The Stem Literacy Project

THE CHEMISTRY OF CLIMATE CHANGE

Exploring Climate Change with PhET Simulations

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Exploring the Chemistry of Climate Change with PhET Simulations The Greenhouse Effect	

Activity Overview	The goal of this lesson is to investigation how atmospheric changes affect the global temperature. This activity has three key components:
	• This activity provides a model for connecting atmospheric changes in terms of the concentration of greenhouse gases to the temperature of the Earth.
	  ○ Explore atmospheric changes and the impact these changes have upon the temperature of the earth.
	  ○ Compare the make-up of ancient atmospheres with the current atmosphere of the earth
	• Explore the impact of layers of gases
	  ○ Manipulate the atmosphere by increasing the gaseous layers and note the changes in the behavior of infrared photons and sunlight photons.
	• Explore the capacity of different compounds within the atmosphere to absorb infrared energy.
	•

Learning Objectives	Upon the completion of these virtual simulations, students will be able to: • Explain basic atomic structure and utilize the periodic table to link the atomic structure of specific elements to the number of protons, neutrons, and electrons. • Distinguish between an atom and a molecule. • Explain that electromagnetic radiation may interact with molecules found in large quantities within our atmosphere. • Relate the amount of energy to molecular motion. • Explain the connection the greenhouse effect in terms of global warming and the concentration of greenhouse gases within the atmosphere. • Design and conduct an investigation to identify the atmospheric gases which are the greatest infrared absorbing ability. • Compare and contrast early atmospheres on Earth with the current atmosphere. Identify and explain the variations in global temperature with reference to ancient and earlier atmospheric content.

Linking to the Standards	**HS-ESS3-5**. Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.
	MS-PS1-1. Develop models to describe the atomic composition of simple molecules and extended structures.
	HS-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.
	CLE Strand 1: Properties and principles of matter and energy
	• 1. Changes in properties and states of matter provide evidence of the atomic theory of matter.
	  ○ C: Physical changes in states of matter changes in materials can be explained by the Kinetic Theory of Matter
	  ▪ Predict the effect of a temperature change on the properties of a material (solids, liquids, and gases)

Linking to the Standards	• 2. Energy has a source, can be stored, and can be transferred but is conserved within a system
	  ○ F: Energy can be transferred within a system as the total amount of energy remains constant
	  ▪ a. Classify the different ways to store energy and describe the transfer of energy as it changes from kinetic to potential while the total amount of energy remains constant.
	CLE Strand 5: Processes and interactions of Earth's systems
	• 1. Earth's systems have common components and unique structures.
	  ○ C: The atmosphere is composed of a mixture of gases including water vapor, and minute particles. a. Relate the composition of gases and temperature of the layers of the atmosphere to cloud formation and transmission of radiation.

Engage
 	
Use this probe to initiate a discussion. Ask students to collaborate on the probe and record their ideas on the white board. Students can then refer back to the whiteboards and reflect upon their initial thinking.
	Engage the students with the probe provided:
	• Distribute the probe and ask the students to read the material for approximately 2 minutes.
	• Dividing students into groups of two, ask the students to share their ideas on the first portion of the probe and to include the reasoning for their answers.
	  ○ Ask that responses be written in complete sentences to enhance clarity.
	• Move to the second portion of the probe and ask the students to group the molecules shown on the page. This is a group project and students should indicate their answers on the whiteboard provided. The molecules are labeled [A-G] and therefore, will not require students to redraw the figures.
	  ○ Ask that the whiteboard responses be saved for future reference as students proceed through the lesson.
	• The molecules shown on the probe will be the focus of one of the initial PhET simulations and it is a good idea to refer back to the whiteboards during the lesson and ask students if they are interested in changing the organization of the figures.
	  ○ Changes will result when students observe the molecules during exposure to electromagnetic energy.

The Lesson EXPLORATION Part 1 **Refreshing Student Knowledge of Atomic Structure and the Periodic Table.**	For this lesson your students should have access to a computer lab to be able to run the various simulations. • Part 1 of Explore of the lesson is focused on a review of atomic and molecular structure. The goal is to review atomic structure and knowledge of the periodic table. Moving from atoms to molecules, students are challenged to construct atoms from the protons, neutrons, and electrons provided. • Begin with the Build an Atom PhET Simulation. The links for this activity are shown on the following page.

Explore Part 1 Atomic and Molecular Structures
 	
Students will be engaged with constructing an atom and identifying the subatomic particles, their charges, the link to the periodic table, and the stability of the nucleus through this simulation.
	https://phet.colorado.edu/sims/html/build-an-atom/latest/build-an-atom_en.html
	• Before beginning this simulation ask students to collaborate in small groups and draw an atom without consulting a resource. The drawing should show all structures and charges. Ask the students to create a block of the periodic table showing all of the key data about the atom drawn.
	  ○ Is the atom neutral?
	  ○ What information would be shown about the atom on the periodic table?
	• As students work through this simulation, they will see a correlation between the atomic structure and the element as shown in the periodic table.
	• Questions to pose during the exploration:
	  ○ What particles do you have to work with in this simulation?
	  ○ Are you limited as to where you can place the particles in the simulation? Explain your observations.
	  ○ What particle or particles affect the identification of the element when constructing an atom?
	  ○ Which particle(s) have the greatest impact on the atomic mass of the element? Why do you think this is true?
	  ○ How can you achieve a net charge of 0 for the atom you construct?
	  ○ Collaborate with your group and determine the 'take home message' for this simulation.

The Build a Molecule PhET Simulation allows for the exploration of molecular structure and bonding.
 	
Building upon Student Knowledge of Atomic Structure to Formulate Molecules and Gain Insight into Molecular Structure.
	https://phet.colorado.edu/en/simulation/legacy/build-a-molecule
	• Students will use the atoms provided to construct molecules. Once the molecules are constructed, students can click on the 3D icon to observe the structure of the molecule, the chemical formula is provided along with the name of the compound. The molecule can be observed as a Ball and Stick model by clicking on the blue icon above the molecule.
	  ○ This simulation takes students through chemical formulas, molecular structure, and subscripts.
	  ○ A discussion of chemical bonding would be appropriate here. There is another application which might be of interest at this point. The PhET simulation for exploring bonds is: **https://phet.colorado.edu/en/simulation/legacy/molecule-shapes**
	  ▪ This simulation allows students to explore molecular shapes and how the shape of a molecule is changed when additional bonds are formed.
	  ▪ Students will be able to observe the shape of molecules as well as a model of the shapes. Bond angles are also available.

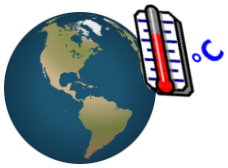
Explore Part 2 Molecules and the Electromagnetic Spectrum
 	
Building upon Student Knowledge of Atomic and Molecular Structure to Explore the Absorption of Energy in Sunlight.
 	
Enhance Students' Understanding of the Electromagnetic Spectrum
 	
Emphasize the energy levels within the electromagnetic spectrum.
 	
Link wavelength with the color of light within the visual spectrum. Can we see infrared radiation? How is infrared different from the visual spectrum?
	For this portion of the lesson, students will explore the interaction of molecules and various forms of energy within the electromagnetic spectrum.
	
	https://phet.colorado.edu/en/simulation/legacy/molecules-and-light
	• The Molecules and Light PhET simulation builds upon students' understanding of the structure of molecules and explores the basic molecular absorption for each class of electromagnetic radiation: microwave, infrared, visible light, and ultraviolet light.
	  ○ This activity links back to the probe in which students were asked to sort the molecules into groups. The sorting should take on greater importance as they observe the reaction of these molecules to infrared radiation.
	• Ask students to click on the Electromagnetic Spectrum within the Molecules and Light PhET Simulation.
	• Student pages are provided which will engage students in running the Molecules and Light simulation and recording their observations. Encourage students to search for patterns in the response to microwave, infrared, visible, and ultraviolet energy levels with the electromagnetic spectrum. Ask the students to note the characteristics of molecules which absorb the light energy most effectively.
	  ○ Students will note that when exposed to infrared energy, energy absorption will be indicated by the vibration or flexing of the molecule. Also note that the molecule will also emit infrared energy which has the potential to energize another molecule. The result is that the energy remains trapped and cycling with the atmosphere.
	• Remind students to consider the molecular structure of the molecule and to determine an explanation for the absorbance of energy by certain molecules. It is important to remember that many of these molecules are actually gases found in the atmosphere and contribute to global warming and ultimately climate change.
	• As students manipulate the simulation, ask them to identify a pattern in terms of the molecules which respond to the various wavelengths of light.
	• The response of several of the substances to infrared energy is interesting and
	  ○ What rule could be used to predict the response of a molecule to the various levels of electromagnetic energy?
	• Ask student teams to revise the initial sorting of the molecules based upon their observations and share basic explanations for molecular behavior with the class.
	  ○ This activity will prepare students to think about greenhouse gases and how the chemistry of certain gases results in a gradual warming of the earth's atmosphere.
	• Be certain to emphasize the importance of the type of number and type of bonds formed within the molecules studied.
	• Following this activity, ask the students to reflect upon the initial sorting of the molecules completed with the probe during the engage portion of the lesson and ask them if they wish to make changes.
	  ○ Ask students to share their whiteboards with the class and explain the changes made to the initial sorting of the molecules.

Explain
 	
Up to this point, students are constructing or refreshing their knowledge of atomic structure, chemical bonding, and molecular structure.
 	
The question at hand is how can these aspects of chemistry help us to understand the relationship between gases within our atmosphere and climate change?
	The Explain portion of the lesson engages students with building connections between the structure of the molecular structure of the molecule, the response of the molecule to infrared energy and ultimately linking to the greenhouse effect.
	
	The American Chemical Society provides this explanation of the greenhouse effect:
	
	Think about the manner in which a greenhouse works to understand greenhouse gases. The transparent windows of a greenhouse (or a car parked in the sunlight) transmit the warming visible rays of the sun, prevent the resulting warm air from leaving, and hence maintain a warmer environment inside than outside the structure. In the Earth's atmosphere, some trace gases absorb infrared radiation from the solar-warmed surface of the planet and transfer energy to the many other surrounding molecules. The result is Earth's temperatures higher than they would be in the absence of these gases. The atmospheric gases and a greenhouse work in quite different ways, but the resulting effect, higher temperature in both cases, has led to the nomenclature "greenhouse gases" for the atmospheric gases responsible for the atmospheric warming effect. (http://www.acs.org/content/acs/en/climatescience/greenhousegases.html)
	
	It is important to remember that when infrared radiation is absorbed by molecules an increased vibration may result. Collisions between the molecules within the atmosphere can transfer the energy and ultimately increases the thermal energy held by some of the atmospheric gases. Atmospheric gases which are IR absorbers include CO_2, CH_4, N_2O, and O_3. The water molecule is also an important greenhouse gas and like the previously identified greenhouse gases, water molecules are also able to absorb IR energy and contribute to the warming of the atmosphere.
	
	https://phet.colorado.edu/en/simulation/legacy/greenhouse
	• At the beginning of the simulation, the earth's temperature is reset to cold and light photons begin to come from the sun. Students can control the speed of the photon with the slider scale, the pause button, and the step button [allows individual frames to be observed].
	  ○ Students can also control the make-up of the atmosphere by adding or removing greenhouse gas concentration. It is also possible for students to investigate the make-up of earth's earlier atmospheric conditions.
	  ○ The students also have control of the number of clouds. Remember that clouds are largely made up of water and will impact the temperature of the atmosphere.
	• As students regulate the composition of the atmosphere, they are able to observe changes in the temperature of the atmosphere.
	  ○ In effect, this simulation builds upon students' prior knowledge of molecular structure and the impact of greenhouse gases upon the Earth's climate.
	  ○ This simulation focuses upon the nature of greenhouse gases within the atmosphere and variations in atmospheric make-up and global temperature.

	• In the second pane, students are able to explore the impact of glass layers upon temperature, this is a way for students to understand the name 'greenhouse' effect. A greenhouse maintains a warmer temperature because the glass holds in heat.
	• In the third pane, students are able to observe characteristic infrared [IR] absorption of atmospheric gases.
	  ○ Remember that not all molecules are IR absorbers. Instruct students to watch the response to IR of the gases
	
	http://www.hhmi.org/biointeractive/greenhouse-effect
	• This is the Howard Hughes Medical Institute BioInteractive site. You will find a series of videos focused on the greenhouse effect at this site. Download the first video [Large (MOV) 18 MB.
	  ○ This video provides a very nice summary for the greenhouse effect which underscores the chemistry content of this lesson. The video is brief, only 2 minutes and 14 seconds.

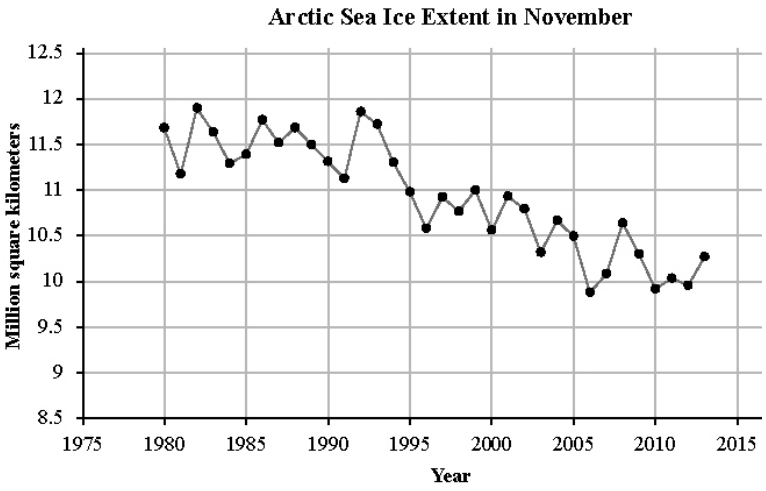
Extrapolate	During the Extrapolate phase, students will compare the make-up of the atmosphere during the three periods in the earth's history [Ice Age, 1750, and Today]. The goal of this activity is to incorporate mathematics into the lesson. The Greenhouse Effect simulation will be used during this portion of the lesson.
	
	http://phet.colorado.edu/en/simulation/greenhouse
	Students will be asked to use the Greenhouse Effect simulation to quantify the differences between the make-up of the atmosphere during the three points in earth's history (Ice Age, 1750, and Today).
	• Ask students to focus on CO_2 concentration and to quantify the difference over time.
	• Ask students to correlate changes in CO_2 concentration with temperature changes within the atmosphere and to identify the periods which experience the greatest increase in temperature.
	Integrating mathematics
	• Challenge students to calculate the rate of increase in CO_2 between 1750 and the atmosphere today in parts per million per year [ppm/year].
	  ○ Using their calculations, students should determine when the Ice Age is likely to have occurred. [The last Ice Age took place during the last 1,000 years of the Pleistocene from approximately 110,000 and 12,000 years ago.]
	  ○ Ask students to think about why this might have happened, be certain to emphasis both a quantitative and qualitative explanation.

Evaluation	Evaluation throughout this lesson takes several forms including:
	• The initial probe which is designed to reveal students' perception of the greenhouse effect in terms of likely causes of the warming of the earth's atmosphere.
	  ○ Ask students to sort the molecular structures using a whiteboard. Even though the Part 1 of the probe is collected upon completion, Part 2 of the probe or the molecular structure sorting using whiteboards should remain with student teams for future reference and discussion during the Molecules and Light PhET Simulation. Remember to ask students if they wish to make changes to the manner in which the molecules have been sorted during the Molecules and Light simulation.
	  ○ The Discussion of Part 1 of the probe is an effective venue for students to reveal knowledge of atmospheric gases and the warming of the atmosphere. The probe could be used to stimulate a discussion following the completion of the simulations.
	• There are multiple written assignments which are aligned to the various PhET Simulations, these assignments could also provide insight into student understanding of the chemistry of climate change.
	• The Green House Effect Assessment can be used to engage students individually or as teams with the
	Specific examples for evaluation within the context of this unit include:
	• The probe introduced during the Engage portion of the lesson [Formative Assessment].
	• The Argumentation Challenge to be used at the close of the lesson [Summative Assessment]



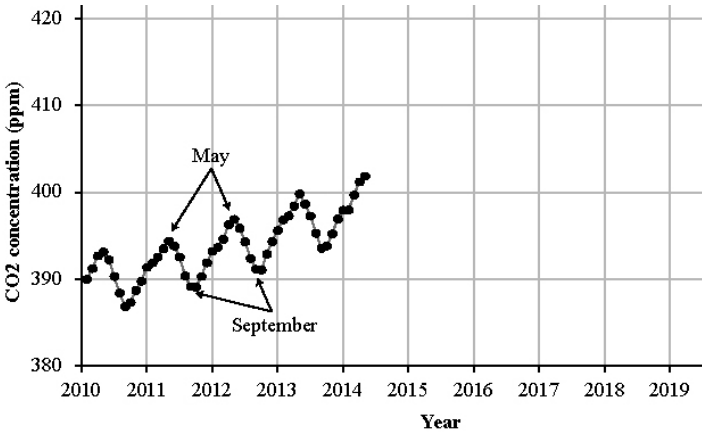
Probe: The Chemistry of Climate Change

Ms. Worth was guiding her class in a discussion about global warming. She asked the students what they thought the cause of global warming might be. Two graphs were presented to the class. The students were asked to explain how they thought the two graphs are related in terms of climate change. The graphs are shown below:



The Arctic Sea Ice Extent in November shows the data about the extent of Arctic Sea Ice in terms of millions of square kilometers from 1980 to 2013. The data was gathered by satellites taking pictures of the earth and capturing the sea ice each November to determine any changes in the area covered by the sea ice. These data are from the National Snow and Ice Data Center.

M



The data shown in this figure shows the concentration of CO_2 in the earth's atmosphere beginning in 2010 and continuing through 2014. These data were collected at the Mauna Loa Observatory in Hawaii. The observatory is located on the summit of Mauna Loa which is 13,680 feet above sea level.

Four students responded with the following explanations. Circle the response(s) you think are correct and explain your choice(s) on the back of this sheet:

Maria: Acid rain forming in our atmosphere because of high concentrations of CO_2 from power plants causing the sea ice to melt.

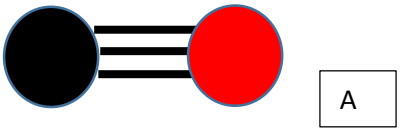
Blake: It is the increase in CO_2 in our atmosphere from burning all of that gasoline that is the major culprit! The CO_2 prevents heat from leaving the atmosphere.

Norman: I think the graphs do not show the real problem. It is all of the methane produced by cattle and pigs. These animals put methane into the air which holds the heat in the atmosphere.

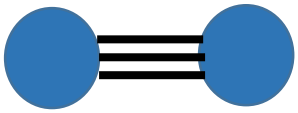
Anita: It is not the CO_2 that is the problem, plants use CO_2 in photosynthesis, it is the thinning of the ozone layer that is causing the earth to warm. More sunlight is able to reach the surface of the earth.

Sort the molecules:

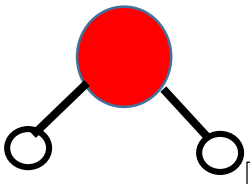
You will find ball and stick models for multiple molecules. Study the molecules carefully and then decide how to organize them into groups. You can make as many groupings as you like, be sure to explain your reasoning for the groups you create. Use the legend below for additional information.



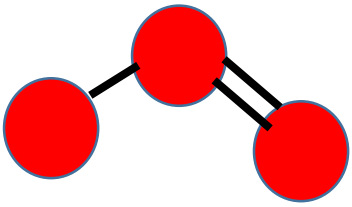
A



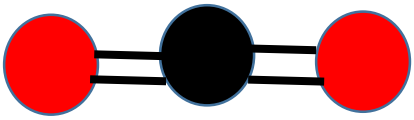
B



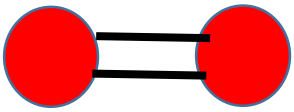
C



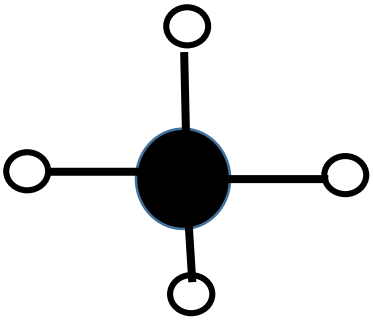
D



E

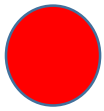


F



G

Nitrogen



Oxygen

Carbon

Hydrogen

Build an Atom Simulation

The authors of this activity are Timothy Herzog & Emily Moore
(https://phet.colorado.edu/en/contributions/view/3954)

Complete the Build an Atom simulation and respond to the questions below:

1. After working with the Build an Atom Simulation, what rule do you think can be used to determine the **atomic mass** of the element?

2. Create a definition for each of the terms shown below using complete sentences.

Element Symbol	
Charge	
Atomic Number	
Mass Number	
Ion	
Neutral Atom	

3. Briefly explain how the elements are arranged on the periodic table.

Atom 1	Atom 2	Relationship between atom 1 and atom 2
$^{12}_{6}C$	$^{13}_{6}C$	☐ Isotopes ☐ Same Atom, Not Isotopes of Each Other ☐ Different Element
Carbon-12	$^{12}_{6}C$	☐ Isotopes ☐ Same Atom, Not Isotopes of Each Other ☐ Different Element
Argon-40	Argon-41	☐ Isotopes ☐ Same Atom, Not Isotopes of Each Other ☐ Different Element
An atom with 13 protons and 13 neutrons	An atom with 14 protons and 13 neutrons	☐ Isotopes ☐ Same Atom, Not Isotopes of Each Other ☐ Different Element

Build a Molecule: PhET Simulation

The author of this activity is Jackie Esler

https://phet.colorado.edu/en/contributions/view/3440

1. *CLICK ON THE* **MAKE MODELS TAB**
2. Using the atoms combine those together to form the molecules listed. You may have to click on the *kits* to make new molecules. When a molecule is completed *click* on the *3d* button to look at the structure. *Click* on ball and stick and draw the ball and stick model.
3. When your collection is complete a new set of molecules will appear. Continue until you fill in the chart below. (you will need to go through 8 or 9 collections)

Collect the following compounds write the name of each compound and draw a ball and stick model. Indicate the polarity of each molecule.

Chemical Formula Name Polar/Non Polar Ball and Stick model

CH_4 _____

CH_3Cl _____

H_2O_2 _____

SiH_4 _____

PH_3 _____

N_2 _____

CH_3F _____

NH_3 _____

CO_2 _____

H_2O_2 _____

MOLECULES and LIGHT Simulation

The author of this activity is Kelly Lancaster

https://phet.colorado.edu/en/simulation/legacy/molecules-and-light

Today you are going to use a sim to explore how light interacts with molecules in our atmosphere.

I. Explore the sim with a partner.

What are some of your observations?

II. Explore what happens for each type of light.

What patterns did you find?

What ideas do you have about how the sim relates to your everyday life?

III. Identify the location of each type of light along the electromagnetic spectrum and indicate the relative amount of energy transmitted by each.

Identify the wavelength of each of the four light forms and indicate the location along the spectrum:

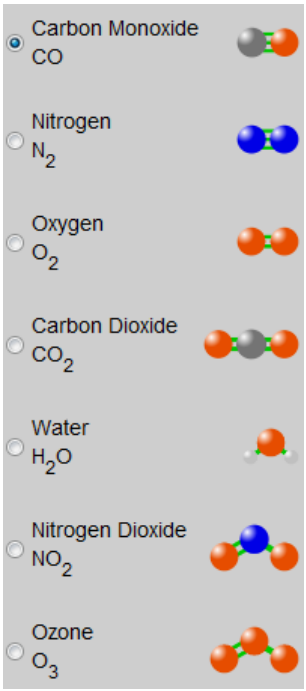
Microwave:

Infrared:

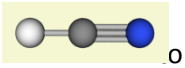
Visible:

Ultraviolet

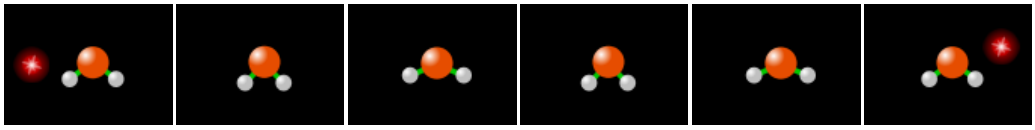
IV. Explore what happens for each molecule.



What patterns did you find?

Based on your observations, how would you predict HCN  o interact with microwaves?

V. Look closer at how infrared light affects water in the sim or in the images below.

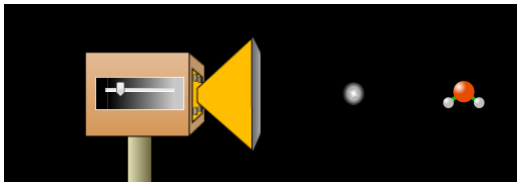


What do you think is happening?

VI. Pick one of the topics below to study in more depth. Prepare to share your ideas with the class by making sense of what you discover.

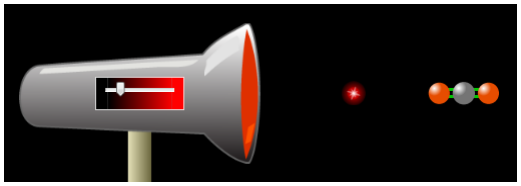
1. **Microwaves**

How do microwave ovens work?



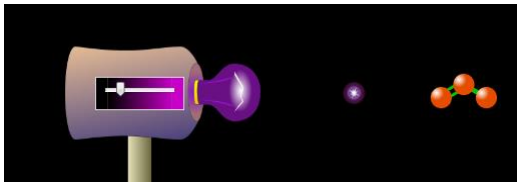
2. **Greenhouse effect**

What is a greenhouse gas?



3. **Ozone layer**

Why is the ozone layer important?



The Chemistry of Climate Change Simulation
Investigating the Greenhouse Effect

Your Team Challenge:

- **Step One: Atmospheric composition**

The challenge for your team is to begin by exploring the past atmospheric conditions found on earth. There are three times identified by the simulation which include: current atmospheric composition today, the atmospheric composition during 1750, and the atmospheric composition during the ice age. In the table below, record the composition of the atmosphere for all three times. The quantities of CO_2, CH_4, and N_2O are all measured in Parts per Million. Water vapor is measured in a percentage of relative humidity.

PhET Simulation: The Greenhouse Effect – Pane 1: Greenhouse Effect			
Greenhouse Gas Composition	**Ice Age Atmosphere Composition**	**1750 Atmosphere Composition**	**Today: Composition of the Atmosphere**
H_2O			
CO_2			
CH_4			
N_2O			
Atmospheric Temperature			
Clouds	1 cloud	2 clouds	3 clouds
Atmospheric Temperature			

- Refer to the data recorded above and explain your observations. How did the temperature of the atmosphere vary among the three different time frames?

- **Step Two: Photon Absorption**
  - Explore the natural ability of certain molecules to absorb and emit Infrared Radiation [IR]. Run the simulation by testing the atmospheric gases identified in the panel on the right side of the simulation and complete the table below:

Atmospheric Gases Data Table – Step 3 of the Greenhouse Effect PhET Simulation		
Gas	**Greenhouse Gas**	**Non-Greenhouse Gas**
Methane CH_4		
Carbon Dioxide CO_2		
Water H_2O		
Nitrogen N_2		
Oxygen O_2		

Explain how you classified the atmospheric gases as greenhouse or non-greenhouse gases.

- What rule did you use to classify the gases?

- Relate your classification to the data gathered when you used the 'Build the Atmosphere' function on the lower right side of your screen.

Name _____ Date _____

Exploring the Greenhouse Effect [modified from Climate Change Ed. Stanford University-School of Earth, Energy, and Environmental Sciences: https://pangea.stanford.edu/programs/outreach/climatechange/curriculum/3-greenhouse-gases-and-energy-balance].

During this activity you will work within your team to investigate the role of CO_2 in terms of the temperature of the earth's atmosphere.

Learning Goals:

- Explain the role in carbon dioxide [CO_2] in the atmospheric temperature of the earth.
- Explain the chemistry of a greenhouse gas.
- Design an investigation to determine the effect of increased levels of CO_2 on the temperature of gases trapped in a clear 2L soda bottle.

Materials:

2-2l clear plastic soda bottles
2 identical light sources [simulating energy from the sun]
Thermometers
2 methods of making CO_s

- Alka-seltzer tablets placed in water yield CO_2 production
- Vinegar and baking soda mixed together yield CO_2 production

Protocol:

- Discuss with your group the different ways you thought to set up the investigation
- Design the set up to be used during the investigation.
- Identify the method you will use to create and capture CO_2
- Collaborate with your team to design an experiment that will test the effect of carbon dioxide on the temperature of the atmosphere (air)? Use the following table as a guide when creating the experimental design your team will use.

Guiding Question:

Hypothesis:

Experimental Design:

Independent Variable (IV): The *independent variable* is the variable that is purposely changed or manipulated through the investigation. A single investigation should have only one IV. It is important to note how the independent variable will be changed.	
Independent Variable	
Describe how you will control the IV during the investigation	
Control Group (basis for comparison)	

Dependent Variable (DV): The *dependent variable* changes in response to the independent variable. It is the responding variable which is measured during the investigation.	
Dependent Variable	
How you plan to measure the DV	

Constants: Factors that are kept the same and not allowed to change. It is important to control all but <u>one variable</u> at a time to be able to interpret data accurately.	
Constants to be controlled during the investigation	

Diagram of experimental set up (as a group)

to

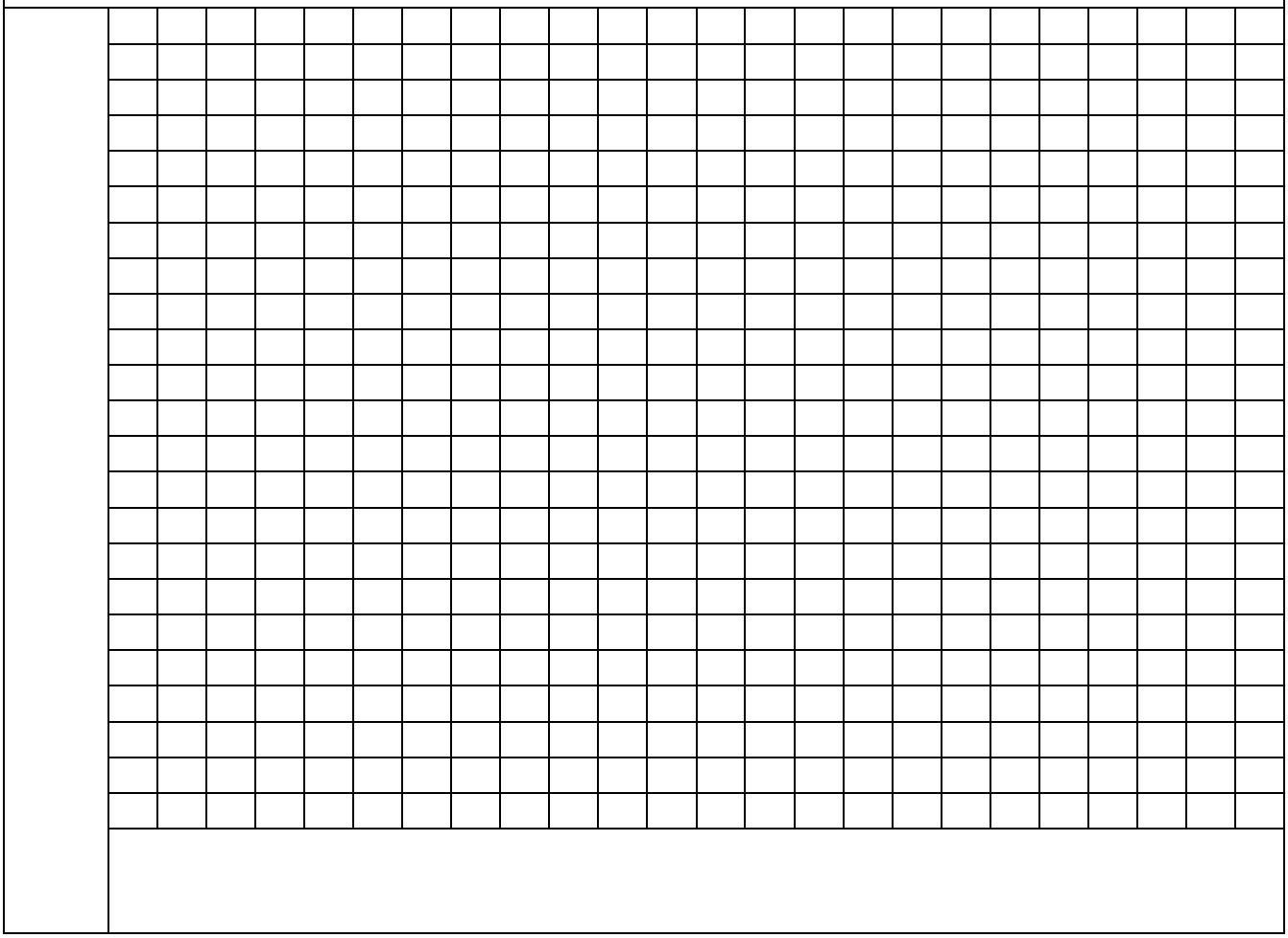
Data Collection:

Once your experiment is set up, begin recording the temperatures in the bottles. Use the blank table below.

Time	Set up 1 =	Set Up 2 =	Set Up 1: Trial 2 =	Set Up 2: Trial 2 =
0 minutes				
2				
4				
6				
8				
10				
12				
14				
16				
18				
20				

Using graph paper or an Excel spreadsheet to graph the temperature of the air within the 2L bottles against the time placed within the light source.

Graph Titile:



Analysis

What conclusions can you draw from this activity?

Does carbon dioxide concentration have an effect on the temperature of the gases within the 2L bottles? Incorporate the molecular structure of CO_2 in your explanation.

The Chemistry of Climate Change
Assessment

The basics of Scientific Argumentation:

Argumentation is a critical aspect within science. New knowledge [claims] reported by researchers undergoes a peer review process during which members of the scientific community validate or refute the claim (Norris, Philips, & Osborne, 2007). It is important to note that claims made by research scientists are not opinions but rather an explanation designed to provide an answer to a specific research question (Sampson and Schleigh, 2013).

Your Challenge:

You and your teammates are conducting research on atmospheric chemistry and the identification of specific atmospheric gases which contribute to the warming of the atmosphere and ultimately to climate change. Carefully review the Guiding Question with your team mates. Next, review the responses generated through each of the PhET Simulations and identify a claim or explanation to address the Guiding Question. Collaborate with your team to identify evidence gathered through the PhET simulations which supports your claim. Finally, explain your reasoning or justification for the evidence your team selected. In other words, explain the connection between the evidence identified and the claim proposed by your team. Consider the steps provided below and use the Argumentation Components Table to craft your argument. It is important to note that there will be a peer review of all arguments conducted in class which will provide important feedback for each team to refine and enhance the effectiveness of the argument.

- Transfer the table below to your white board and complete the table.
  - First, identify the guiding question for your argument.
  - Second, review the evidence gathered during the PhET Simulations to identify a claim.
  - Third, identify the evidence which supports your claim.
  - Fourth, provide your team's reasoning for selecting the evidence cited to support your claim.
  - Five, there will be a peer review session. During this session, one member of your team will remain with your whiteboard to answer questions while the other members will circulate throughout the room and use post-it notes to provide feedback on the argumentation of the other teams.
  - Six, following the peer review, teams will review all of the feedback from classmates and revise their argument.
  - Seven, each team member will write his or her own explanation for the argument developed by the team. Even though the argumentation process was a team effort, each individual should write an essay explaining the team's claim, evidence, and justification.

Guiding Question:

Your Claim:

Your Evidence:

Your Justification for the Evidence:

Sampson, V. & Schleigh, S. (2013). *Scientific Argumentation in Biology: 30 Classroom Activities.* NSTA Press, Arlington, Virginia,

Glossary of Terms

Vocabulary Term	Definitions
Atmosphere	The gaseous envelope surrounding the earth. Approximately 78% of the dry atmosphere is made up of nitrogen gas, 20.9% is made up of oxygen, 0.93% is made up of the inert gas, argon, and 0.039% is made up of carbon dioxide and small quantities of other gases. Water vapor is also found within the atmosphere, however, the quantity of water vapor is highly variable.
Atoms	Atoms form the foundation of chemistry and form everything within the universe. This includes all forms of matter. Solids are composed of densely packed atoms, liquids are composed of atoms which are attracted but not held in tight solid structures, and gases in which atomic/molecular particles are much farther apart.
Biofuels	This term refers to any fuel source derived mainly from plant materials and may also be referenced as biomass. Ethanol is an example of a biofuel.
Bonding	The very basic idea of bonding is that atoms tend to have full outer electron shell. Atoms of the element sodium have a single electron in the outermost shell. Sodium is likely to give up that electron and form an ion. The electron will be gained by another atom. The ionic compound 'sodium chloride' forms when sodium loses an electron to chlorine. As a result, the sodium ion has fewer electrons than protons and has a positive charge, while chlorine has more electrons than protons and has a negative charge.
Carbon Dioxide	A naturally occurring gas which is produced as a waste product of cellular respiration by nearly all living organisms. Carbon dioxide is required by plants for the manufacture of simple sugar [glucose] during photosynthesis. Also a product of burning fossil fuels, the level of carbon dioxide has continually increased within the atmosphere.
Climate	Climate refers to long term weather patterns. The classical period in terms of climate is three decades as defined by the World Meteorological Organization [WMO].
Covalent bonding	When bonds are formed through sharing electrons, the bond is said to be covalent. The electron actually orbits around the nuclei of both atoms to form a new substance or a molecule.
Electrons	Negatively charged sub-atomic particles which are in constant motion, spinning as well as revolving around the nucleus in energy orbitals or shells which are located within specific distances from the nucleus of the atom. The shells are referenced by the letters K, L, M, N, O, P, and Q. The K shell is closest to the nucleus of the atom.

Electromagnetic spectrum	A range of all forms of electromagnetic radiation, energy that travels from the sun and other stars. The spectrum ranges from high energy gamma rays to very low energy radio waves. The visible spectrum is included within the electromagnetic spectrum and ranges from higher energy blue light to lower energy red light.
Fossil Fuels	Sources of energy including coal, oil, or natural gas that is formed within the earth from plant and animal material.
Glacier	A multi-year accumulation of snowfall which does not melt and results in a mass of ice at least o.1km^2 in area. Glaciers are typically in motion in response to gravity.
Global Warming	The gradual increase in the temperature of the earth's atmospheric envelope which has the potential to alter climate creating a warmer earth with higher sea levels.
Greenhouse Effect	The trapping and building up of heat within the earth's atmosphere. Greenhouse gases within the atmosphere behave much like the panes of glass within a greenhouse which trap heat and create a warmer climate within the greenhouse.
Greenhouse gases	Any gas that has the potential to absorb and emit infrared radiation within the atmosphere.
Infrared Radiation [IR]	Our eyes are not able to detect infrared radiation which has a longer wavelength than the colors of light included within the visual spectrum.
Isotope	An atom of an element with the same number of protons and electrons but a different number of neutrons is known as an isotope. For example carbon typically occurs as carbon-12, however, there are other forms of carbon in which the atoms have different numbers of neutrons. Carbon-14 is an isotope of carbon which has an additional two neutrons within the nucleus. If you study the periodic table, you might notice that the atomic mass of the element [the number of protons and neutrons within the nucleus] is rarely an even number. This characteristic is explained by the isotopes of the elements.
Methane	A hydrocarbon consisting of one carbon atom bonded to four hydrogen atoms. Methane is considered to be a greenhouse gas with the potential to cause global warming.
Molecule	A single particle of a compound made up of one or more atoms of different elements joined together chemically. Oxygen and carbon are both elements, but when combined chemically a new substance known as carbon dioxide is formed which has properties unique from the atoms of both initial elements.

Neutrons	Neutrons are sub-atomic particles found within the nucleus. Neutrons have a mass which is approximately the same as that of protons. Neutrons along with protons play a major role in the mass and also in the radioactive properties of matter.
Nitrous Oxide	A compound formed from one atom of nitrogen and two atoms of oxygen. Nitrous oxide is considered to be a greenhouse gas with the potential to cause global warming.
Nucleus	The center of an atom which is made up of protons and neutrons. The nucleus has a positive charge since protons have a positive charge and neutrons are neutral with no charge.
Ozone	The triatomic form of oxygen which is a constituent of the atmosphere. Stratospheric ozone plays a critical role in protecting the earth from solar ultraviolet light.
Photosynthesis	The process by which plants take in CO_2 from the atmosphere, H_2O from the soil and use light energy from the sun to from simple sugars or glucose.
Polar Covalent Bonds	Covalent bonds in which the electrons are not equally shared by the atoms. Water is an excellent example of a polar covalent bond. Oxygen is a much larger atom than hydrogen, as a result, the electron tends to be retained by the oxygen atom, creating a region of negative charge around oxygen and a region of positive charge around the hydrogen atoms.
Protons	Positively charged particles found in the nucleus of the atom. Unlike neutrons, protons have a positive charge. In a neutral atom, the number of protons and electrons are equal.

Common Misconceptions about Climate Change

1. Many individuals confuse weather with climate. Therefore, changes in weather patterns occurring over a single season are interpreted as changes in climate.
    a. Climate is the average of weather patterns of a minimum of 30 years.

2. Changes in the ozone layer are related to global warming.
    a. Ozone is a triatomic form of oxygen found in the troposphere which protects the earth from Ultraviolet radiation.

3. A persistent change in the weather lasting over a long period of time is an indication of changes in the weather.
    a. Persistent changes in the weather are an indication of climate change.

4. Changes in the atmosphere, such as increasing levels of CO_2 are natural and not influenced by human activity on earth.
    a. The increase of greenhouse gases [CO_2 and CH_4] are the result of human activity including burning fossil fuels and raising large numbers of animals as food source.

5. Global warming is caused by the depletion of ozone.
    a. The depletion of ozone is a serious problem in terms of the protection from UV radiation. The depletion of ozone is not related to global warming.

Bostrom, A., Morgan, M.G., Fischhoff, B., & Read, D. (1994). What do people know about global climate change. *Risk Analysis,* 12 (6), 960-970.

Sterman, J. D., & Sweeney, L. B. (2007). Understanding public complacency about climate change: Adults' mental models of climate change violate conservation of matter. *Climate Change,* 80, 213-238.