Course: *Chemistry* **Unit #:** *5: Chemistry of Climate Change*	**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 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 6 Constructing Explanations and Designing Solutions
- Practice 8 Obtaining, Evaluating, and Communicating

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

- HS-PS1-6. Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium

- 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-PS4-3. Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other
- HS-PS4-4. Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter
- HS-ESS2-4. Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.
- HS-ESS2-5 Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.
- HS-ESS2-6. Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere
- 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.B: CHEMICAL REACTIONS

- In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present.

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. That there is a single quantity called energy is 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

- 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.
- Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down).

PS3.D ENERGY IN CHEMICAL PROCESSES AND EVERYDAY LIFE

- The main way in which that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis.
- Solar cells are human-made devices that likewise capture the sun's energy and produce electrical energy.
- Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.

PS4.B: ELECTROMAGNETIC RADIATION

- Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features.
- When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells.

ESS2.C THE ROLES OF WATER IN THE EARTH’S SURFACE PROCESSES

- The abundance of liquid water on Earth’s surface and it’s unique combination of physical and chemical properties are central to the planet’s dynamics. These properties include water’s exceptional capacity to absorb, store, and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve and transport materials, and lower the viscosities and melting point of rocks.

ESS2.D: WEATHER AND CLIMATE

- The foundation for Earth’s global climate systems is the electromagnetic radiation from the Sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy’s re-radiation into space.
- Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.

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 social 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

Digital Citizenship
- *9.4.12.DC.8: Explain how increased network connectivity and computing capabilities of everyday objects allow for innovative technological approaches to climate protection.*

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 independently use their learning to explain how human activity can contribute to climate change.

Department Goals:
Students will:

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design, critique, and carry out experiments in order to investigate scientific questions and/or propose solutions.
apply mathematics to express relationships efficiently and accurately.
effectively communicate scientific ideas and evidence-based arguments to an appropriate audience through written and oral means.

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<u>Enduring Understandings</u>
Students will understand that. . .

EU 1
climate change involves a complex system of interactions between the sun's radiation and the earth's matter.

EU 2
gases respond in predictable ways to changes in their conditions.

EU 3
the components of solutions combine in predictable ways that yield a wide range of properties.
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<u>Essential Questions</u>

EU 1

How is the earth's temperature determined and what controls it?
Why and how does human activity affect the temperature of the earth?
What makes heat?
How do matter and energy interact with each other?
If humans can cause the earth to warm, can they also cause it to cool?

EU 2

Why are gases different from liquids and solids?
How do gases respond to changes in their physical environments?
How can everyday phenomena be used to illustrate how surrounding conditions affect the behavior of a gas?
How can gas properties help explain atmospheric phenomena such as wind or weather?
How do scientists measure the various properties of gases in the atmosphere (and in the lab)?

EU 3

How do chemical reactions in the air and ocean impact the earth's climate?
What is so special about H_2O?

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	• Why and how do the properties of water change when various types of substances are added to it? • How do pH changes affect ocean life? • What kinds of changes are big enough to have an effect on the giant ocean??
Knowledge *Students will know . . .* *EU 1* • radiation from the sun can be modeled as a wave when it transfers energy through space, and as a particle when it interacts with a given molecule. (PS3.A, PS4.B) • different ranges of the electromagnetic spectrum cause different effects when absorbed by particles. (PS4B) • the earth's climate depends on how the sun's radiation interacts with particles in the atmosphere, ocean, and land. (PS3.A, ESS2.D) • atmospheric warming results from increased motion of atmospheric particles. (PS3A, ESS2.D) • atmospheric molecules that can absorb visible or infrared radiation can act as greenhouse gases to keep the earth's surface and atmosphere warm. (PS4.B) *EU 2* • a simple model can be used to predict the behavior of most gas samples due to the large spacing between particles (SEP 2, PS1.A)	*Skills* Students will be able to. . . *EU 1* • differentiate ranges of the electromagnetic spectrum by relative energy (PS4.B) • associate ranges of the electromagnetic spectrum with the effects their photons can have when absorbed by a molecule (PS4.B) • explain photosynthesis and solar cells as examples of how the sun's energy can be used once absorbed by the appropriate substances. (PS3.D) • use the carbon cycle to explain how human activity increases carbon dioxide concentrations and affects climate change. (ESS2.D)

• the temperature of a gaseous substance is directly proportional to the average kinetic energy of the gas particles. (PS3.B) • heat transfer among atmospheric gases can be predicted by analyzing the stability of the system and its energy distribution. (PS3.B) • all forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks, as well as benefits.(ESS3.A) *EU 3* • the equilibrium between gas molecules in the atmosphere and in the ocean is affected by the concentration and numbers of all types of molecules present. (PS1.B) • the unique properties of water allow it to be a solvent for a wide variety of substances. (ESS2.C) • combining water with substances changes the properties of the water in predictable ways. (ESS2.C)	*EU 2* • model the results of changing various gas conditions (SEP 2, PS3.B) • apply gas relationships to explain phenomena, such as wind, high/low pressure areas, or difficulty breathing on a mountain top. (ESS2.D, SEP 6) • (*Honors only)* calculate values showing how gas molecules respond to changing conditions. (PS3.B) *EU 3* • Apply reaction dynamics, such as equilibrium and rates, to explain changes in the ocean and/or atmosphere.(PS1.B) • apply scientific reasoning to predict consequences of various human actions on ocean life. (ESS3.A)

Stage Two - Assessment

<u>Other Evidence:</u>

- *Assessments on*
    - *Kinetic molecular theory*
    - *Relationships between gas variables*
    - *Properties of solutions*

- *Models of matter/energy interactions*
- *Case study answers*
- *Simulation responses*
- *Lab Reports/ Lab analysis questions*

Stage Three - Instruction

<u>*Learning Plan:*</u> **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 linked to a Resource Folder**

*Click this link for a simple and comprehensive teacher guide to climate change in chemistry!
https://teachers-climate-guide.fi/chemistry/

UNIT PHENOMENON: Greenhouse

1. Show simple diagram of greenhouse. (EU1, A)
    - Elicit prior knowledge: (allow for discussion, but teacher should not yet correct any incorrect statements)
        1. How does a greenhouse work?
        2. Compare/contrast this to the earth's greenhouse effect
2. Lesson: Let's break it down - How do gases respond to changing conditions? POGIL: **Kinetic Molecular Theory** (EU2, M/T)
    - Summarize with:
        1. Gases are fundamentally different from liquids/solids because the molecules are far apart
        2. Atmosphere contains many different particles
        3. Temperature measures average kinetic energy of particles

LESSON PHENOMENON: The pressure inside a football in cold weather

3. Demo or photo/video of a balloon shrinking in cold temperature.
    - Prompt for students: Explain what is happening inside the balloon to cause it to shrink.
4. **Deflategate Case Study** Intro (Did the Patriots cheat?) (EU2, A/M)
    - Present an overview of the Deflategate phenomenon.
    - Think-Pair-Share: Develop potential explanations for the phenomenon, along with what experiments could be done to support the explanation.
    - Analyze Data: Present the information from the Case Study for students to review. (A/M)

   i. What patterns do you notice in the data sets?
   ii. How do these patterns support or refute potential explanations?
   iii. What further questions must be answered to determine whether cheating occurred? (M/T)

5. Activities: Determine properties of gases and qualitative relationships between some properties using labs or simulations such as those listed below: (EU2, A/M)
   - https://betterlesson.com/lesson/638115/gas-laws-lab
   - **Experimental Design Gas Variables**
   - **Vernier Intro Activity PV & PT**
   - Demos: **Mini Bell Jar Kit**
   - Can crush demo or video: https://youtu.be/JsoE4F2Pb20
   - PhET Simulation https://phet.colorado.edu/sims/html/gases-intro/latest/gases-intro_en.html or
   - Nasa simulation https://www.grc.nasa.gov/WWW/K-12/airplane/Animation/frglab2.html
6. [*Honors only*] Activities to determine quantitative relationship between variables
   - POGIL: **25 Gas Variables** (A/M)
   - Lab: Any involving quantitative gas law calculations (M/T)
7. Deflategate Case Study Assessment: [*CP/Acc will need to modify final questions to be qualitative.*] Complete the Case Study and make a recommendation, with justification based on the interrelated gas properties.(EU2, M/T)

8. Revisit greenhouse phenomenon - Small group discussion: How can the gas property relationships help us to explain what happens inside a greenhouse? (EU 2, M/T)
   - Watch video: https://youtu.be/JtTDx8_dlsE
   - Then, whole-class modeling exercise (guided by teacher, but with minimal input): Develop a way to represent molecules, light, and heat. Use these to show the various interactions that cause a greenhouse to stay warm. Discuss the gas particles inside the greenhouse and explain the observed effect (inside of greenhouse gets warm) using particle-level explanations of the changing gas variables.
9. Model a different phenomenon. Show video of wind, such as: https://youtu.be/-s7zOubwXmc ; or https://youtu.be/edsNPCwU9lo, or distribute different phenomena, such as hot air balloons, high-altitude breathing difficulties, drinking straw, plunger, helium balloon vs air balloon. (EU 2, T)
   - Students draw particle-level models on large poster paper, along with applications of gas variables and KMT to explain how their assigned phenomenon works.
   - Students present to each other and answer questions from peers and/or teacher.

LESSON PHENOMENON: "Global Warming"

10. Present scenario: (Be sure students already know that any matter warmer than absolute zero will emit radiation.) The sun is ~5500^{o}C and emits a range of wavelengths, with highest intensity in the ranges of UV, Vis, and near IR. The earth is ~16^{o}C

and emits a range of wavelengths, mostly in thermal IR region..The sun's energy is sent through space in all directions, but space is only ~-270ºC. So why doesn't space heat up?

- Class or small group discussion to see what students know and to note any misconceptions.

11. Watch the simulation at: https://climate.nasa.gov/climate_resources/139/video-global-warming-from-1880-to-2020/ (EU 1, A)
    - Elicit prior knowledge - Is all global warming bad? What causes the atmosphere to stay warm or get warmer? Why does human activity play a role in this? Why is this (as "climate change") in the news all the time?
    - Groups develop a list of things they know and questions they have.
12. Heat energy (EU 1, M)
    - Pre-assess student knowledge on energy and heat transfer mechanisms: conduction, convection, radiation
    - Video: Temperature and Energy - https://highschoolenergy.acs.org/content/hsef/en/how-do-we-use-energy/temperature-energy.html
    - Collisions are a way of exchanging energy – (this is a major understanding for atmospheric warming)
13. Revisit the sun-space-earth scenario - How have your ideas changed about why space doesn't get hot when the sun's energy moves through it? (EU 1, T)
    - Summarize: there has to be matter to absorb the energy and get "hot"; the sun's radiation transfers energy across space and does not rely on any kind of matter to get from one place to another; the radiation energy isn't "heat" until something absorbs it, and gains kinetic energy

14. How matter absorbs energy (EU1, M)
    - Group task Prompt: We know that everything needs energy in order to do things. We eat our energy. Our devices consume electrical energy. List common things you've seen or heard of that absorb energy from the sun and describe the effect of absorbing this energy.
        i. Students should list things such as photosynthesis makes plants grow, solar cells provide electricity, UV light causes sunburn, the sun makes concrete feel hot…
    - Teacher demonstration: Set up a heat lamp to shine equally on a solid, a liquid and a gas (air). Measure and compare temperatures (or just feel them) after a set time.
    - Discussion/Review topics:
        i. What makes them get hotter?
        ii. What happens to the particles in the substances when the light shines on them?
        iii. Do the particles in gases, liquids and solids differ in how they react to the heat lamp?
        iv. Each was exposed to the same amount of "heat", so why are they different temperatures?
15. Revisit greenhouse phenomenon - How can you use the three heat transfer mechanisms to refine your explanation of how the gas molecules behave in the greenhouse? Did the original class model reflect this? If not, how could the model be modified to reflect this new knowledge? (EU 1, EU 2, T)

- At this point, the focus should be that "heat" is what we call it when matter absorbs energy, increasing its kinetic energy, thus increasing temperature. Matter can also emit lower energy radiation for something else to absorb...

16. So, is the earth's atmosphere the same as a greenhouse?
    - Activity: Simulations of electromagnetic radiation interacting with molecules. (EU1, A/M)
    - https://acswebcontent.acs.org/chemistry-in-context/suite/applets/ozone/ozone.html
        i. Direct or guide students toward the conclusion that different regions of the sun's radiation will affect a molecule differently, and some won't interact at all.
    - https://acswebcontent.acs.org/chemistry-in-context/suite/applets/collisional-heating/collisional-heating.html
        i. Guide students to be able to answer: Did the molecule absorb energy? How do you know? Where did the energy go? Why isn't it stopping?
            1. Prompt students: If the molecule absorbs the energy and vibrates faster, does it just keep that energy and keep doing that?
                a. Ask students how that one molecule could possibly give some energy away.
        ii. Next click to show the other molecules in the atmosphere. Guide students toward the following:
            1. Each absorption by the focus molecule will eventually cause a different molecule to gain energy and move fast. (*Note that a molecule CAN simply re-emit the same or a lower-energy photon, but this sim focuses on the transfer between molecules.)*
    - View the graphical animations at: https://www.esrl.noaa.gov/gmd/ccgg/trends/history.html
        i. Relate this to the short video of earth's temperature from 1880 to 2020.
    - Summarize students' ideas of how gases and energy absorption might relate to the earth being warmed by the sun.
17. Revisit Heat demo. Use questions such as those below to guide students toward thinking about the molecules.
        i. Why does it make sense that solids, liquids, and gases absorb energy differently from each other?
        ii. So what parts of the earth probably absorb most of the sun's energy?
            1. What happens to that energy?
            2. When and from where does the atmosphere gain energy?
    - Work in pairs to list and describe as many energy transfers as possible between the atmospheric molecules and any other aspect of the sun and earth system..
18. Students will use a simulation activity, such as: https://phet.colorado.edu/en/simulation/legacy/greenhouse to examine why greenhouse gases help the earth stay warm and to explain the effects of too few or too many greenhouse gases in the atmosphere. (EU 1, EU 2, M/T)
19. Greenhouse vs greenhouse effect (EU 1, EU 2, T)
    - Create a model of the greenhouse effect on earth. Compare and contrast this to the model of the greenhouse.
    - Identify relevant interactions of energy and matter and show the various types of energy transfer involved in each phenomenon.

LESSON PHENOMENON:More Climate Change effects! Oyster larvae Pacific NW dying in hatcheries, leaving no oysters to harvest

20. Oyster Video (only show the first bit, before the explanation): https://youtu.be/x7MpI9dZIjk (EU3, M)
    - Lab: Conductivity of solutions vs pure water Electrolytes vs Nonelectrolytes (ionic vs. covalent)
        i. Why would pure (distilled) water be unhealthy for sealife? (A/M)
21. Physical properties of water and ocean - conceptually (EU3, A/M)
    - Review unique properties of water such as its ability to absorb heat and its universality as a solvent.
    - Lab Investigation: compare a physical property (melting/freezing/boiling) of water and water with various solutes dissolved.
        i. Follow up: How could changes in mineral concentration affect the ocean and how it interacts with the rest of the earth's systems? (focus on simple colligative properties and basic equilibrium effects)
22. Measuring acidity (EU3)
    - Review/assess prior knowledge – pH scale (qualitative)
    - Lab: https://www.exploratorium.edu/snacks/ocean-acidification-in-cup (EU3, A)
        i. Summarize: How does carbonation affect pH?
    - Demo of water absorbing carbon dioxide, such as: https://www.noaa.gov/sites/default/files/atoms/files/Ocean_Acidification_and_Dry_Ice.pdf
    - Lab investigating effects of liquids of various pH on eggshells, such as: http://www.cisanctuary.org/ocean-acidification/PDFs-WorkshopPage/Hands_on_acivities/OA_Shells.pdf (EU3, M)
    - ChemMatters (Feb 2018) article: **Acidic Seas** (EU3, A/M)
        i. Why is pH an important consideration in the ocean?
        ii. How does carbon dioxide contribute to the pH of the ocean?
        iii. What can human beings do to help to slow/reverse ocean acidification?
    - Simulation: (EU3, M/T) https://acswebcontent.acs.org/chemistry-in-context/suite/applets/ocean-acidification-clean/ocean-acid.html
        i. Use the simulation to help investigate the equilibrium concepts from the previous article.
23. Solubility of Gases
    - Lesson Phenomenon: Open a new soda bottle (or can)
        i. Students observe, explain, wonder
        ii. Demo or experiment: Students decide what conditions to test (Possible options below)
            1. Using the amount of sound upon opening, try different conditions to see how they affect the amount of carbon dioxide that stays dissolved.
            2. Determine how much carbon dioxide is dissolved in soda (find a way to get it out and measure it, like with a pressure gauge or using the volume of a bag/balloon)
            3. How does pH change with different amounts of carbon dioxide dissolved (stir, heat, or leave open to remove carbon dioxide, maybe leave pH probe tracking overnight)

- Equilibrium of gas solubility
    1. Carefully heat a closed flask containing a volume of soda, with pressure sensor attached. Note that the gas is still there. Use gas laws (qual or quant) to discuss amount of gas that must be there before and after heating. Where do the rest of the molecules come from or go, if the system is closed?
    2. Present the dissolving process as an equilibrium process.
        1. Practice predicting or interpreting different changes like concentration (or pressure) and temperature

24. Return to Oyster phenomenon (EU3, T)
    - Show remainder of the Oyster video from above.
    - Use a flowchart model to describe how extra atmospheric carbon dioxide could lead to premature death of the oyster larvae. Description should include particle-level changes, energy changes, and equilibrium effects.
    - Video: https://youtu.be/kxPwbhFeZSw Keep your model out while you watch the video. Make any modifications or additions you see in the video.
    - Predict how the Oyster phenomenon would change if the ocean temperature increased, due to climate change.