Course: *Chemistry* **Unit # *4*:** *Chemistry Powers our World*	**Year of Implementation:** 2021-2022
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Stage One - Desired Results	
Link(s) to New Jersey Student Learning Standards for this course: https://www.state.nj.us/education/cccs/2020/ https://www.nj.gov/education/cccs/2016/science/	

Unit Standards:

Science and Engineering Practices
The content of this unit will strengthen student skills in the following SEPs.

- Practice 1 Asking Questions and Defining Problems
- Practice 2 Developing and Using Models
- Practice 3 Planning and Carrying Out Investigations
- Practice 4 Analyzing and Interpreting Data
- Practice 5 Using Mathematics and Computational Thinking
- Practice 7 Engaging in Argument from Evidence

Performance Expectations:
The content of this unit will contribute to students ability to meet the following performance expectations:

- HS-PS1-4. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy
- HS-PS1-8. Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.
- HS-PS3-1. Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.

- HS-PS3-2. Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects).
- HS-ESS1-1 Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy that eventually reaches Earth in the form of radiation.
- HS-ESS1-3 Communicate scientific ideas about the way stars, over their life cycle, produce elements.
- HS-ESS3-2 Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.

Disciplinary Core Ideas:
The content of this unit addresses partially or completely each of the following DCIs, as specified in the Knowledge and Skills statements.

PS1.A: STRUCTURE AND PROPERTIES OF MATTER
- Stable forms of matter are those in which the electric and magnetic field energy is minimized. A stable molecule has less energy, by an amount known as the binding energy, than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart.

PS1.B: CHEMICAL REACTIONS
- Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in total bond energy (i.e., the sum of all bond energies in the set of molecules) that are matched by changes in kinetic energy.

PS1.C: NUCLEAR PROCESSES
- Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve changes in nuclear binding energies. The total number of neutrons plus protons does not change in any nuclear process.
- Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials from the isotope ratios present.

PS3.A: DEFINITIONS OF ENERGY
- Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. There is a single quantity called energy due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms.
- At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.
- These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the

configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space.

PS3.B: CONSERVATION OF ENERGY AND ENERGY TRANSFER

- Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system.
- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
- Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior.
- The availability of energy limits what can occur in any system.

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.
- Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.

ESS1.A: THE UNIVERSE AND ITS STARS

- Other than 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.

ESS3.A: NATURAL RESOURCES

- All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks, as well as benefits. New technologies and regulations can change the balance of these factors.

NJSLS Career Readiness, Life Literacies, and Key Skills

The content of this unit will contribute to a student's ability to meet the following standards.

Creativity and Innovation

- 9.4.12.CI.1: Demonstrate the ability to reflect, analyze, and use creative skills and ideas

Critical Thinking and Problem-solving

- 9.4.12.CT.2: Explain the potential benefits of collaborating to enhance critical thinking and problem solving

Global and Cultural Awareness

- 9.4.12.GCA.1: Collaborate with individuals to analyze a variety of potential solutions to climate change effects and determine why some solutions (e.g., political. economic, cultural) may work better than others

Information and Media Literacy

- 9.4.12.IML.3: Analyze data using tools and models to make valid and reliable claims, or to determine optimal design solutions
- 9.4.12.IML.5: Evaluate, synthesize, and apply information on climate change from various sources appropriately
- 9.4.12.IML.6: Use various types of media to produce and store information on climate change for different purposes and audiences with sensitivity to cultural, gender, and age diversity
- 9.4.12.IML.7: Develop an argument to support a claim regarding a current workplace or societal/ethical issue such as climate change

Technology Literacy

- 9.4.12.TL.3: Analyze the effectiveness of the process and quality of collaborative environments.

Transfer Goal: Students will be able to compare the inputs, outputs, risks, and benefits of various energy generation technologies to make an evidence-based claim regarding which energy generation technology they would most support.

Department Goals:
Students will:

- construct, interpret, and refine models (scientific and mathematical) to explain the physical and natural world.
- effectively communicate scientific ideas and evidence-based arguments to an appropriate audience through written and oral means.
- evaluate for their validity arguments that rely on scientific reasoning presented in the popular press or other informational sources.

Enduring Understandings	*Essential Questions*
Students will understand that. . . *EU 1* energy from the sun is transformed naturally and by human intervention into all other forms of energy.	*EU 1* • Can humans transform energy in the same ways as nature can? • Is any one energy source enough to power the whole world? • How could we run out of energy? • How are humans able to get the energy from the sun and use it for their needs? *EU 2*

EU 2 nuclear reactions power the sun and stars and release significantly more energy than chemical reactions. *EU 3* chemical reactions absorb or release energy in a predictable way, based on the bonds broken and formed.	● What makes something "nuclear"? ● Where does the sun get its energy to give to earth? ● How is a nuclear reaction different from a chemical reaction? ● How much control do humans have over nuclear processes? ● Can a nuclear reaction be stopped? ● Why can humans make a nuclear bomb, but not an equally destructive "coal" bomb? *EU 3* ● Why are some forms of energy more beneficial than others? ● Are there limitations to what kinds of energy can be transformed to other kinds of energy? ● How can energy be "stored"? ● Why do chemical reactions involve energy? ● What is the best way to "make" energy to fulfill our needs? ● How is it possible to make energy do what we want it to do, when all of it just comes from the sun?
<u>Knowledge</u> *Students will know . . .* *EU 1* ● the sun transfers energy to earth through electromagnetic waves that carry the energy across space. (PS3.A)	*<u>Skills</u>* Students will be able to. . . *EU 1* ● classify energy transformations within a system.(SEP 2).

• energy can be modeled at the particle level by considering the motion and arrangement of all particles in the system. (PS3.A) • as energy transformations and exchanges within a system occur, the total energy of the system remains constant. (PS3.A, PS3.B) • energy can be observed macroscopically in various ways, such as heat, light, motion, or sound. (PS3.A) *EU 2* • nuclear fusion in the sun is the source of all energy that is eventually transferred to the earth. (PS3.D) • nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve changes in nuclear binding energies. (PS1.C) • the total number of neutrons plus protons does not change in any nuclear process. (PS1.C) • radioactive substances follow a characteristic decay pattern. (PS1.C) • the earth's elements were originally formed in stars by nuclear reactions. (ESS1.A) *EU 3* • stable forms of matter are those in which the electric and magnetic field energy is minimized. (PS1.A) • a molecule is stabilized by the same amount of energy that it would take to pull it apart. (PS1.A) • the chemical potential energy of a system depends on the arrangement of all particles in the system. (PS1.B) • kinetic and potential energy are both involved in a chemical reaction system. (PS1.B) • we can predict energy exchanges between systems because all inputs to one system will equal the outputs of the other.(PS3.B)	• analyze models to identify and compare energy transfers between parts of a system or between systems. (SEP 2, 5) • peer-evaluate models showing energy changes from the sun to the earth for clarity and accuracy. (SEP 2) *EU 2* • use multiple models to represent isotopes and how they change in a nuclear process. (PS1.C, SEP 2) • find and analyze patterns in data and use them to predict modes of nuclear decay. (PS1.C, SEP 4) • use half-life models to justify claims, such as age of fossils or length of exposure to radioactive medicine. (PS1.C, PS2.C, SEP 5) • use or revise models to communicate the change a nucleus undergoes during a nuclear process. (PS1.C, SEP 2) *EU 3* • use given bond energies to predict whether a reaction system will absorb or release heat. (PS3.B, SEP 5) • model energy changes in reactions using a potential energy diagram. (PS3.B, SEP 2,5) • classify energy manifestations as kinetic or potential energy. (PS1.B, SEP 2)

• although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment. (PS3.D) • all forms of energy production have risks and benefits that must be considered. (ESS3.A)	• make a claim about a specific energy technology by considering the risks and benefits. (ESS3.A, SEP 7)

Stage Two - Assessment

Other Evidence:

- Student-created models and iterations
- Quizzes on:
  - Isotope notations showing changes during nuclear processes
  - Evaluation of chemical reactions as energy absorbing or releasing
- Student-generated claims, evidence and reasoning for explanations of phenomena and of lab results
- Lab reports and student answers to lab-related questions

Stage Three - Instruction

Learning Plan: **Suggested Learning Activities to Include Differentiated Instruction and Interdisciplinary Connections: Each learning activity listed must be accompanied by a learning goal of A= Acquiring basic knowledge and skills, M= Making meaning and/or a T= Transfer.**

***Bolded activities are hyperlinked to a resource folder.**

UNIT PHENOMENON: Centralia Mine Fire Still Burning

1. Show video clip such as:https://youtu.be/NSIjB96H4Sc
2. Prompt:
   a. Imagine yourself as a scientist standing in Centralia today, looking around at all the effects of this long-burning coal mine fire. You want to know what is happening in this town, so you ask some questions to get a better understanding of the phenomenon, its causes and its results. Identify as many questions as possible that you could ask about this mine fire.

    b. Draw a sketch that shows a possible sequence of events or interactions that led to the initial mine fire and then what keeps it sustained over time.

1. Lesson Phenomenon: Flame - Show a short video clip of fire. Ask “What is fire?” or “What is a flame?”
    - Assignment (~divide task among students so each student is comparing fire to one state of matter, and solid, liquid, and gas are evenly assigned) (EU 1, M)
        i. Make a claim about fire, as related to your designated classification. The claim will state whether fire can or cannot be classified as such. Then, using the claim-evidence-reasoning strategy explain their claim through personal experience and student’s own scientific knowledge.
        ii. Collect without discussion, and tally the votes to announce how many students said it can or cannot be classified in each of the three ways. Allow for a bit of discussion of these results. If students have questions, write them down for later.

2. Lab Activity: Observation of a candle flame (one example of activity is at this link: (EU 1, M/T) https://highschoolenergy.acs.org/content/hsef/en/how-do-we-use-energy/combustion-and-burning.html)
    - Review prior concepts of combustion reactions
    - Summarize concepts: combustion, energy release, bond breaking/forming is endo/exothermic; chemical energy = potential energy; requirements of burning= fuel, oxygen, energy
3. Revisit flame phenomenon (EU 1, T)
    - Discussion Has anybody changed their minds from the initial claim?
    - Group modeling activity: Draw a model of a flame/fire, showing how the parts you can’t see allow you to see the actual flame.
    - Challenge: Can your model explain why the flame doesn’t just go on forever?
    - Discuss/summarize as needed:
        i. we can only see the light where there is matter that is emitting it
        ii. energy is involved in every transformation

4. Lesson: What is Energy (EU 1, A/M)
    - Elicit prior knowledge: Small-group discussion, “What are some types of energy you know about and how do they work? What kinds of energy were involved in the candle activity? How do you know?”. Students report out and teacher/class discuss as appropriate.
    - Video – intro types of energy: https://highschoolenergy.acs.org/content/hsef/en/what-is-energy/what-is-energy.html
    - Recall or review prior knowledge: Conservation of energy
    - Revisit the mine fire sequence model:
        i. From learning about flames and about types of energy, enhance your model by explaining how energy might be involved in the mine fire continuing to burn.

ii. Students should share/explain models in any appropriate way.

Human “made” energy

5. Lesson Phenomenon: Reaction Demonstration(s) - Exothermic reaction (EU 3, A)
    - Examples of exothermic reaction demos:
        1. Alcohol cannon: https://www.flinnsci.com/alcohol-cannon-ap7410/vpd0053/
        2. Underwater fireworks: https://www.flinnsci.com/underwater-fireworks---chemical-demonstration-kit/ap8728/
        3. Flaming vapor ramp: https://www.flinnsci.com/flaming-vapor-ramp---chemical-demonstration-kit/ap6154/
        4. Ignite hydrogen gas - many different method options… here is one: https://www.flinnsci.com/hydrogen---what-a-bang-student-laboratory-kit/ap5958/

        ii. Review as needed: molecules, covalent bonding, reaction types and stoichiometry. Note: You don't have to use model kits for the modeling part of this phenomenon, but if you'd like you, you'll want to choose only reactions involving molecular compounds.
    - Using model kits, prepare molecule models of reactants. Students then work in small groups to create a stop-action film (FlipGrid or other) showing what bonding changes occur and discussing all energy inputs and outputs.
6. Class discussion: (referring back to the demo) Did I create energy when I demonstrated the reaction? (EU 1, M/T)
    - Humans don’t create energy (cons. of energy), we take the energy that the sun gave us and transform it to other kinds.
    - Brainstorm: What are ways you know of that we make energy in a form that is useful to us?
    - It is said that energy is “stored in bonds”. This is a mental construct that works in certain situations, but is misleading.
        i. Video: https://youtu.be/XEM9TWNcX0M
        ii. What is the real deal with energy and molecules?
7. Lesson Chemical Energy (EU 3, M/T)
    - Global Energy Flows: https://www.glbrc.org/outreach/educational-materials/global-energy-flows . Review/summarize:
        i. Much of our transformed energy is wasted as heat
        ii. Earth’s energy budget is why we get to live here
        iii. Research and technology is always trying to be more efficient, cleaner, less waste…
        iv. Many sources use combustion

- Lab Investigation about endothermic and exothermic reactions (Possible lab activities could be: Make best hot pack or cold pack; Heat of fusion of ice or lauric acid; Measuring heat content of food, etc). Focus on where the heat comes from and where it goes. Lab lesson should include: (EU 3, M/T)
    i. Calorimetry to measure/calculate heat exchange
    ii. Introduction of Potential Energy diagram showing reactants and products, and student analysis using lab results
    iii. Conservation of Energy allows us to track energy exchange
    iv. Revisit candle flame phenomenon: Analyze it in terms of energy using observations as evidence.
- POGIL **30 Bond Energy** (EU 3, M)
    i. When summarizing, relate this back to the reaction demo and elicit student responses for how it applies or for how confident they are that their original video had correct explanations.
- Lab: Energy Content of fuels or food using calorimetry and burning something to heat a can of water. (EU 3, T) Objectives:
    i. Use Model 2 from Bond Energy POGIL to create a PE Diagram like that in Model 3, but for the substances in the lab.
    ii. Describe the energy change as a change in bond strength/stability

8. Revisit exothermic reaction models. (EU 3, M/T)
    - Students should now "assess" their own or another group's original explanation video. Teacher should use what was in the original videos to create a rubric that will point students toward assessing appropriate concepts.
    - If appropriate, students can also repeat the modeling exercise with new knowledge and either create a new video or explain in person to the teacher.
9. Revisit Mine Fires (EU 3, T)
    - Brief introduction of the fire triangle (fuel - oxygen - heat). Basic idea of firefighting is to remove one of these three requirements. Without all three, there can be no fire.
    - Prompt: Make a fire triangle model of a mine fire. Show, using each side of the triangle, how the conditions of a mine fire make it very difficult to put out
    - Summarize
    - Transition to next lesson: Ask students why the mine has so much "energy" in it. Where did the mine get that energy? (carbon cycle starting at the sun). Where does the sun's energy come from? (leads to next lesson)

Nuclear Energy

10. Lesson Phenomenon: Stars (or sun) and nuclear explosion mushroom cloud (EU 2, A)
    - Show a short video clip of the sun or star to notice the “glow”. Show a short video clip or a simulation that shows a mushroom cloud after a nuclear explosion.
    - In pairs, compare and contrast the two phenomena. (moderate as needed, depending on students prior knowledge)
    - Summarize that both come from nuclear reactions!

- Pairs again: How does the energy of this kind of reaction compare to combustion reactions we've seen? What do you know about nuclear energy? What questions could be answered to help you understand this phenomenon and how it differs from combustion?

11. Nuclear Reactions (EU 2, A/M)
    - Brief teacher review of periodic table and isotope symbols
        i. Video What are Isotopes?: https://youtu.be/faB9Gb7bl9I
    - **ChemMatters Oct 2013 Fusion Next Frontier** (A/M)
    - POGIL: **Nuclear Fission and Fusion** (A/M)
    - Video (simple explanation for why fusion releases energy) https://youtu.be/pusKlK1L5To
    - Chain Reaction Video (https://www.youtube.com/watch?v=XIvHd76EdQ4)
12. Nuclear Decay (EU2, M/T)
    - Sim Lesson: **Are All Atoms Radioactive?** (includes band of stability) (A/M)
    - Lesson: **Alphas Betas Gammas Oh My**
    - Nuclear decay applications to medicine: Radioactive/Nuclear Bone Scans (T)
    - Various practice opportunities to model nuclear processes using particles and using symbols.
13. Summarize nuclear processes (EU 2, M)
    - Strong force within nucleus is the strongest force we know
    - When new strong force interactions can be made, lots of energy is released
    - This is what fuels stars/sun
14. Wrap-up: (EU 1, T)
    - Summarize all of the energy flows, starting with the sun, that occur to create a mine fire.
        i. Example of the first few energy transfers could be: Nuclear reactions release energy to fuel the sun and the sun's energy is captured by plants; people/animals eat plants for energy, etc...

15. Project: Alternative energy technologies (Below are example tasks for this activity) (EU 1, EU 3, T)
    - **Project: Sustainable Energy Evaluation**
    - Jigsaw Elicit prior knowledge of the carbon cycle, then show an image like shown in the link to address the role of fuels in the carbon cycle: https://www.noaa.gov/education/resource-collections/climate/carbon-cycle
    - Video: What if we burned all the fossil fuels? https://youtu.be/fxJc2csvpLY
    - Distribute a different energy technology to each small group of students. (Could include solar cells, nuclear, different fossil fuels, and any clean and/or renewable resources. These can be transportation-related, electricity-generating, etc)
    - Groups will determine basic mechanisms, identify energy transformations, and list pros and cons of this technology.
    - Then jigsaw the groups so each now has 1 person w/ a given technology.

i. Within this new group, discuss and rank the technologies, in terms of importance for funding. Share out to the class and be ready to justify.

- This is the entry point for the EU 1/EU 3 Performance Task..