentration, pressure, temperature).
- Chemical reactions are often reversible; the amounts of reactants and products are in condition-dependent balance.

Essential Question(s):

- Why are some chemical reactions reversible while others are not?
- How can a chemical system be 'constantly changing' at the molecular level while appearing perfectly still to the naked eye?
- How can the concept of equilibrium be applied to a real-world situation?

Examples of Engaging Phenomenon:

- SIDS (Sudden Infant Death Syndrome)
  https://thewonderofscience.com/hsps16
- Formation of methanol using CO_2
  https://www.youtube.com/watch?v=fRmElElYtnQ
- Several drops of hydrochloric acid were added to an orange mixture of water and potassium dichromate (K2CrO7). The mixture turned yellow.
  https://www.youtube.com/watch?v=23J07qrwgjA
- Cobalt/Copper complexes changing colors
  https://www.youtube.com/watch?v=36AtKeYjG6k
- In the 1970s scientists observed that the concentration of ozone (O3) in the upper atmosphere began decreasing.
  https://earthobservatory.nasa.gov/world-of-change/Ozone
  https://scied.ucar.edu/learning-zone/atmosphere/discovering-culprits-causing-ozone-holes
- A bottle of carbonated soda appears to have fewer bubbles before it is opened than after it is opened.

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https://www.flavorman.com/media/answers-to-your-4-biggest-questions-about-carbonation# https://www.rockymountainsoda.com/blogs/soda-news/how-carbonation-works-in-soda?srsltid=AfmBOorv2HKDdFJ9uVtkY7ge1rziWFecEGtLx98IrGb7cfsSDSrCWb-0 ● Equilibrium and Concentration Gizmo

Students will know: (Disciplinary Core Ideas)	As evidenced by: (Science & Engineering Practices)
PS1.B: Chemical Reactions ● The fact that atoms are conserved, together with knowledge of the elements involved, can be used to describe and precinct chemical reactions. **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. ***DCI OBJECTIVES:*** ● Reversible reactions happen continuously forwards and backwards, attempting to reach chemical equilibrium. ● Reversible reactions can be driven forwards (towards products) and backwards (towards reactants) based on change in factors after chemical equilibrium is achieved. This concept is Le Chatelier's Principle.	**Using Mathematics and Computational Thinking** **Constructing Explanations and Designing Solutions** ● 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. ● Describe criteria and constraints, including quantification when appropriate. 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. ● 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

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	resources). ● 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.

Cross Cutting Concepts:
Stability and Change

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

Academic Vocabulary:

- Science vocabulary students ARE expected to know: Reversible, Irreversible, Forward, Backward, Chemical Equilibrium, Le Chatelier's Principle

- Additional tier 2 words that students should be familiar with: Chemical System, Reaction Quotient, Shift in Equilibrium, Equilibrium Constant
-

Science vocabulary students are NOT expected to know:

- Recombination of chemical elements, stable, chemical system, chemical reaction rate

Resources: NGSS Phenomenon Master List

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Unit 4: Chemistry Topics

Priority Standard (Performance Expectation): Acids and Bases	
Big Idea(s): ● Acids and bases are categories of substances with distinct chemical and physical properties that can be measured using the pH scale. Neutralization reactions occur when acids and bases react to form water and a salt.	
Essential Question(s): ● How can two clear liquids be chemical 'opposites,' and what determines if a substance will heal a sting or dissolve a metal? ● What happens at the molecular level when an acid and a base are mixed?	
Examples of Engaging Phenomenon: ● The "Magic" Pitcher (Red Cabbage Indicator) https://www.worldofmolecules.com/experiments/red_cabbage_indicator.htm ● Stinging Ants and Baking Soda: Explaining why a base helps a formic acid sting. ● Ocean Acidification https://oceanservice.noaa.gov/facts/acidification.html	
Students will know: (Disciplinary Core Ideas)	As evidenced by: (Science & Engineering Practices)
● The pH scale (0–14) is used to classify substances as acidic (0-6), neutral (7), or basic (8-14) with values farther from 7 on either end being stronger.. ● Indicators such as litmus paper and phenolphthalein change color to identify whether a substance is acidic, neutral, or basic. Universal Indicator paper can also approximate a numeric pH value for a substance. ● A hydronium ion (H_3O^+) forms when a hydrogen ion (H^+) attaches to a water molecule (H_2O). It is the ion responsible for the acidic properties of a solution. When the concentration of hydronium ions is high, the solution is acidic and has a low pH (below 7). A hydroxide ion (OH^-) is made of one oxygen atom bonded to one hydrogen atom and carries a negative	● **Classify** substances as acidic, basic, or neutral based on observable properties (taste, touch, reactivity). ● **Measure** the pH of common household liquids using indicators or pH probes. ● **Predict** the products of a simple neutralization reaction. ● **Explain** the relationship between ion concentration and the pH value.

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charge. It is the ion responsible for the basic (alkaline) properties of a solution. When the concentration of hydroxide ions is high, the solution is basic and has a high pH (above 7). ● Neutralization is a chemical reaction between an acid and a base that reduces acidity or basicity in a solution and produces products of water and a salt. ● Correct safety practices, including the use of personal protective equipment (PPE), and proper disposal procedures are critically important when working with corrosive substances. **(TRADE CONCEPT)**	

Cross Cutting Concepts:
Cause and Effect
Adding an acid or base to a solution causes a measurable change in pH and indicator color

Academic Vocabulary:
Expected: Acid, Base, pH Scale, Neutral, Indicator, Corrosive, Neutralization, Salt.

Tier 2: Concentration, Ion, Dissociation, Aqueous, Buffer.

Resources: NGSS Phenomenon Master List, Titration Gizmo, pH Analysis Gizmo

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Priority Standard (Performance Expectation): Organic Chemistry	
Big Idea(s): ● Carbon atoms have a unique ability to form four bonds, allowing for the creation of a vast variety of complex molecules, including hydrocarbons and polymers.	
Essential Question(s): ● How can one single element be responsible for the complexity of a diamond, the energy in your fuel, and the DNA in your cells? ● How do small changes in an organic molecule's structure change its use (e.g., fuel vs. plastic)?	
Examples of Engaging Phenomenon: ● The Smell of Esters: How different carbon chains create the smell of bananas vs. wintergreen https://www.scientificamerican.com/article/making-perfumes-and-flavorings-that-smell-sweet/ ● Crude Oil Distillation: How gasoline, kerosene, and asphalt all come from the same source. ● Combustion of Methane: https://www.youtube.com/watch?v=8m9_Xvun83o	
Students will know: (Disciplinary Core Ideas)	As evidenced by: (Science & Engineering Practices)
● Carbon has four valence electrons that allow it to form multiple covalent bonds and create a wide variety of complex and diverse organic molecular structures. ● Hydrocarbons are organic compounds made only of carbon (C) and hydrogen (H) atoms.Three basic types of hydrocarbons are alkanes, alkenes, and alkynes. Alkanes contain only single bonds between carbon atoms (C–C). Alkenes contain at least one double bond between carbon atoms (C=C). Alkynes contain at least one triple bond between carbon atoms (C≡C). These differences in bonding affect the structure, reactivity, and properties of hydrocarbons. ● Polymers such as plastics are formed from repeating monomer units. The structure of the monomers influences the properties of the resulting polymer.	● Model simple organic molecules using ball-and-stick kits. ● Identify functional groups in common products (e.g., ethanol in sanitizer). ● Name simple unbranched alkanes (methane through octane). ● Distinguish between natural and synthetic polymers.

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• Organic compounds can be classified based on the specific functional group they contain, which largely determines their chemical properties and reactivity. Functional groups include: Alcohols (-OH), Carboxylic Acids (-COOH), Amines (-NH_2), Ketones (C=O within carbon chain), Aldehydes (C=O at the end of carbon chain), and Esters (-COO-). • Common organic solvents and fuels are often used in automotive and construction trades. Users must demonstrate safe handling, storage, and disposal practices to prevent accidents and environmental contamination. **(TRADE CONCEPT)**	

Cross Cutting Concepts:
Structure and Function

- **The specific arrangement of carbon atoms and functional groups determines the properties of the material**

Academic Vocabulary:
Expected: Carbon, Organic, Hydrocarbon, Polymer, Monomer, Saturated, Unsaturated, Alkane.

Tier 2: Isomer, Functional Group, Distillation, Synthetic, Combustion

Resources: NGSS Phenomenon Master List, Organic Molecules Gizmo, Plastics and Polymers

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Priority Standard (Performance Expectation): Gas Laws	
Big Idea(s): ● Gas particles are in constant, random motion. Their behavior can be explained by the Kinetic Molecular Theory, which relates particle motion to pressure, volume, and temperature.	
Essential Question(s): ● How does the invisible, high-speed 'bumping' of gas particles determine if a scuba diver survives or a hot air balloon flies? ● How does heating a gas change its pressure?	
Examples of Engaging Phenomenon: ● The Imploding Soda Can: https://www.youtube.com/watch?v=JsoE4F2Pb20 ● How Popcorn Pops: The role of water vapor and pressure. ● Boyle's Law Marshmallow: https://www.scienceworld.ca/resource/marshmallow-vacuum/	
Students will know: (Disciplinary Core Ideas)	As evidenced by: (Science & Engineering Practices)
● Kinetic Molecular Theory (KMT) is a model describing gas particles as small, constantly moving spheres. It is used to explain observable gas behaviors such as pressure, volume, and temperature changes. Analysis of changes in particle motion and collisions accounts for gas laws and the behavior of real gases. ● Pressure is the result of gas particles constantly moving and colliding with the walls of a container	● Identify and describe the relevant components in mathematical representations (Boyle's, Charles's, and the Combined Gas Laws), including variables for pressure (P), volume (V), and temperature (T). ● Analyze and interpret graphical data (such as V vs. T or P vs. V graphs) to determine if a relationship is direct or inverse and use that evidence to predict the behavior of a gas system when one variable is manipulated. ● Construct an explanation for macroscopic gas phenomena (such as why a pressurized container may fail at high temperatures) by using

• Temperature is the measure of the average kinetic energy of particles, meaning that when temperature increases, the particles move faster. • Volume is the amount of space a gas occupies. Gases occupy the entire volume of their container because gas particles move freely and spread out to fill the available space. • A vacuum is a space with no gas particles present, meaning there are no particle collisions and therefore no gas pressure. • The safe use of compressed air and pneumatic tools including using proper pressure, protective equipment, and safe handling procedures is necessary to prevent injuries and accidents from high-pressure air. **(TRADE CONCEPT)**	a chain of reasoning that connects mathematical predictions to the Kinetic Molecular Theory.

Cross Cutting Concepts:
Systems and System Models:

- Using the Kinetic Molecular Theory to model how a gas system behaves under different conditions

Academic Vocabulary:
Expected: Pressure, Volume, Temperature, Gas, Kinetic, Collision, Expansion, Compression.

Tier 2: Postulate, Elastic, Average Kinetic Energy, Kelvin, Atmospheric Pressure.

Resources: NGSS Phenomenon Master List, Boyle's Law and Charles's Law Gizmo,Gas Properties Simulation (PhET)

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Appendix A: Vocabulary

Absorb: The process by which an atom or molecule takes in energy (such as electromagnetic radiation).
Activation Energy: The minimum amount of energy required to initiate a chemical reaction.
Alpha Decay: A type of radioactive decay in which an atomic nucleus emits an alpha particle.
Alpha Particle: A particle consisting of two protons and two neutrons (a helium nucleus) emitted during radioactive decay.
Anion: A negatively charged ion formed by gaining electrons.
Atmosphere: The envelope of gases surrounding a planet or star.
Atom: The smallest unit of an element that maintains the chemical properties of that element.
Atomic Arrangement: The specific spatial orientation of atoms within a molecule or crystal lattice.
Atomic Mass: The weighted average mass of the isotopes of an element.
Atomic Number: The number of protons in the nucleus of an atom, which determines the element's identity.
Atomic Radius: The distance from the center of the nucleus to the outermost electron shell.
Atomic Symbol: A one- or two-letter abbreviation used to represent a chemical element.
Attraction: A force that pulls objects toward each other, such as opposite charges in an ionic bond.
Attractive: Tending to pull objects together.
Avogadro's Number: The number of representative particles in one mole of a substance (6.022×10^{23}).
Backward: In a reversible reaction, the direction from products back to reactants.
Balanced Equation: A chemical equation that has the same number of atoms of each element on both the reactant and product sides.
Beta Decay: A type of radioactive decay in which a beta particle (electron or positron) is emitted.
Beta Emission: The process of releasing a beta particle from a decaying nucleus.
Beta Particle: A high-speed electron or positron emitted during radioactive decay.
Big Bang Theory: The prevailing cosmological model explaining the early development and expansion of the universe.
Black Dwarf: A theoretical stellar remnant formed when a white dwarf becomes sufficiently cool that it no longer emits significant heat or light.
Boiling Point: The temperature at which a liquid's vapor pressure equals the external pressure, causing it to turn into a gas.
Bond Energy: The measure of bond strength in a chemical bond; the energy required to break the bond.
Break: The process of overcoming the attractive forces between atoms (requires energy).
Catalyst: A substance that increases the rate of a chemical reaction by lowering the activation energy without being consumed.
Cation: A positively charged ion formed by losing electrons.
Change Form: The transformation of matter or energy from one state or type to another.
Charge: A physical property of matter (positive or negative) that causes it to experience a force when placed in an electromagnetic field.

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Chemical Bond: The lasting attraction between atoms, ions, or molecules that enables the formation of chemical compounds.
Chemical Change: A process where one or more substances are altered into one or more new and different substances.
Chemical Equilibrium: The state in which both reactants and products are present in concentrations which have no further tendency to change with time.
Chemical Reaction Rate: The speed at which reactants are converted into products.
Chemical System: A set of interacting substances under observation.
Chemosynthesis: The synthesis of organic compounds by bacteria or other living organisms using energy derived from reactions involving inorganic chemicals.
Closed System: A physical system that does not allow certain types of transfers (like matter) in or out of the system.
Coefficient: A number placed in front of a chemical formula in an equation to indicate the number of moles or molecules involved.
Collision: The event where two particles come into contact; necessary for a chemical reaction to occur.
Collision Theory: The theory stating that for a reaction to occur, particles must collide with sufficient energy and correct orientation.
Combustion: A high-temperature exothermic redox chemical reaction between a fuel and an oxidant.
Composition Astronomical Evidence: Data regarding the chemical makeup of celestial bodies derived from spectroscopy.
Concentration: The amount of a substance per defined space or unit of volume.
Conductivity: The measure of a material's ability to allow the flow of an electric current.
Conductor: A material that allows heat or electricity to flow through it easily.
Conserve: To maintain a quantity (like mass or energy) at a constant total amount during a process.
Construct: To build or synthesize a model or chemical structure.
Contact Force: A force that acts at the point of surface contact between two objects.
Convection: The transfer of heat by the movement of a fluid (liquid or gas) or plasma within a star.
Core: The innermost part of a star or planet where high-pressure reactions or dense materials are found.
Coronal Mass Ejections: Large expulsions of plasma and magnetic field from the Sun's corona.
Cosmic Microwave Background (CMB) Radiation: The electromagnetic radiation left over from the early stages of the universe.
Covalent Bond: A chemical bond that involves the sharing of electron pairs between atoms.
Create: In chemistry, often refers to the formation of new products from reactants (though mass is never created).
Criteria: The standards or requirements used to judge a material or design.
Dark Energy: A theoretical form of energy that tends to accelerate the expansion of the universe.
Dark Matter: A hypothetical form of matter that does not emit or reflect light, but exerts gravitational force.
Decay Curve: A graph showing the relationship between the amount of a radioactive substance remaining and time.
Decay Rate: The speed at which a radioactive substance disintegrates.

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Decomposition: A chemical reaction in which a single compound breaks down into two or more elements or new compounds.
Dense: Having a high mass per unit volume.
Density: The ratio of mass to volume for a substance.
Destroy: In chemistry, the concept of breaking down a substance (though mass is never destroyed).
Dissolve: The process where a solute passes into a solvent to form a solution.
Double Bond: A covalent bond in which two pairs of electrons are shared between two atoms.
Double Replacement: A type of chemical reaction where two compounds react, and the positive ions (cation) and the negative ions (anion) of the two reactants switch places.
Ductile: The ability of a material to be stretched into a wire without breaking.
Durable: The ability of a material to withstand wear, pressure, or damage.
Electrical Conductivity: The ability of a substance to carry an electric current.
Electrical Forces: The attractive or repulsive interaction between any two charged objects.
Electron: A subatomic particle with a negative charge, located outside the nucleus.
Electron Configuration: The distribution of electrons of an atom or molecule in atomic or molecular orbitals.
Electron Sharing: The mechanism of covalent bonding where atoms share valence electrons.
Electron Transfer: The mechanism of ionic bonding where one atom gives up electrons to another.
Electromagnetic Energy: A form of energy that is reflected or emitted from objects and travels through space in waves.
Electromagnetic Spectrum: The range of all types of electromagnetic radiation, from radio waves to gamma rays.
Electronegativity: A measure of the tendency of an atom to attract a bonding pair of electrons.
Electrostatic Forces: The forces between particles that are caused by their electric charges.
Element: A pure substance consisting only of atoms that all have the same number of protons.
Emit: To give off or discharge, such as a photon of light or a radioactive particle.
Endothermic: A process or reaction that absorbs energy from its surroundings, usually in the form of heat.
Energy: The capacity to do work or produce heat.
Energy Level: The specific amount of energy an electron has in an atom.
Energy Transfer: The movement of energy from one location or object to another.
Environmental Impact: The effect that a chemical or process has on the surrounding ecosystem.
Equilibrium Constant: The ratio of product concentrations to reactant concentrations at equilibrium (K_{eq}).
Evidence: Data or observations used to support or refute a scientific claim.
Excess Reactant: The reactant in a chemical reaction that remains after a limiting reactant is completely consumed.
Exothermic: A process or reaction that releases energy into its surroundings.
Expand: To increase in volume or spread out.
Explanation: A statement that clarifies how or why a phenomenon occurs based on evidence.
Fission: A nuclear reaction in which a heavy nucleus splits into smaller nuclei with the release of energy.
Flammability: The ability of a substance to burn or ignite, causing fire or combustion.

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Flexible: The ability of a material to bend easily without breaking.
Form: The process of creating new chemical bonds (releases energy).
Forward: In a reversible reaction, the direction from reactants to products.
Forward/Reverse Reaction: The two directions of a reversible chemical process.
Frequency: The number of wave cycles that pass a given point per unit of time.
Friction: The resistance that one surface or object encounters when moving over another.
Function: The specific activity or purpose of a material or molecule.
Fusion: A nuclear reaction in which atomic nuclei of low atomic number fuse to form a heavier nucleus with the release of energy.
Galaxy: A gravitationally bound system of stars, stellar remnants, interstellar gas, dust, and dark matter.
Gamma Decay: A type of radioactive decay in which a nucleus emits gamma radiation (high-energy photons).
Gamma Radiation: High-energy electromagnetic radiation emitted from the nucleus of an atom.
Groups/Families: Vertical columns on the periodic table with similar chemical properties.
Half-life: The time required for half of the radioactive atoms in a sample to decay.
Heat Energy: The total kinetic energy of the particles in a substance.
Hydrogen Bond: A weak attraction between a hydrogen atom (bonded to an electronegative atom) and another electronegative atom.
Hydrophilic: Having a tendency to mix with or dissolve in water ("water-loving").
Hydrophobic: Tending to repel or fail to mix with water ("water-fearing").
Increase/Decrease: To become greater or smaller in size, amount, or intensity.
Insulator: A material that does not easily allow the flow of heat or electricity.
Interaction: The effect that two or more objects or substances have on each other.
Intermolecular Force: The force of attraction or repulsion between neighboring molecules.
Intramolecular Force: Any force that holds together the atoms making up a molecule or compound (e.g., covalent bonds).
Ion: An atom or molecule with a net electric charge due to the loss or gain of one or more electrons.
Ionic Bond: A chemical bond formed by the electrostatic attraction between oppositely charged ions.
Ionization Energy: The energy required to remove an electron from a gaseous atom or ion.
Ionosphere: The layer of Earth's atmosphere that contains a high concentration of ions and free electrons.
Irreversible: A reaction that proceeds in one direction only to form products.
Isotope: Atoms of the same element that have the same number of protons but different numbers of neutrons.
Iterative Improvement: The process of repeatedly refining a design or material to reach an optimal result.
Law of Conservation of Mass/Matter: The principle that matter is neither created nor destroyed in a chemical reaction.
Le Chatelier's Principle: If a stress is applied to a system at equilibrium, the system will shift to counteract that stress.
Lewis Dot Structure: A diagram that shows the bonding between atoms of a molecule and the lone pairs of electrons.
Life Cycle: The sequence of changes a star undergoes from formation to its final state.
Life Span: The duration of time an object (like a star) exists.

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Light: Electromagnetic radiation that is visible to the human eye.
Limiting Reactant: The reactant that is completely consumed first in a chemical reaction, limiting the amount of product formed.
Lone Pairs: A pair of valence electrons that are not shared with another atom in a covalent bond.
Long-Chained Molecules: Molecules (like polymers) made of many repeating units linked together.
Main Sequence Star: A star in the main part of its life cycle, fusing hydrogen into helium in its core.
Malleable: The ability of a material to be hammered or rolled into thin sheets.
Material Strength: The ability of a material to withstand an applied load without failure or deformation.
Matter: Anything that has mass and takes up space.
Melting Point: The temperature at which a solid becomes a liquid.
Metal: Elements that are typically shiny, good conductors, and malleable.
Metallic Bond: A bond formed by the attraction between positively charged metal ions and a "sea" of delocalized electrons.
Metalloid/Semimetal: Elements with properties intermediate between those of metals and solid nonmetals.
Model: A representation of a system or phenomenon used to help understand or predict its behavior.
Molar Mass: The mass of one mole of a substance (g/mol).
Mole: The SI unit for amount of substance, equal to Avogadro's number of particles.
Monomer: A molecule that can be bonded to other identical molecules to form a polymer.
Motion: The change in position of an object over time.
Network Material: A material where atoms are bonded in a continuous, repeating three-dimensional network.
Network Solid: A chemical compound in which the atoms are bonded by covalent bonds in a continuous network extending throughout the material.
Neutron: A subatomic particle with no charge, located in the nucleus.
Noble Gas: Elements in Group 18 that are generally unreactive due to having a full valence shell.
Nonmetal: Elements that are typically poor conductors and brittle in solid form.
Nonpolar Bond: A covalent bond in which electrons are shared equally between two atoms.
Normal Force: The support force exerted upon an object that is in contact with another stable object.
Nuclear Fusion: See *Fusion*.
Nuclear Reaction: A process in which two nuclei or a nucleus and an external subatomic particle collide to produce one or more new nuclides.
Nucleosynthesis: The cosmic process of creating new atomic nuclei from preexisting nucleons.
Nucleus: The small, dense, positively charged center of an atom containing protons and neutrons.
Observable Universe: The portion of the universe that can be seen from Earth with current technology.
Octet Rule: The tendency of atoms to prefer to have eight electrons in their valence shell.
Particle Size: The physical dimensions of the individual units of matter; smaller sizes increase surface area and reaction rates.
Periodic Table: A tabular display of chemical elements organized by atomic number and recurring properties.
Periods: Horizontal rows on the periodic table.
Pharmaceuticals: Chemical substances used for medical treatment or drug production.
Phase: A physically distinctive form of matter, such as solid, liquid, or gas.

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Photosphere: The visible surface of a star.
Photosynthesis: The process by which green plants use sunlight to synthesize foods from carbon dioxide and water.
Physical Change: A change in which the form or appearance of matter changes, but no new substances are formed.
Polar Bond: A covalent bond in which electrons are shared unequally, resulting in a partial charge.
Polarity: The distribution of electrical charge over the atoms joined by a bond.
Polymer: A large molecule composed of many repeated subunits (monomers).
Potential Energy Diagram: A graph showing the changes in potential energy as a reaction progresses from reactants to products.
Pressure: The force exerted per unit area.
Primordial Radiation: Radiation (like the CMB) originating from the beginning of the universe.
Product: A substance that is formed as the result of a chemical reaction.
Properties: Characteristics used to identify or describe a substance.
Proton: A subatomic particle with a positive charge, located in the nucleus.
Pure Substance: A material made of only one type of particle (atom or molecule) with constant properties.
Radiation: The emission or transmission of energy in the form of waves or particles.
Radioactive: Describing a substance that spontaneously emits radiation.
Radioactive Decay: The process by which an unstable atomic nucleus loses energy by radiation.
Reactant: A substance that takes part in and undergoes change during a reaction.
Reaction Quotient: A measure of the relative amounts of products and reactants present in a reaction at a given time (Q).
Reaction Rate Constant: A proportionality constant (k) in the rate law that relates reaction rate to concentrations.
Reaction Rate Graph: A visual representation of how the concentration of reactants or products changes over time.
Reactivity: The tendency of a substance to undergo chemical reaction, either by itself or with other materials.
Red Giant: A large, cool star that has exhausted the hydrogen in its core and is now fusing heavier elements.
Red-Shift: The displacement of spectral lines toward longer wavelengths (the red end of the spectrum) in radiation from distant galaxies.
Release: To give off energy or particles.
Repulsion: A force that pushes objects away from each other, such as like charges.
Repulsive: Tending to push objects apart.
Resistance: A measure of the opposition to current flow in an electrical circuit.
Reversible: A reaction that can proceed in both the forward and backward directions.
Reversible Reaction: A chemical reaction where the reactants form products that, in turn, react together to give the reactants back.
s/p/d/f Orbitals: Regions of space around a nucleus where electrons of specific energy levels are likely to be found.
Shift in Equilibrium: The movement of a system's equilibrium position in response to a change in conditions.

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Single Bond: A covalent bond in which one pair of electrons is shared between two atoms.
Single Replacement: A reaction in which one element is substituted for another element in a compound.
Singularity: A point in space-time in which gravitational forces cause matter to have infinite density (e.g., the start of the Big Bang).
Solar Cycle: The nearly periodic 11-year change in the Sun's activity.
Solar Flares: A brief eruption of intense high-energy radiation from the Sun's surface.
Solar Maximum: The period of greatest solar activity in the solar cycle.
Solar Minimum: The period of least solar activity in the solar cycle.
Solar Wind: A stream of charged particles released from the upper atmosphere of the Sun.
Solubility: The ability of a solute to dissolve in a solvent.
Soluble: Capable of being dissolved.
Solute: The substance that is dissolved in a solution.
Solvent: The substance in which the solute dissolves.
Space Weather: The conditions in space (usually caused by the Sun) that can affect Earth and its technological systems.
Spectra: The range of electromagnetic radiation emitted or absorbed by a substance, used for identification.
State of Matter: One of the distinct forms in which matter can exist (solid, liquid, gas, plasma).
Stellar Evolution: The process by which a star changes over the course of time.
Stickiness: Informal term for the intermolecular forces (adhesion/cohesion) between surfaces.
Stoichiometry: The calculation of reactants and products in chemical reactions based on the law of conservation of mass.
Structure: The arrangement of atoms or molecules in a substance.
Subscript: A small number written to the right and below a chemical symbol to indicate the number of atoms.
Sun: The star at the center of our solar system.
Sunspot: A spot or patch appearing from time to time on the Sun's surface, appearing dark by contrast with its surroundings.
Surface Tension: The cohesive force at the surface of a liquid that causes it to behave like a stretched elastic membrane.
Synthesis: A chemical reaction in which two or more simple substances combine to form a more complex product.
Synthetic: A material made by chemical synthesis, especially to imitate a natural product.
Temperature: A measure of the average kinetic energy of the particles in a substance.
Theoretical Yield: The maximum amount of product that could be formed from a given amount of reactant.
Thermonuclear Reactions: Nuclear fusion reactions occurring at extremely high temperatures.
Trade-offs: Situations involving losing one quality or aspect in return for gaining another.
Transformation: A change in the identity or structure of an atom or molecule.
Trend: A predictable change in properties as you move across or down the periodic table.
Triple Bond: A covalent bond in which three pairs of electrons are shared between two atoms.
Unbalanced Equation: A chemical equation that does not follow the law of conservation of mass (different number of atoms on each side).

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Universe: All of space and time and their contents.
Unstable: Tending to undergo spontaneous change, such as a radioactive nucleus.
UV Radiation: Ultraviolet radiation; electromagnetic radiation with a wavelength shorter than visible light.
Valence Electron: An electron in the outermost shell of an atom that can participate in chemical bonding.
Valence Shell/Energy Level: The outermost occupied energy level of an atom.
Vapor Pressure: The pressure exerted by a vapor in thermodynamic equilibrium with its condensed phases.
Viscosity: A measure of a fluid's resistance to flow.
Volatility: The tendency of a substance to vaporize.
Wavelength: The distance between successive crests of a wave.
White Dwarf: A small, very dense star that is typically the size of a planet, formed when a low-mass star has exhausted its fuel.
Yellow Dwarf: A main-sequence star of spectral type G (like our Sun).