DESCRIPTOR

Wanda Bryant, chemistry teacher at Henry Ford High School in Detroit, has created a module examining the properties of gases and gas laws, the electromagnetic spectrum and remote sensing, greenhouse gases and climate change, and ends with students examining ways to mitigate climate change. Inquiry and content area literacy strategies are incorporated throughout to meet the needs of all learners and math skills utilized to deepen understanding of scientific content.

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Chemistry-10th

Module title: What's in the atmosphere that affects climate? Why should I care?

Introduction: The earth can be divided into four systems-the lithosphere, the hydrosphere, the biosphere, and the atmosphere. Each of these systems has a specific role in keeping the earth going and in the storage of carbon. They each play a part in affecting the weather, and therefore climate. This module focuses on the atmosphere and consists of three units**,** examining the properties of gases and gas laws, the electromagnetic spectrum and remote sensing, greenhouse gases and climate change, and ends with students examining ways to mitigate climate change. Inquiry and content area literacy strategies are incorporated throughout to meet the needs of all learners and math skills utilized to deepen understanding of scientific content.

Major Understandings:

1. Particles in all matter are in constant motion until the temperature reaches absolute zero. Absolute zero is the theoretical temperature at which matter has the least energy, the limit of how cold matter can get. If substances could be cooled to absolute zero they would not emit any electromagnetic radiation.
2. The order and organization in the universe is illustrated in the pressure, volume and temperature relationships which can be predicted by models, mathematical equations and graphs.
3. The same number of all gaseous molecules will occupy the same volume under the same conditions.
4. Chemical compounds always have the same formula and the same composition.
5. Electromagnetic waves transfer energy and information from place to place without a material medium, and visible light is a form of electromagnetic radiation. Light waves reflect, scatter, refract, and interfere with each other in ways similar to mechanical waves. Our perception of color is a result of the color of light incident on an object and the colors that are reflected and absorbed by the object.
6. Predicting and mitigating the potential impact of global climate change requires an understanding of the mechanisms of Earth's climate, involving studies of past climates, measurements of current interactions of Earth's systems and the construction of climate change models.

UNIT ONE-Properties of Gases and the Gas Laws

All matter consists of atoms that are in constant motion. Solids have strong forces of attraction between their atoms, liquids less, and gases hardly any. As the internal energy in a substance increases, so does the motion of the atoms, usually resulting in a decrease in the force of attraction and an increase in volume. Temperature is the measure of the average kinetic energy of the atoms in a substance. The amount of internal energy in a substance determines its state. The earth's atmosphere is a complex mixture of several "gases", either atomic or molecular in nature. Air consists primarily of N_2 (78%) and O_2 (21%), with small amounts of several other substances, including Ar (0.9%).

C2.2c-Explain changes in pressure, volume, and temperature for gases using the kinetic molecular model.
C3.4g Explain why gases are less soluble in warm water than cold water.
C4.5a-c Provide macroscopic examples, atomic and molecular explanations, and mathematical representations (graphs and equations) for the pressure-volume, pressure-temperature, and temperature-volume relationships in gases.
C5.2f Predict volumes of product gases using initial volumes of gases at the same temperature and pressure.

Resource: https://www.oakland.k12.mi.us/Portals/0/Learning/gaslaw.pdf

Safety concerns: Always wear goggles and a lab apron to protect eyes and clothing. Clean up the lab and all equipment after use, and dispose of substances according to proper disposal methods. Wash your hands thoroughly before you leave the lab after all work is finished.

Day 1

I can describe the kinetic molecular theory.

1.2i I can explain the progression of ideas and explanations that lead to science theories that are part of the current scientific consensus or core knowledge.
C2.2B Describe the various states of matter in terms of the motion and arrangement of the molecules (atoms) making up the substance.
C4.3B Recognize that solids have a more ordered, regular arrangement of their particles than liquids and that liquids are more ordered than gases.

Materials: internet access, kinetic molecular theory worksheet

ENGAGE: Focus questions: How are particles arranged in a solid, liquid, and gas? To answer this question, have students arrange themselves in a large circle, locking arms with a partner (solid). Next, have students hold hands (liquid). Finally, have students grasp the pinkie (gas).

EXPLORE: Students take notes in science notebook on the tutorial Particulate Nature of Matter at chemthink.com. The teacher must sign up to receive a code. Students use the code to register by creating a username (I have students use firstname.last name) and password. The teacher has access to student results. See appendix A11-A14 for details.

EXPLAIN:
Students complete questions below using
http://crescentok.com/staff/jaskew/ISR/chemistry/class16.htm

The Kinetic Theory Name _____

1. The Kinetic Theory explains _____
2. An elastic collision occurs when _____
3. Oxygen molecules in air have over _____ collisions per second.
4. The SI unit for pressure is the _____

5. Standard atmospheric pressure is equal to _____

6. The SI unit for energy is the _____

7. Kinetic energy is calculated using the equation:

8. _____ temperatures are required when working Gas Law problems.

9. According to the Kinetic Theory, a liquid is defined as: _____
10. A solid is defined as _____
11. A gas is defined as _____
12. Plasmas exist at temperatures over _____

13. At 25 ^{o}, ionic compounds exist in the _____ phase.

14. At 25 ^{o}, nonpolar molecular compounds exist in the _____ phase.

15. Intermolecular forces are called weak forces because they are:
16. Identify and describe the contributions each of the following scientists made to what we know about the kinetic molecular theory:
    a. Ludwig Boltzmann
    b. Robert Boyle
    c. Jacques Charles
    d. John Dalton

ELABORATE: Use tear/share strategy. Please see appendix A4-6 for directions. Additional questions to be used during discussion could include:

1. Much of the volume occupied by a gas is empty space. This explains which characteristic of gases?
a. limited compressibility
b. low density
c. fixed volume
d. ability to dissolve into a liquid

2. The kinetic-molecular theory considers collisions between gas particles to be
a. predictable.
b. slow.
c. elastic.
d. inelastic.

Day 2

ELABORATE: Students use **http://crescentok.com/staff/jaskew/ISR/chemistry/class17.htm** to answer the following questions in their science notebooks:

1. List five ways gases differ from solids and liquids.
2. Properties of a gas that can easily be measured are?
3. What is standard atmospheric pressure?
4. List all the conversion factors used in gas law problems.
5. Temperature is a measure of what?
6. List three tips for working with the gas laws.
7. What is the SI unit for pressure?

EVALUATE: Use 3-2-1 review, appendix A10, to have students summarize their thinking on the kinetic molecular theory and individuals who contributed to our understanding of the theory. For example, students could list **3** facts about what was learned, **2** interesting ideas, and **1** thing they still have questions about. Modifications to this assignment include: List **3** key terms related to what you just learned, **2** ideas you would like to know more about, and **1** concept or skill you think you have mastered. Students successfully complete chemthink.com questions on the Particulate Nature of Matter.

Day 3

Focus Question: What are the properties of gases?

Materials: 3 1/2/ index cards, water, small glasses, balloons, freezer, empty soda cans, hot plate, film canisters, alka-seltzer,

ENGAGE: Students complete K and W on what they know about the properties of gases in science notebooks.

EXPLORE: Properties of gases station lab activities. In groups of four, students will rotate through the 5 stations, spending 5-7 minutes at each station.

Activity 1-observing gas pressure: Fill a small glass with water to the rim. Place an index card on the top of the glass. Working over a sink, use one hand to press the index card firmly to the top of the glass, keeping the hand in place. Remove your hand from the index card. **Card stays due to atmospheric pressure.**

Activity 2-observing volume changes: Inflate balloon and secure. Measure diameter and record in science notebook. Students make predictions in their science notebooks about how cold and heat would affect balloon diameter. Insert balloon into freezer for 30 minutes, measure diameter **(decreases).** Place balloon under warm light for 30 minutes. Measure diameter **(increases).**

Activity 3- teacher demonstration crush the can: Add 15mL of water to empty soda can, heat until boiling, invert can into bowl of ice) see page 24 of resource guide **(gas properties-temperature, pressure, and volume)**

Activity 4-pop your top: Half fill film canister with water, add crushed Alka-Seltzer, immediately add lid and stand back. **Carbon dioxide gas formed in reaction exerts so much pressure it pops the top of the canister.**

Day 4

Focus question: What is the relationship between temperature and solubility of a gas?
Real world connection: Why is pop kept in a refrigerator?

Activity 6-The Effect of Temperature on Solubility of gases. Please see resource activity #1, https://www.oakland.k12.mi.us/Portals/0/Learning/gaslaw.pdf, pages 9-12 for detailed materials and procedure.

EXPLAIN: For each station, students are to determine why each phenomenon occurs and relate explanation to gas pressure, volume, and temperature (see other conclusions and discussion questions on page 11 and 24-25 of the resource).

Day 5

ELABORATE: Students take notes in science notebook on the Behavior of Gases tutorial at Chemthink.com.

EVALUATE: Students identify gas property observed with each activity using L of KWL and answer questions on the Behavior of Gases at chemthink.com. See appendix A11-A14 for details on chemthink.com.

Day 6 and 7

C2.2c I can explain changes in pressure, volume, and temperature for gases using the kinetic molecular model.
C4.5a-c Provide macroscopic examples, atomic and molecular explanations, and mathematical representations (graphs and equations) for the pressure-volume, pressure-temperature, and temperature-volume relationships in gases.

Materials: internet access, pencils, graph paper, rulers, science notebooks

Focus Questions: What is the relationship between pressure and volume? Volume and temperature?

ENGAGE: Teacher performs marshmallow in a syringe demonstration (see resource page 24 for detailed instructions). Students record observations and make written predictions in science notebooks.

Boyle's Law states that the volume of a confined gas is inversely proportional to the pressure exerted upon it and can be mathematically expressed as $P_1V_1=P_2V_2$

Charles' Law states that the volume (V) of a confined gas is directly proportional to its temperature (T) in Kelvin. $\frac{V_1=V_2}{T_1=T_2}$

EXPLORE: Boyle's Law: P-V relationships (C2.2c) Students complete module located at:

http://www.chem.iastate.edu/group/Greenbowe/sections/projectfolder/flashfiles/gaslaw/boyles_law_graph.html and Charles' Law: V-T relationship

http://www.chem.iastate.edu/group/Greenbowe/sections/projectfolder/flashfiles/gaslaw/charles_law.html

Please see resource https://www.oakland.k12.mi.us/Portals/0/Learning/gaslaw.pdf, pages 13-17 for detailed procedure and lesson description.

EXPLAIN: Students use graph to answer the following questions:

1. At a pressure of 3 atmospheres, what is the volume of gas?
2. As the pressure of the gas increases from 1 atmosphere to 2 atmospheres, does the volume increase or decrease?
3. When the volume of gas is 8L, what is the pressure exerted upon it?
4. As the temperature of the gas increases from 250K to 350K, does the volume of gas increase or decrease?

5. What is the volume of this gas sample when the temperature is 300K?
6. What is the temperature of the gas when it occupies a volume of 250mL?

ELABORATE: Have students solve Boyle's Law and Charles' Law equations. For example, At a winter carnival, a balloon is filled with 5.00 L of helium at a temperature of 273 K. What will be the volume of the balloon when it is brought into a warm house at 295 K? Students are assigned related problems from chemteam http://www.chemteam.info/GasLaw/Gas-Boyle.html and http://www.chemteam.info/GasLaw/Gas-Charles.html.

EVALUATE: Students copy data table in science notebooks, graph results, and self assess using graph rubric. See appendix A15 for graph rubric.

Safety concerns: Follow district's internet usage policy.

Real world example: hot air balloons

Day 8

Gay-Lussacs Law: P-T relationships (C2.2c) states if volume and amount of gas is constant, as the temperature of an enclosed gas increase, the pressure increases (direct relationship)

Materials: internet access, science notebooks, graph paper, pencils, rulers

C2.2c I can explain changes in pressure and temperature for gases using the kinetic molecular theory.

Focus question: What is the relationship between pressure and temperature?

$P_1 \times V_1 = P_2 \times T_1$

ENGAGE: Students make prediction by answering focus question in their science notebook.

EXPLORE: http://www.goalfinder.com/Downloads/Pressure_temp_relation.swf

ELABORATE: Students complete problems from chemteam http://www.chemteam.info/GasLaw/Gas-Gay-Lussac.html

EVALUATE: Teacher assigns a problem for students to complete and students answer focus question on an exit ticket.

Real-world examples: pressure cookers

UNIT TWO-The Electromagnetic Spectrum and Remote Sensing

We use our senses when observing the world around us. Some senses require us to come in contact with what we are sensing-we touch and taste-while others allow us to perceive objects at a distance-we see and hear. In the second case, we are sensing objects that are remote from our eyes or ears-we are doing remote sensing. Over the years, our ability to see more of the environment has evolved from using cameras attached to hot air balloons to the launching of the first remote sensing NASA Landsat satellite in July 1972, designed to image and map land surface features. This unit examines the basics of the electromagnetic spectrum and its application to scientific tools used to study the environment.

Safety: be careful with scissors, follow internet policy

P4.6AI can identify the different regions of the electromagnetic spectrum and compare them in terms of wavelength, frequency, and energy.
C2.4D I can compare various wavelengths of light (visible and non-visible) in terms of frequency and relative energy.

MATERIALS:
Meter stick or metric ruler (marked in millimeters)
Scissors
Scotch tape
Poster board/ 1 for every four students
Several pieces of paper in the following colors: red, orange, yellow, green, blue, violet, white, and black (paper will be cut into 1-inch-wide strips)
Black marker
Prism
Flashlight (optional)
A copy of EMS Measurement Data Sheet for each student

ENGAGE: Day 9

1. Do a demonstration of light passing through a prism. Students should see the light break up into the visible spectrum. Then place the second prism on the inverse angle to change the spectrum back to white light. The students will record in their spiral notebooks what they have observed. They will also record what they believe caused what they observed.
2. Teacher holds up a compact disc slowly positioning at different angles with respect to the light in the room. Ask the students to comment about what they see. **Ask them whether or not they believe there is a connection between what happens with the compact disc and with rainbows**. Ask them to record their hypothesis in their science notebooks.

PROCEDURE:

1. In this activity, students will create a model of the infrared, visible, and ultraviolet

portions of the electromagnetic spectrum. The model they create will be made to scale based on wavelength.

2. Hand out data sheets to each student and divide the class into small groups of four. Make sure each group has the materials necessary for the activity.
3. Explain to students that the wavelengths for the visible, infrared, and ultraviolet portions of the spectrum are represented in meters on their data sheets. Students will need to complete a metric conversion calculation to find the length of the waves in nanometers. Explain to students that one nanometer is 10^{-9} of a meter. The scale that will be used to build their model of the spectrum is 1 nanometer equals 1 millimeter. So if a wavelength is *X* nanometers, the model for that wavelength should measure *X* millimeters. Students will need to show the work they've done on their calculations in the space provided on the data sheet. See appendix A38 for data sheet.
4. Model the metric conversion calculation for red light on the board as an example.
5. Have students fill in the scale length in the millimeters column on their data sheet for red light. This column should always be the same as the final answer for wavelength in nanometers.
6. Explain to students that the colored strips of paper will be used to represent the different colors in the visible spectrum. Use red paper for red light, orange paper for orange light, etc. White paper will represent infrared, and black paper will represent ultraviolet.

EXPLORE: Day 10

7. Have each group cut a strip of red paper that is the same length as the number they have written in the column for scale length in millimeters. (If standard 8.5 × 11-inch paper was used to make the strips, one strip by itself will not be long enough to make the model. Point out to the groups that they may need to tape more than one strip together to get a long enough length of paper.)
8. Once groups have a piece of red paper that is 750 millimeters (75 centimeters) long, have them mark the *actual* wavelength of red light, 7.5 × 10-7 meters or 750 nanometers, on the strip.
9. Each group should now complete a metric conversion calculation and cut strips for each of the electromagnetic waves represented on the data sheet. When the groups have finished, they should have eight strips of paper of different lengths and colors in their model.
10. Have groups align their strips horizontally, directly underneath each other, with the longest strip (which should be infrared) on top and the shortest strip (which should be ultraviolet) on the bottom. Tape all of the strips together to make one large sheet.

EXPLAIN:

1. Based on what you have learned about wavelengths, why do you think the color spectrum appears in the sequence that it does?

2. Based on the activity today, can you explain what happened during the demonstration with the compact disc?
3. If electromagnetic radiation **A** has a lower frequency than electromagnetic radiation **B**, then, compared to **B**,
   a. the wavelength of **A** is shorter.
   b. the energy of **A** is lower.
   c. A is more particle-like.
   d. Both (a) and (c)

Teacher notes: Discuss how wavelength contributes to the amount of refraction, or the deflection of light waves as they pass from one substance to another. Red light has the longest wavelength in the visible spectrum and therefore refracts the least. It is found at the top of the visible spectrum. Violet light has the shortest wavelength in the visible spectrum and therefore reflects the most. It is seen at the bottom of the spectrum.

EVALUATE: Once model is constructed, students choose 3 electromagnetic waves which must include visible light, to make 3 way venn diagram. The results of the venn diagram are summarized using formula writing. Please see appendix A20-21 and A8 for student example, rubric, and directions for formula writing. (Lesson plan modified from "Color Spectrum. How does it work?" developed by Karen Kennedy, former high school teacher and educational consultant. Downloaded from the Discovery Education website.

ELABORATE: Assign as homework

Objectives: Make accurate observations of a visible change. Develop a testable hypothesis. Design a simple experiment, including a control. Gather data and interpret the results of their observations and experiment.

C1.1g I can use empirical evidence to explain and critique the reasoning used to draw a scientific conclusion or explanation.
C1.1h I can design and conduct a systematic scientific investigation that tests a hypothesis. Draw conclusions from data presented in charts or tables.
C1.1E Describe a reason for a given conclusion using evidence from an investigation.

Materials: UV beads from Educational Innovations, rawhide to string beads

Let Me See Those Beads Activity

You have been given a bead bracelet.

1. As you go through the class/day, make at least two observations about the beads.

Observation 1

Observation 2

2. Write down at least two questions you/ your group have about these beads.

Question 1

Question 2

3. Given the materials in your home, design an experiment to answer one of your questions.

Experimental design

1. Ask a question:
2. Develop a hypothesis
3. Describe method used to test hypothesis (be sure to describe your control group for the experiment).
4. Data table (include control group) and should be constructed **BEFORE** the experiment is conducted so it's ready for you to record your findings.
5. This is what I can say about my hypothesis, based on the data I collected.
6. I could improve my experimental procedure if I …
7. Some additional questions that I still have (or have developed) about these beads…

EVALUATE: Students make a one slide Powerpoint poster of their findings that includes observations, questions, hypotheses, data table, conclusion (see appendix A28 for example).

EXTEND: Students navigate to http://earthobservatory.nasa.gov/Features/RemoteSensing/remote.php to answer these questions:

1. What is remote sensing?
2. How does the process of remote sensing work?
3. What is electromagnetic radiation? (review)
4. The amount of radiation an object emits is dependent on what factor?

Students read article at http://earthobservatory.nasa.gov/Features/RemoteSensing/remote_03.php to answer the following questions in their science notebooks:

1. What is a photon?
2. What does the energy of a photon determine?
3. Compare and contrast IR, visible, and UV in terms of relative energy and wavelength(remind students what was learned from the electromagnetic spectrum model project)

EVALUATE: Students use GIST strategy to summarize remote sensing, absorption bands and atmospheric windows. See appendix A9 for details on the GIST strategy.

Days 11-15

Driving Question: How can scientific tools help us understand human impact on the atmosphere?

P4.9B Explain how various materials reflect, absorb, or transmit light in different ways.

Resources: Digital Earthwatch Software
For software downloads:
http://www.lawrencehallofscience.org/gss/rev/ip/
For lesson directions:
http://www.globalsystemsscience.org/studentbooks/dew

ENGAGE: Students watch NASA videoclips located at http://nasa.ibiblio.org/video/NASAConnect/NASAConnect-HiddenTreasures/qt/NASAHT-RemoteSensing.mov. The teacher can stop the video where it talks about GIS-Geographic Information Systems.

EXPLORE: Students complete Global System Science Lessons, Digital EarthWatch (DEW) Software lessons 1-7 to deepen understanding of remote sensing technology and how it is used to study the environment. The lesson investigations are:

1. Three-color light-download DEW Color Basics software
2. Pixels and colors-download DEW Digital Image Basics software
3. Measuring length in digital images-download DEW Analyzing Digital Images software
4. Measuring area in digital images-download DEW Analyzing Digital Images software
5. Spectral Analysis-download DEW Digital Image Basics software
6. Temporal Analysis of Satellite Images-download DEW Vegetation Analysis software

EXPLAIN: see lesson investigation
ELABORATE: see lesson investigation
EXTEND: Students complete DEW lesson on Exploring and Measuring Light
http://www.globalsystemsscience.org/studentbooks/dew/ch5
EVALUATE: Students successfully complete all investigations with 30% credit going to completion of 6.1 False Color Surface Feature from Spectral Analysis lesson and 7.1 Changes in Mt. St. Helens.

UNIT THREE-Greenhouse Gases and Climate Change

Driving Question: How does the composition of the earth's atmosphere affect its properties and behavior?

Why study the atmosphere? The atmosphere gives us the oxygen we breathe and carries off the carbon dioxide we exhale. It filters out most harmful forms of sunlight and traps outgoing heat from earth's surface. The atmosphere transports energy making the whole planet liveable. GLOBE measurements within the Atmosphere investigation aids scientific understanding of weather, climate, and atmosphere composition. GLOBE-Global Learning and Observation to Benefit the Environment, is a worldwide hands on primary and secondary school-based science and education program. Using GLOBE protocols, students make observations and collect data on an atmosphere study site established at the school. Students examine the data for patterns and generate questions to be investigated. Measurements to be taken throughout the unit include:

1. **Aerosol optical thickness**-small particles called aerosols in the atmosphere affect whether the sky looks blue or milky, clear or hazy. They also influence the amount of sunlight reaching the surface. Satellites infer this property of the atmosphere using remote sensing while ground-based observations provide direct measurements to determine aerosol concentration.

2. **Water vapor**-water vapor is the primary greenhouse gas that helps control temperatures in the lower atmosphere and on earth's surface.

3. **Clouds** are formed from water vapor and obscure the ground when the earth is viewed from space. Satellites cannot observe the ground when it is cloudy and that can affect many scientific investigations such as surface temperature.

4. **Surface temperature**-is the radiating temperature of the ground surface and is key in studying the energy cycle-the transfer of heat within the environment.

5. **Surface ozone**-ozone is a highly reactive gas present in the air around us. Knowing the amount of ozone in the air is important for understanding the chemistry of the atmosphere and its effect on the health of plants and animals, including us.

Atmospheric composition measurements are supported by measurements of clouds, barometric pressure, wind direction, and current temperature, all done according to GLOBE protocols. Online climate models are utilized to develop understanding of the complex interactions of the earth's climate system. Predicting and mitigating climate change requires an understanding of the mechanisms of earth's climate, study of past climates, measurements of current interactions of Earth's systems and the construction and use of climate change models.

Resources: http://www.globe.gov/web/atmosphere-climate/overview

Safety: Follow district internet usage policy, see GLOBE protocols and field guides.

E4.p2A I can describe the composition and layers of the atmosphere.

E2.2C Describe natural processes in which heat transfer in the earth occurs by conduction, convection, and radiation.
E4.p2B I can describe the difference between weather and climate.
E5.4A-I can explain the natural mechanism of the greenhouse effect including comparisons of the major greenhouse gases (water vapor, carbon dioxide, methane, nitrous oxide, and ozone.
C1.1C I can conduct scientific investigations using appropriate tools and techniques.
E5.4C-I can analyze the empirical relationship between the emissions of carbon dioxide, atmospheric carbon dioxide levels, and the average global temperature over the past 150 years.
B3.4C-I can examine the negative impact of human activities.
B3.4d I can describe the greenhouse effect and list possible causes.
B3.4e I can list the possible causes and consequences of global warming.

Climate Literacy Principles

1. The Sun is the Primary Source of Energy for Earth's Climate System.
2. Climate is regulated by complex interactions among components of the Earth's system.
3. Life on earth depends on, is shaped by, and affects climate.
4. Human activities are impacting the climate system.

ENGAGE: Day 16

Give ICCARS pretest (see appendix A16-A19).

Focus Questions: What is the difference between weather and climate? How are weather and climate related?

ENGAGE: Students answer focus question in science notebooks by reading article located at http://www.nasa.gov/mission_pages/noaa-n/climate/climate_weather.html. Students watch Piecing Together the Temperature Puzzle located at http://climate.nasa.gov/imagesVideo/climateReel/index.cfm

EXPLORE: Students perform GLOBE activity 1 from weather to climate, examining short term air temperature data. http://www.globe.gov/web/scrc/overview/climate-foundations/weather-and-climate

EXPLAIN: see activity for student questions.

ELABORATE: Students perform GLOBE activity 2 from weather to climate, examining long term air temperature data in order to understand the difference between weather and climate. http://www.globe.gov/web/scrc/overview/climate-foundations/weather-and-climate

EVALUATE: Students make venn diagram comparing and contrasting weather and climate and summarize results with formula writing.

EXTEND: Students perform GLOBE cloud protocol where they learn the meteorological concepts of cloud heights, types, and cloud cover and learn the ten basic cloud types. Students establish atmosphere study site according to GLOBE protocols.

Day 17

Objectives:

1. Describe the effect of greenhouse gases on photons and the temperature.
2. Describe the effect of clouds on photons and the temperature.
3. Compare the effect of greenhouse gases to the effect of glass panes.
4. Describe the interaction of photons with atmospheric gases.
5. Explain why greenhouse gases affect the temperature.

ENGAGE: Teacher will have students respond to the following misconceptions regarding the greenhouse effect:

a. The greenhouse effect is bad.
b. The greenhouse effect is because of pollution.
c. Because other greenhouse gases exist, CO_2 is unimportant.
d. The greenhouse effect works like a physical greenhouse.
e. Any change will be tiny and gradual.

EXPLORE: Students navigate to : http://phet.colorado.edu/en/simulation/greenhouse. Click on "Run Now" to run the simulation.

Name _____ *Period* _____

Greenhouse Effect

1. What do the yellow dots moving down represent?_____
2. What do the red dots represent?_____ Watch them carefully. Do they all move upwards? _____ Why or why not?

Today

Record the composition of the atmosphere (on the right side of the screen):

H_2O (water vapor)	
CO_2 (carbon dioxide)	
CH_4 (methane)	
N_2O (nitrous oxide)	

(ppm means "parts per million")

Record the temperature on the thermometer:

K (kelvin)	
°F (degrees Fahrenheit)	
°C (degrees Celsius)	

1750

Click on "1750" on the right side of the screen to set the atmosphere to the proportions for that date. Wait a few minutes for the temperature to stabilize.

Record the composition of the atmosphere (on the right side of the screen):

H_2O (water vapor)	
CO_2 (carbon dioxide)	
CH_4 (methane)	
N_2O (nitrous oxide)	

Record the temperature on the thermometer:

K (kelvin)	
°F (degrees Fahrenheit)	
°C (degrees Celsius)	

Ice Age

Click on "Ice Age" on the right side of the screen to set the atmosphere to the proportions for Earth's last major ice age. Wait a few minutes for the temperature to stabilize.

Record the composition of the atmosphere (on the right side of the screen):

H_2O (water vapor)	
CO_2 (carbon dioxide)	
CH_4 (methane)	
N_2O (nitrous oxide)	

Record the temperature on the thermometer:

K (kelvin)	
°F (degrees Fahrenheit)	
°C (degrees Celsius)	

Glass Layers

Click on the "Glass Layers" tab at the top of the screen. On the right side of the screen, set the Number of Glass Panes to "1".

1. Watch the yellow photons carefully. Do they pass through the glass or are they blocked? _____
2. Watch the red photons carefully. Do they pass through the glass or are they blocked? _____ (Move the slider at the bottom of the screen to slow down the animation if necessary.)
3. Record the temperature on the thermometer: _____K, _____ °F.
4. Your family's car has been parked outside on a cold but sunny day. When you get in the car, it is much warmer than the air outside. Explain how this can happen.

EXPLAIN: Photon Absorption

Click on the "Photon Absorption" tab at the top of the screen.

5. A methane molecule sits in the middle of the screen. Use the slider on the left side of the screen to shoot some infrared photons at the molecule. Do all the photons pass through the molecule? _____
6. When a photon gets absorbed, what happens next? _____ _____ When a new photon is emitted, is it always sent in the same direction? _____

Use the buttons on the right side of the screen to test different molecules. Record your observations in the table below. Write "yes" if any photons get absorbed; write "no" if no photons get absorbed.

Which gases absorb photons?

	Infrared Photons	*Visible Photons*
CH_4 (methane)		
CO_2 (carbon dioxide)		
H_2O (water vapor)		
N_2 (nitrogen)		
O_2 (oxygen)		

1. Which three gases contribute to the greenhouse effect in our atmosphere?_____
2. Which two gases do NOT contribute to the greenhouse effect? _____

ELABORATE:

1. Write down your observations of what happens during the three featured time periods: Today, 1750 and Ice Age.
2. Change the number of clouds for each time period and write down your observations.
3. Scientists predict CO_2 levels to increase from 490 – 1260 ppm by the end of the century. Run a simulation that will help you predict how this change will affect temperature. What do you find?

EVALUATE: Student use GIST strategy to answer objectives. See appendix A9 for details on the GIST strategy. Revisit misconceptions through classroom discussion.

Day 18

EXTEND: Students complete investigation 6.1, The Findings from Mauna Loa, from Global System Science climate change books. www.globalsystemscience.org/studentbooks/cc/ch6/investigation. This investigation answers the question how is the atmosphere changing?

Day 19

ENGAGE: Students watch visual and record summary using formula writing (see appendix) in science notebook at http://news.bbc.co.uk/2/shared/spl/hi/sci_nat/04/climate_change/html/greenhouse.stm

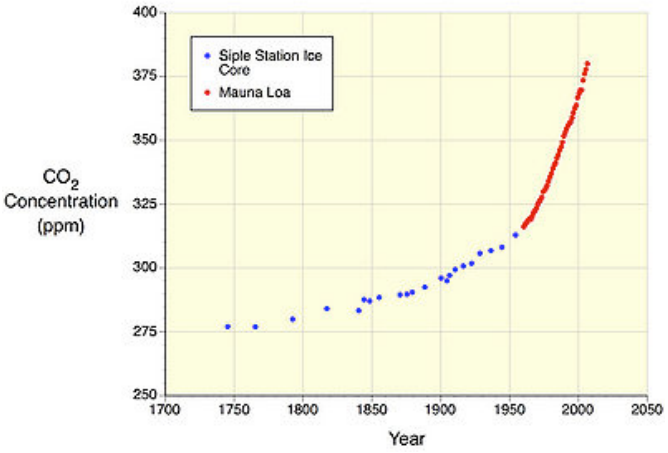
Focus Question: Which atmospheric gas (CH_4, CO_2, H_20, N_2, or 0_2) is the best absorber of infrared photons? *Rank these gases from worst absorber to the best absorber.*

Lab Background Information

Table 1: *Average composition of the Earth's atmosphere up to an altitude of 25 km.*

Gas Name	Chemical Formula	Percent Volume
Nitrogen	N_2	78.08%
Oxygen	O_2	20.95%
*Water	H_2O	0 to 4%
Argon	Ar	0.93%
*Carbon dioxide	CO_2	0.0360%
Neon	Ne	0.0018%
Helium	He	0.0005%
*Methane	CH_4	0.00017%
Hydrogen	H_2	0.00005%
*Nitrous oxide	N_2O	0.00003%
*Ozone	O_3	0.000004%
* variable gases		

Figure 1: Atmospheric Concentration of Carbon Dioxide (1744-2005)



1. **CH_4** is a very strong greenhouse gas. Since 1750, methane concentrations in the atmosphere have increased by more than 150%. The primary sources for the additional methane added to the atmosphere (in order of importance) are: rice cultivation; domestic grazing animals; termites; landfills; coal mining; and, oil and gas extraction.
2. The volume of **CO_2** has increased by over 35% in the last three hundred years. This increase is primarily due to human activities such as combustion of fossil fuels, deforestation, and other forms of land-use change. It is now fact—the increase is causing global warming through an enhancement of the greenhouse effect.
3. **H_20** (water vapor) varies in concentration in the atmosphere both spatially and temporally. Water vapor has several very important functional roles on our planet. For example, the condensation of water vapor creates precipitation that falls to the Earth's surface providing needed fresh water for plants and animals. Additionally, it helps warm the Earth's atmosphere through the greenhouse effect.

4. N_2 is removed from the atmosphere and deposited at the Earth's surface mainly by specialized nitrogen fixing bacteria, and by way of lightning through precipitation. The addition of this nitrogen to the Earth's surface soils and various water bodies' supplies much needed nutrition for plant growth.
5. O_2 is exchanged between the atmosphere and life through the processes of photosynthesis and respiration. Photosynthesis produces oxygen when carbon dioxide and water are chemically converted into glucose with the help of sunlight.
6. **Remember, infrared radiation is heat.**

EXPLORE: Creating an Experiment to Answer a Scientific Question

Which atmospheric gas (CH_4, CO_2, H_20, N_2, or 0_2) is the best absorber of infrared photons?

Check things off as you go!

Rank these gases from worst absorber to the best absorber.

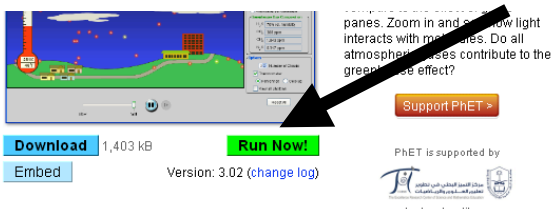
☐ **Step 1:** Go to www.phet.colorado.edu

☐ **Step 2:** Click on *Play with sims*

☐ **Step 3:** Click on *Physics*

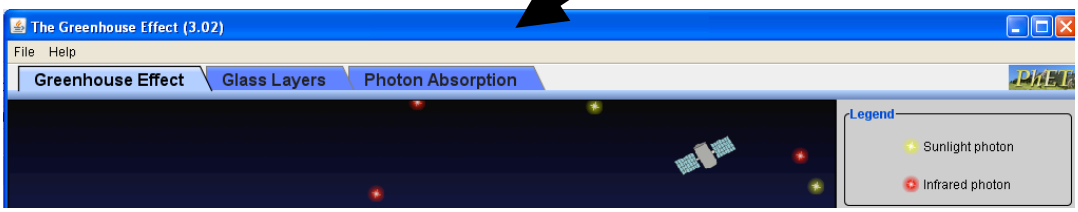
☐ S on it.

☐ **Step 5:** Click on Run Now!

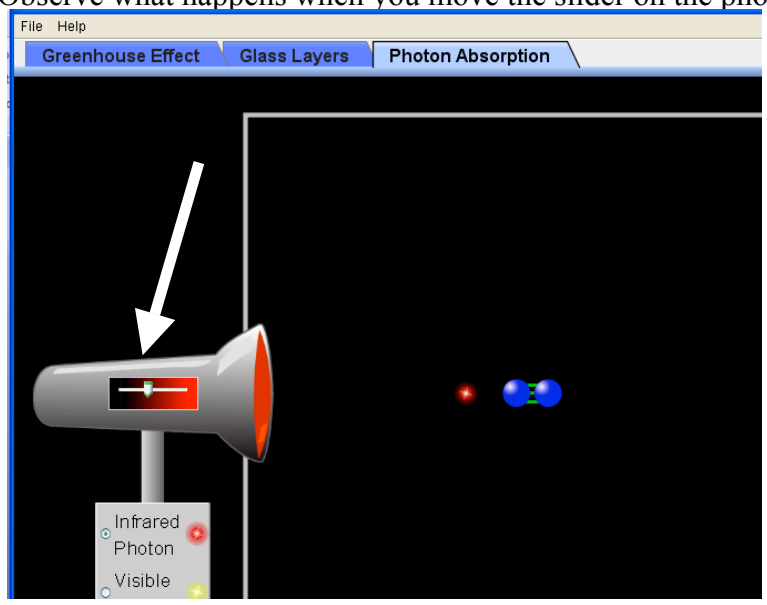


☐ Simulation

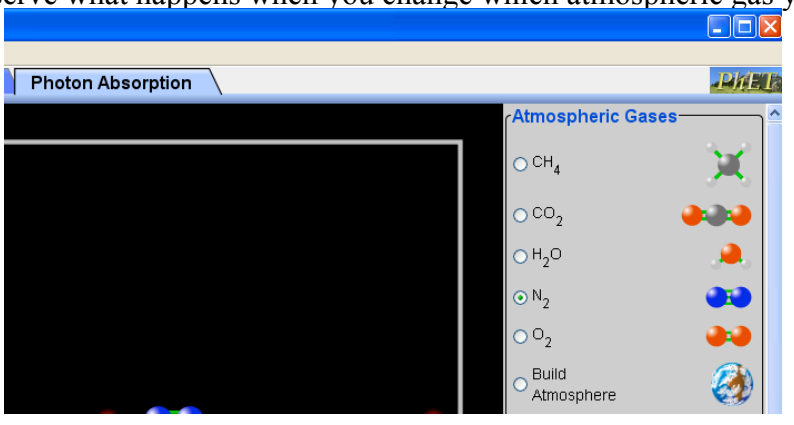
☐ **Step 7:** Click on the Photon Absorption Tab



☐ **Step 8:** Observe what happens when you move the slider on the photon emitter.



☐ **Step 9:** Observe what happens when you change which atmospheric gas you are examining.



☐

Step 10: After examining how this application works for a few minutes, you are now ready to begin your lab!

Task: Using the PHET Greenhouse Effect Simulation (specifically, the photon absorption application), you will be **creating** and **conducting a lab** that answers the scientific question: *Which atmospheric gas (CH_4, CO_2, H_20, N_2, or 0_2) is the best absorber of infrared photons? Rank these gases from worst absorber to the best absorber.*

Below are the steps you must follow to create and conduct a perfect lab. Check things off as you go.

Note: For the purposes of this lab, you can assume that everyone has access to this PHET application. Therefore, you don't need to explain how to get to it in your lab.

<u>Planning Your Experiment (all plans should be recorded in science notebook)</u>

☐ **Step 1:** Write a hypothesis that follows the hypothesis guidelines in the attached rubric. Make sure that it is specific and measurable and includes background information.

☐ **Step 2:** Design an experimental that will directly answer the scientific question and follows all of the guidelines in the rubric. It is suggested that you sketch out your experiment by writing a rough draft **before** you begin writing your procedures.

☐ **Step 3:** Write out your experimental procedures. These should be in a list format and should follow all of the guidelines given in the rubric. Consider including screen shots.

<u>Conducting Your Experiment</u>

☐

Step 1: Create a data table. Make sure that it has a title.

Step 2: Follow your procedures, start collecting your data and record your results in your data.

Writing Your Lab Report

Step 1: Closely examine the attached rubric and all of its parts.

Step 2: Create a title for your lab (you may want to do this last!).

Step 3: Write the background information section of your lab. **Refer to the rubric** and be sure to write at least one full paragraph. Additionally, you must **include diagrams** and label them as figures (you should start with Figure 1.1).

Step 4: Write your hypothesis.

Step 5: Write your experimental procedures.

Step 6: Present your data and results in an organized way. You **must** include a **data table**.

Step 7: In paragraph form, analyze your results. **Refer to the rubric.**

Step 8: In paragraph form, write your conclusions. **Refer to the rubric**. You must include a discussion of transmission, absorption, and reflection of electromagnetic waves. Importantly, be sure to explain the implications of your findings. What does this mean for the future of our planet? Use the given background information to help you!

Step 9: Be sure you've followed the formatting guidelines **outlined in the rubric**.

Step 10: Using the attached rubric, grade your own lab report. Be sure to record a total grade out of 100. Staple your lab report to the self-completed rubric.

EXPLAIN AND EVALUATE: See appendix A33-A35 for **Infrared Absorbers Lab Report - Grading Rubric**

ELABORATE: Day 20 PHET MOLECULES and light simulation

With this simulation, students will further explore how light interacts with molecules in the atmosphere. http://phet.colorado.edu/en/simulation/molecules-and-light. See appendix A22-27 for details.
EXTEND: Students perform GLOBE water vapor protocols. Students use a near infrared sun photometer to measure the amount of sunlight reaching the ground at wavelengths that are correlated to water vapor

Driving Question: How does the composition of the earth's atmosphere affect its properties and behavior?

Thermal energy can be transferred in three ways: conduction, convection, and radiation. Conduction occurs when two substances with different temperatures come in contact with each other. The warmer, faster-moving molecules collide with the cooler, slower-moving molecules and gives up some of their energy. Convection is heat transfer by the motion of molecules in currents and can only occur in liquids and gases. When one part of a liquid or gas is heated, the motion of the molecules in that part increases. As the motion increases, the molecules begin to spread out and become less dense. The molecules in the cooler part of the substance are more closely packed together. Since the heated molecules are less dense, they rise, while the cooler, denser molecules sink. This motion produces currents that carry heat energy. Greenhouse gases are molecules with three or more component atoms, which have unevenly distributed electrons and are efficient at trapping thermal energy (heat). They are able to absorb infrared radiation and then re-radiate it, most often to another greenhouse gas molecule. Eventually the heat flows to the upper atmosphere and outer space, but the gases slow down this heat transfer, acting like a layer of insulation. Many of the chemical reactions that take place between trace gases in the atmosphere are affected by temperature. To understand weather, climate, and atmospheric composition, measurements of surface and air temperature are required.

ENGAGE: Day 21
Students read LAYERS OF THE ATMOSPHERE located at
www.srh.noaa.gov/srh/jetstream/atmos/layers.htm to complete data table:

Layers of the atmosphere	**Distance above the earth's surface (km)**	**Describe the relative temperature and gas interactions.**
Troposphere		
Stratosphere		
Mesosphere		
Thermosphere		

Exosphere		

EXPLORE: Students complete GLOBE precipitation protocols and digital multi-day max/min data sheet.
ELABORATE: Students perform weather station calibration data sheet. For ease of data collection, use integrated 7 day data sheet

EVALUAT E: Students use GIST writing strategy, appendix A9, to summarize the following topics:

1. List the layers of the atmosphere.
2. Describe the temperature differences between each layer of the atmosphere.
3. Explain how these temperature differences affect the gases and interaction with ultraviolet radiation.

EXTEND: Students complete carbon tracking sheet located at http://www.need.org/needpdf/ExploringClimateChange.pdf. Through this activity, students deepen their understanding of how carbon cycles through the earth's systems-atmosphere, biosphere, hydrosphere, and lithosphere.

Days 24-25
Objectives:

1. interpret satellite images to understand the global distribution of ozone;
2. identify the Antarctic ozone hole in satellite images;
3. analyze images to quantify the area of the ozone hole over time; and
4. produce a graph showing the area of the ozone hole over time.

Materials: ImageJ, Microsoft Excel,

ENGAGE: Students watch Exploring Ozone located at http://climate.nasa.gov/imagesVideo/climateReel/index.cfm

EXPLORE: Students open and explore ozone images and highlight and measure ozone hole http://serc.carleton.edu/eet/ozonehole/index.html

EXPLAIN: Students read case study: Why Should We Care if There is a Hole in the Ozone Layer? and answer these questions in science notebook;

1. What is the ozone hole?
2. How do low ozone concentrations pose risks for humans?

Students navigate to http://earthobservatory.nasa.gov/Features/Ozone/ozone_4.php-montoring ozone from space, to answer the following questions:

1. Why is ozone crucial for life on earth?
2. What is good ozone and bad ozone?
3. How is ozone created?

Students watch animations on the relative heights of atmospheric layers and ozone formation and destruction. http://earthobservatory.nasa.gov/Features/Ozone/ozone_2.php
Students answer the following questions in their science notebooks:

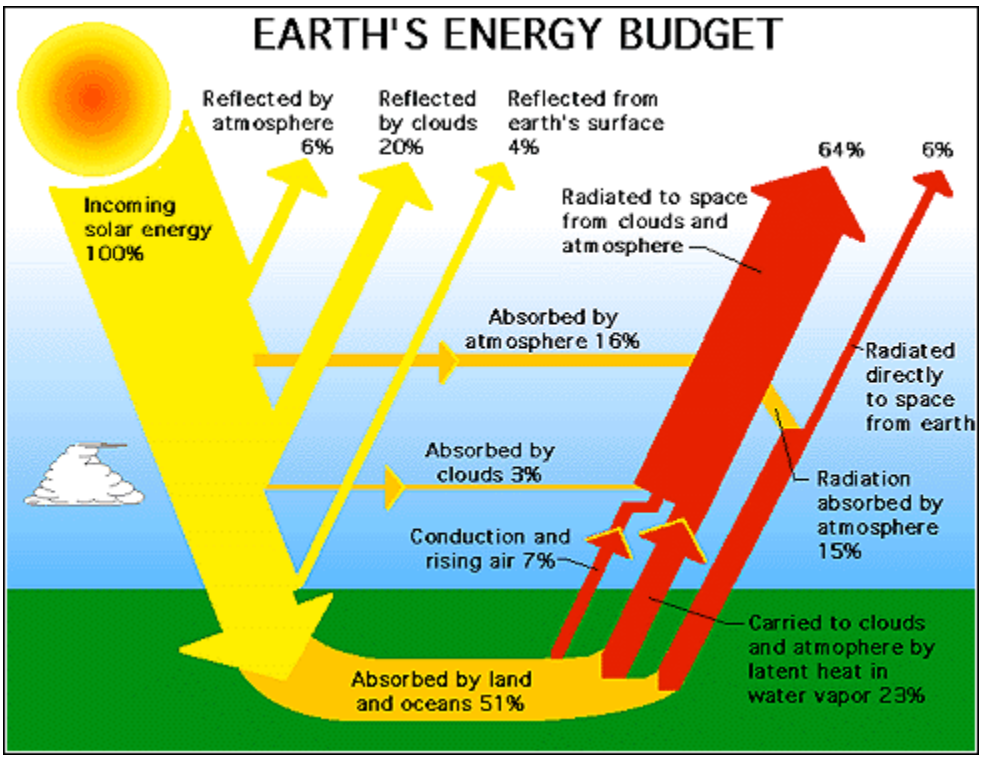
1. Ozone: What is it, and why do we care about it?
2. At what height is the ozone layer located?
3. Write the chemical equations for ozone formation and destruction.
4. What are CFCs? How do these molecules destroy ozone?
5. Describe ozone depletion.
6. How is ozone monitored from space?

ELABORATE: Students complete GLOBE ozone data sheet Ozone protocol. Students expose a chemically sensitive strip to the air for an hour and determine the amount of ozone present using an ozone strip reader
EVALUATE: Graph ozone hole data in Excel and answer these analysis questions:

1. Did the size of the ozone hole increase, decrease, or stay the same over the nine years you analyzed? What might account for the changes?
2. How might you go about discovering why one of the years' holes was much smaller than the others? Outline a plan for finding out how that year might have been different from other years.
3. Does an ozone hole ever form over the Arctic Region? Outline a plan for using TOMS images to look for a hole in the Northern Hemisphere.

Day 26

Driving Question: How does solar radiation influence conditions on earth?



Days 27-28

ENGAGE: .Students read A Closer Look at Greenhouse Gases, page 38 from NEED Exploring Climate Change Curriculum. Students answer the following questions in their science notebooks:

1. When energy is sent from the sun, the _____ wavelengths such as _____ and _____, pass through the atmosphere and strike the surface of the earth.
2. Much of this radiation is transformed to _____ energy and the _____ energy and radiated back into space.
3. In terms of chemical bonds, explain why the greenhouse gases can absorb infrared energy while oxygen gas and nitrogen gas cannot.

EXPLORE: Students work in pairs to complete Effect of the Sun's Energy on the Ocean and Atmosphere http://icp.giss.nasa.gov/education/radforce/

EXPLAIN: Students analyze graph produced.

ELABORATE: Students diagram radiation balance.

Teacher notes: As the energy of the Sun reaches the atmosphere of the Earth, it interacts with the gases. The selectivity of the gases in this interaction is dependent on the wavelength of the energy and determines whether it is absorbed, reflected, or simply scattered. Greenhouse gases, such as carbon dioxide, water vapor, nitrogen oxides, methane, and ozone, absorb energy. Some of these gases such as water vapor, ozone, and small particles called aerosols

can also reflect energy. Scattering, caused by aerosols and other gas molecules, changes the energy's direction, in turn altering the overall energy budget. **Earth's temperature is about the amount of energy in vs. the amount of energy out. When energy in is > energy out: earth's temperature increases. When energy in is < energy out: temperature decreases. Question:** How do humans affect energy in and energy out? Sulfur emissions from burning coal and aerosols that act like mirrors, cool the planet while greenhouse gases warm the planet.

EVALUATE: Students complete draw conclusion questions:

1. Does the region you have studied absorb more energy than it emits? Defend your answer with the results of your calculations.
2. Describe how the solar energy flux absorbed at the particular location you are studying varies over the course of the year?
3. How does the solar energy flux absorbed by the tropics vary over the course of a year? How does this compare to the change at the polar latitudes?
4. At the equator, how does the total absorbed energy flux for the year compare to the total emitted? At the polar regions, how does the total energy flux absorbed for the year compare to the total emitted?
5. What must be happening in terms of energy flow between the tropics and the poles to maintain total radiative balance of the planet?
6. What dynamic processes can maintain the temperature of the tropics despite a net energy input?

ELABORATE: Collect GLOBE atmosphere data. Once students have completed all GLOBE protocols, have students look for patterns in the data by asking the following questions:

a. What do you notice about….?
b. Do you see any patterns?
c. How do you think this works?
d. What can we do with this information?
e. What is similar or different about _____ and _____?
f. What questions do you have or what do you want to know about _____?

EXTEND: Students perform GLOBE surface temperature protocol. Students use an infrared thermometer (IRT) to measure the temperature of the earth's surface.

Day 29

ENGAGE: Students watch Hello Crud (4min, 41 sec) located at http://climate.nasa.gov/imagesVideo/climateReel/index.cfm. Students record sources of aerosols in their science notebooks.

EXPLORE: Students complete GLOBE atmosphere investigation Aerosols Data sheet.

EXPLAIN: Students read case study, How do Carbon Monoxide and Aerosol Concentrations Affect Earth's Atmosphere? Students then answer the following questions in science notebooks:

1. What are aerosols? What are they composed of?
2. What are the major sources of aerosols?
3. Are aerosols evenly distributed throughout the atmosphere? If not, why not?
4. Why is it important for scientists and policy makers to understand the role of particulates in the atmosphere?
5. What NASA instrument (sensor) gathers information on aerosols? What does the sensor measure in the atmosphere to determine the amount of aerosols?

ELABORATE: Students perform GLOBE aerosols protocol. Students use a red/green sun photometer to measure the amount of sunlight reaching the ground when clouds do not cover the sun.

EXTEND: Students watch NASA videoclip located at http://nasa.ibiblio.org/video/NASAConnect/NASAConnect-TheMeasurementOfAllThings-AtmosphericDetectives/qt/NASAMOAT-AerosolMeasurementAndRemoteSensing.mov and answer the following questions in their science notebooks:

1. How do aerosols affect our health?
2. What is remote sensing?
3. Name two types of remote sensing and give examples of each.
4. How are aerosols in the atmosphere measured?

Students complete parts II-V from Earth Education Toolkit Activity: Using Satellite Images to Understand Earth's Atmosphere located at http://serc.carleton.edu/eet/atmosphere/index.html

EVALUATE: Students accurately analyze the relationship between aerosol optical thickness (AOT) and carbon monoxide (CO) concentrations.

Homework: Students read March 7, 1975 New York Times article, What's being done about those killer aerosol cans? Nothing and write a summary using formula writing. See appendix A8 for directions on formula writing.

Day 30

ENGAGE: True or False Humans are responsible for climate change. Students respond to this statement and give reasons for choice in science notebooks.

EXPLORE: What are human caused sources of carbon dioxide? Students perform investigation 6.2 www.globalsystemscience.org/studentbooks/cc/ch6/investigation

EXPLAIN: Students use the link below to answer questions in science notebook.
https://koshland-science-museum.org/explore-the-science/earth-lab/causes#.T_Ha_Bee5m0

1. How do CO_2 emissions differ from country to country?
2. Which countries produced the most CO_2 in 2000?

3. Which countries are expected to see a significant increase in their CO_2 emissions by 2025?
4. Describe the impact of the following human activities on climate change:
    a. Residential
    b. Commercial
    c. Industrial
    d. Transportation
5. What are indicators of climate change?

https://koshland-science-museum.org/explore-the-science/earth-lab/changes#toput

6. What is proxy data? What can it tell us about past climates?

https://koshland-science-museum.org/explore-the-science/earth-lab/trends#.T_Hd4Ree5m0

7. How are coral reefs affected by climate change?

http://www.youtube.com/watch?v=Jn5-ARXmQlQ

ELABORATE- Day 17

ENGAGE: Students watch climate change in a nutshell videos clips 1-11 http://www.planetnutshell.com/climate/ to define climate, record evidence and effects of rapid climate change and solutions. Total viewing time is about 25 minutes.

EXPLORE:

In science notebooks, students summarize the vital signs of the planet located at

http://climate.nasa.gov/keyIndicators/index.cfm

EXPLAIN:

EVALUATE: Students complete following quizzes located at http://climate.nasa.gov/quizzes/index.cfm

- Warm Up
- Freeze Frame
- Sea Change
- It's a Gas

EVALUATE: On exit tickets, student list three human activities that impact the climate system and three ways to reduce human impact on the climate system.

Give ICCARS posttest. See appendix A16-A19.

EXTEND:

C1.2f I can critique solutions to problems, given criteria and scientific constraints.
C1.2G I can identify scientific tradeoffs in design decisions and choose among alternative solutions.

To mitigate climate change means to make its impact less severe. Since carbon dioxide stays in the atmosphere for a long time, reducing emissions alone is not adequate. Policy makers must consider ways to adapt to any future impacts on the environment.

Culminating Activity: Students perform Wedge Challenge from NEED curriculum located at http://www.need.org/needpdf/ExploringClimateChange.pdf, pages 61-86. Students become decision makers and work in teams to determine the technologies and practices that will be most effective at reducing carbon emissions and stabilizing the climate.