It’s a Gassy World!

Exploring the relationship between CO_2, rising ocean temperature and climate change

Maryland Loaner Lab Teacher Packet

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It's a Gassy World! Activity Overview

It's a Gassy World! is designed to introduce middle school students to the relationship between the warming of the water in the ocean (as a result of global climate change) and whether this warming changes the oceans ability to store carbon dioxide (CO_2). In this activity students work to answer the driving question "Will warm oceans be better or worse at absorbing CO_2?" As they work to answer this question, students will gain experience with using the Scientific Practices (as defined in the Next Generation Science Standards) by designing an investigation to explore how temperature affects water's ability to absorb CO_2. Students will be challenged to collect data, analyze and interpret the results of their investigation, and connect their findings to global patterns of climate change.

Learning Goals:

This lesson aims to have students explore 1) the complex interactions between atmospheric CO_2 levels which are driving climate change and causing global temperatures, including the temperature of the land and ocean water, to become warmer and 2) the ability of warmer oceans to absorb CO_2 thereby impacting the amount of atmospheric CO_2 which, when in the atmosphere, is causing the increased warming.

To achieve this overarching goal, students will:

1. Identify the relationship between the concepts of "Global Warming" and "Climate Change" (Discussion – Engage)
2. Make observations about CO_2 gas dissolved in water (Soda demo -Engage)
3. Construct a scientific explanation about the oceans ability to absorb CO_2 (Video discussion - Engage)
4. Understand the role of CO_2 on Earth as a greenhouse gas and that the rising amounts of CO_2 can change climate (Video discussion - Engage)
5. Use (interpret) scientific models to construct scientific explanations of the rising temperatures of the oceans as a result of the increase in average temperatures on Earth's surface (Carbon Cycle video, Engage)
6. Plan and carry out investigations on how a rise in oceans temperatures changes its ability to absorb CO_2. (Investigation-Explore)
7. Analyze and interpret the data collected during the investigation on the average amount of CO_2 released from warm water versus cold water (what isn't released is absorbed) (Bar Graphs,-Explain)
8. Construct a scientific argument on whether warm water absorbs more CO_2 than cold water by using evidence from the investigation (C-E-R Chart-Explain)
9. Construct a scientific explanation about effects of warming oceans on atmospheric levels of CO_2 (Class Discussion-Elaborate)
10. Ask questions about humans' role in changing levels of CO_2 in the atmosphere (Wonderings – Elaboration)

Grade Level and Time Required to Complete

It's a Gassy World! is designed for grades 6-8.

Time Needed:

Engagement: 30-45 minutes
Exploration: 90 -120 minutes
Explain: 60- 90 minutes
Elaborate: 10 minutes
Evaluate: 10 minutes

Materials and Supplies

Below is a table that lists all the materials and supplies needed for this activity. Please note that some of the items (in red) must be supplies by the teacher. The rest are supplied by MDLL.

Item	Amount	Supplied by:	Comments	Return Instructions
CD	1	MDLL	Contains videos in the lesson plan	Return
Unopened bottle of clear, carbonated beverage	≥ 1	Teacher	Used to demonstrate solubility of CO_2. Ideally you will have enough for each student to be able to see the bubbles forming when it is opened.	N/A
Plastic Erlenmeyer Flasks (50 ml)	2/group (20 total)	MDLL	Balloons are attached to Erlenmeyer flasks to capture CO_2 gas escaping from water.	Rinse, dry and return
Alka-Seltzer tablets	33 packets provided (6 packets/group) plus a few extra)	MDLL	Amount needed will vary depending on students' investigational design. Consider giving a few tablets to start with, and require students come to the teacher for additional tablets.	Return all unused tablets
Clear, plastic disposable cups	1/group	MDLL	Used to demonstrate Alka-Seltzer tablets as source for CO_2 for the investigation. Fill with tap H_2O. Use half a tablet per student group. Reuse if you requested multiple class sets.	Do not return
Bee A Scientist Koozies	1/group (10)	MDLL	Place koozie (thermal protector) on plastic beaker to prevent students from burning hands on hot salt H_2O.	Return
Plastic Beakers (250 ml)	2/group (20)	MDLL	Use to hold water at student workstations. Place a thermal protector (koozie) on the beaker holding hot water.	Return
Instant Ocean Mix (to make saltwater)	Enough Instant Ocean mix to make 8 L	MDLL provides Instant	Use Instant Ocean to make salt water (1/4 cup/2 liters.) Half the water should be at should be ~3°C (refrigeration) or below and half at	Return unused bags of Instant Ocean.

	of salt water (~800 ml per student group).	Ocean Salt mix. Teacher provides tap water	room temperature or above. The bigger the difference in temperature between warm and cold, the more likely they will be do see a difference in amount of CO_2 absorbed.	
¼ cup measuring cup	1	MDLL	Used to measure Instant Ocean Mix	Rinse, dry and return.
Balloons	6/student group (Total 60)	MDLL	Amount needed will vary depending on students' investigational design. You may want to give them a small number of balloons to start with, and then require they come to teacher for additional balloons.	Return any unused balloons.
Whiteboards, Pens, and Erasers	1/group (total 10 whiteboard, 10 pens, 10 erasers)	MDLL	Clean whiteboards with dry cloth or paper towel.	Return
Thermometers	1/group (10 total)	MDLL	Students can use to record temperatures of salt water treatments used in their experiment	Return
String	1/group (10 pieces)	MDLL	Piece big enough to measure circumference of balloon (≥ 12 inches). Reuse if you requested multiple class sets.	Return any unused strings
Ruler	1/group (total 10)	MDLL	Used to measure width of balloon.	Return
Tape	1 roll shared by class.	MDLL	Students use to label Erlenmeyer flasks (e.g. hot, cold)	Return unused tape.
2-Liter container	4	MDLL	Used to mix salt water.	Rinse, dry and return.
Hot pot	1	MDLL	Used to heat salt water for the hot water needed in lab. Use to heat water before class. Do not let students pour water directly from hotpot, as it gets extremely hot!	Rinse, dry and return.
Cool It! Bingo Cards	1 set (35 cards)	MDLL	Used in Climate Change Bingo	Return
Experimental Design Picture Steps	8 sets (12 cards per set)	MDLL	Scaffold option for planning investigation	Return
Gloves and Goggles	1/student	Teacher	Teacher provides.	N/A

Student Worksheet	1/student	Teacher	Teacher provides from master copies in Teacher Binder.	N/A

Teacher background information for the *It's a Gassy World!* Activity

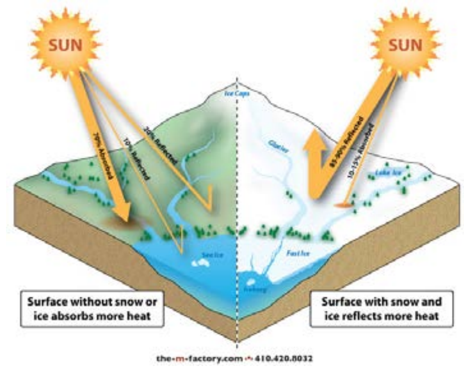
- **CO_2: What it is, where we normally find it**
  - Carbon dioxide, or CO_2, is found as a gas at room temperature. Along with energy from the sun, it is used in photosynthesis by plants to produce sugar. Carbon dioxide is released by plants and animals when sugars or carbohydrates are burned or metabolized. It is also released when materials like fossil fuels (e.g. coal, oil, natural gas which came from plants and animals), or wood are burned. It is one form in which carbon, an element found in all living organisms and some non-living materials, is found as it cycles on earth (explained below).
  - Carbon dioxide is responsible for the bubbles in 'carbonated' soft drinks. Some of the carbon dioxide gas in the drink is released from the liquid when the cap is removed. Baking powder, baking soda, and yeast all release carbon dioxide when part of dough, making baked goods rise. The chemical reactions of the soda or yeast in the dough produces CO_2 which remains in the dough and becomes the air spaces in the cake or bread. Dry ice is the solid form of carbon dioxide, which is produced by cooling carbon dioxide to -110°F.
  - Carbon dioxide gas reacts chemically with water allowing carbon dioxide to be able to dissolve in water. When mixed with water, carbon dioxide reacts chemically with water, producing carbonic acid. After the reaction, carbon dioxide is in a different form so the concentration of carbon dioxide in the water (if measured as CO_2) hasn't gone up and more carbon dioxide can dissolve. Although the reaction is reversible, this process allows water to absorb a lot of carbon dioxide. How much carbon dioxide can be absorbed by water depends upon several things: salinity, temperature and pressure (deep oceans are at a higher pressure than the surface water).
  - While carbon dioxide can dissolve in water and be absorbed by it, it doesn't necessarily remain in the water. How much is retained depends on the same things that determine how much is absorbed: temperature, salinity and pressure. As these change in the ocean, the chemical reaction can reverse and the gas can be released from the ocean back into the atmosphere.
  - Carbon dioxide is naturally present in the atmosphere as part of the earth's carbon cycle; it currently makes up about 0.04% of the air. Carbon dioxide is constantly being exchanged/cycled among the atmosphere, ocean, and land surface as it is both produced and absorbed by many microorganisms, water bodies, plants, and animals. Under natural conditions carbon cycles continually through the earth's natural systems. Emissions and removal of CO_2 by these *natural* processes tend to balance out. The carbon cycle is explained in the first part of this video "1-The Carbon Cycle" http://www.epa.gov/climatestudents/basics/today/carbon-dioxide.html.

- **Greenhouse Gases [GHG]**
  - Our atmosphere contains greenhouse gases and the carbon dioxide that is in our atmosphere is one of the greenhouse gases. It is one of the most abundant ones. These GHG create what we call the 'greenhouse effect'.

- Light from the sun warms the earth. The warm earth radiates heat energy back into the atmosphere, some of which is trapped by these GHG. Without GHG all the warmth would go back into space (the way a hot skillet cools off totally when the burner is turned off). Instead the GHG trap some of the heat giving our earth at an average temperature of 59°F. Without greenhouse gases the earth's temperature would be 0°F. Therefore, the presence of greenhouse gases is critical for life on earth as we know it. More information is available in th video, "2-The Greenhouse Effect" (http://www.epa.gov/climatestudents/basics/today/greenhouse-effect.html).
- However, while a certain level of GHG is critical for biological life as we know it, when the level of GHG increases beyond this 'critical for life as we know it' amount, their impact can become detrimental. Currently the atmospheric concentration of CO_2 is rising as a result of burning of fossil fuels and deforestation [deforestation is covered in the second part of this video http://www.epa.gov/climatestudents/basics/today/carbon-dioxide.html.
- All of this CO_2 has to go somewhere and while much of the CO_2 humans are adding goes into the atmosphere where it can impact the earth's temperature directly because it is a GHG, about 30% dissolves in the earth's waterbodies and this is what our lab activity is about.

- **Why is too much CO_2 a bad thing?**
  - Atmospheric CO_2 is 'only' at 0.04% now, so why is that a problem? While the 'absolute' amount of CO_2 in the atmosphere seems small relative to other gases in the atmosphere, nitrogen (78%) and oxygen (21%), this amount is 40% more than there was about 100 years ago! This is the same increase as if you went from 100 pounds to 140 pounds! That is a BIG increase. Another way to think about the 'magnitude' of 0.04% is that each time you take a breath you inhale 4,000,000,000,000,000,000 molecules of carbon dioxide!
  - By the mid-1800 scientists realized that minor gases in the earth's atmosphere were keeping it warmer than it might be otherwise. This phenomenon was later called the greenhouse effect and the critical role of carbon dioxide as a greenhouse gas revealed at about the same time.
  - Climate, the long term patterns of temperature, precipitation, winds, etc., depends on temperature and as temperature changes so will the climate around the globe. The extra 'heat' energy from this additional warming due to increased levels of GHG leads to more energy for storms and winds and leads to unusual weather patterns. It also leads to the melting of land ice (glaciers).

- As fresh water from glaciers and ice sheets melts it moves into the oceans, increasing the ocean water mass and water level, but the sea level is also rising because as water warms it expands. Thermal Expansion of Water video: from asapScience: http://www.youtube.com/watch?v=fuvY5YG5zA4.
- This change in the extent of ice is also decreasing the earth's albedo, or the proportion of the surface that reflect sunlight because of its highly reflective, white surfaces. As the amount of white reflective ice surfaces decrease because of ice melting, the amount of darker surfaces increases (exposed water) and dark surfaces absorb sunlight and heat. This adds to the overall warming.



- Over the past 12,000 years, the climate system has been relatively stable, which allowed the development of agriculture and cities, and paved the way for the modern era. As CO_2 increases, we expect the climate to become more variable (e.g. more extreme weather events such as heat waves, droughts, and intense storms, etc., will occur) that will negatively impact some parts of the world particularly along the coasts and in less developed nations.

- **Effects of Sea Level Rise on Baltimore**
  - Higher sea level from thermal expansion of oceans and increased volume of water as a result of inflow of freshwater from glacier melt leads to increase flooding—both the amount of flooding that occurs when it floods and the frequency of flooding events. This link can be used to show students what will happen to Baltimore if sea level rises 1-10 feet http://sealevel.climatecentral.org/surgingseas/place/cities/MD/Baltimore#show=cities&center=12/39.2848/-76.6205.
  - Islands have disappeared in Chesapeake Bay as a result of increases in sea level. This link http://geology.com/sea-level-rise/washington.shtml can be used to zoom in to Baltimore and shows islands disappearing in the Bay as the sea level rises.
  - Any storm events occurring at the same time as 'regular' high tides will have major local impacts beyond what we have seen so far. See http://www.chesapeakequarterly.net/sealevel/main4/ for more information.

- **Climate Change vs. Global Warming**
  - Global warming refers to an increase in average surface temperature from increased greenhouse gas levels, while climate change includes global warming and everything that this warming will affect (change in humidity, intensity of storms, local temperatures, changes in wind patterns, amount of rain, sea level rise, etc.). http://www.nasa.gov/topics/earth/features/climate_by_any_other_name.html)

It's a Gassy World! Preparation Guide

- There is a PowerPoint facilitation guide with video links available on the web (https://www.towson.edu/fcsm/centers/stem/loanerlab/index.html). You should review the PPT and videos to make sure they play on your technology system.
- Prepare the salt water using the Instant Ocean Mix provided by the Maryland Loaner Lab. Follow the instructions on the bags of Instant Ocean. The prepared salt water can be stored for several weeks.
- Refrigerate half of the salt water (~3.75 L) so it is cold on the day of class. Make a plan for how to keep the water cold during class (using ice buckets, or keeping it in the refrigerator until students need it, etc.). The experiment works best if the other half of the salt water is warm. Putting the solution in a sunny window, near a heating vent, or in a hotpot will warm it up.
- We have provided (2) 250 ml beakers so each group can have their warm and cold water at their work station. You can put the thermal protectors (koozies) on half for the warm water.
- Set-up student work stations.
    - You may choose to set up each of the 10 workstations with all the materials needed by each group ahead of time:
        - ~ 180 ml warm temperature salt water (in beaker w/thermal protector)
        - ~ 180 ml of cold/refrigerator temperature salt water (in beaker)
        - 2 Erlenmeyer flasks (50 ml)
        - Up to 6 balloons
        - Up to 3 packets of Alka-Seltzer tablets (6 tablets total)
        - 1 piece of string
        - 1 ruler
        - Several pieces of tape to labels trials
        - 1 worksheet/student
    - You may prefer to have students check out the materials they need as they progress through their investigation. This can help manage how the students use the supplies and keep the students focused on gathering data for their investigation.

It's a Gassy World! Facilitation Guide

The following suggests one way to facilitate this activity. If your students already have a strong background in the concepts, you may choose to skip some of the suggested pre-laboratory discussion topics. If much of this information is new to the students, you may choose to spend more time on these pre-laboratory discussion topics, and to supplement with other classroom resources.

Engage

1. Ask students to independently write in the "What do you know now?" column of their KLEW chart everything they think of when they hear the phrases, "Global Warming", "Climate Change" and "Carbon Dioxide (CO_2)".

- Have students share their ideas with the group, with the teacher capturing each idea on a central white board, and students only offering ideas that are not already stated. You might hear ideas such as greenhouse effect, temperature change, fossil fuel, CO_2, etc.
- At this point there might be several misconceptions that show up (e.g., the hole in ozone layer contributing to global warming, climate change is not real, etc.). It is not necessary to address all the misconceptions at this point, but make a note and work to address them throughout the activity. It is important to note that while the ozone hole did present an important environmental challenge it has *nothing* to do with climate change.
- Eventually, the students will learn the following ideas, as they work through the activity:
    - Currently, the atmospheric level of CO_2 is increasing, with the biggest source of the increase the burning of fossil fuels by humans
    - CO_2 in the atmosphere is causing the earth to warm through a process known as the greenhouse effect.
    - One gas can do many unrelated things--CO_2 in the atmosphere causes the earth to be warm and when dissolved in soda under pressure, causes the soda to have bubbles.

Carbonated Water Demonstration & Observation

2. Tell students we're going to learn more about a gas called CO_2 in the following demonstration. You may want to take a moment to emphasize that we will be using the words "carbon dioxide" and the formula "CO_2" interchangeably throughout this activity. If students are still struggling that carbon dioxide is an invisible gas that is all around them, you can ask them to breathe in and out and discuss that they are exhaling air containing a lot more carbon dioxide compared to the air they inhale.

- Place a large (1-2 liter) bottle of a carbonated clear beverage (with label removed on each to make viewing inside easier and so students cannot read the label) where all students can see.

- Tell students they will be making observations and inferences about the bottle and contents. Ask them to draw a line down the center of their whiteboards and label one side "Observation" and the other side "Predictions". Show them the bottle and ask them to record their observations. To assist, ask :
    - What do you think is in the bottle? [Students will probably say that the bottle contains carbonated water/club soda/seltzer or vinegar or water, etc.]
    - Could it be anything else? [Students generally start to see how their first reaction might be right, but that there were other options that could also be correct – without further evidence to point a direction.]
    - What evidence are you using to predict what is in the bottle? [color of liquid, maybe bubbles escaping, etc.]
    - Shake the bottle and ask questions about the bubbles. [Students usually rule out vinegar and plain water at this point, become more confident in the prediction of carbonated water.]
- Tell the students you are going to unscrew the cap. Have them write/draw their prediction(s) on their white board about what they think they will observe when the cap is unscrewed.
- Very slowly unscrew the bottle cap. Ask students to make observations and write them on their white boards.
- Wait a few seconds to allow students to observe the bubbles. Tighten the cap on the bottle. Expected results:
  - When the cap is loosened, many bubbles will appear throughout the soda and rise up through the water to the surface, where they pop. When the cap is tightened, fewer bubbles will form.
- Ask students:
  - What did you observe when I opened and then closed the bottle of soda? [Bubbles appeared only when the bottle was opened. The bubbles stopped forming when the bottle cap was tightened.]
    - What is the gas that makes these bubbles? [Carbon dioxide (CO_2)]
    - How is carbonated water/club soda/seltzer made? [They are made by dissolving carbon dioxide gas in water under high pressure. At the soda factory carbon dioxide gas is added to water under high pressure to make carbonated water. The pressure forces more gas to dissolve than ordinarily would. When the pressure is released, i.e. the cap removed, the gas can escape.]
  - Where was the CO_2 before the bottle was opened? [The carbon dioxide was dissolved in the water.]
  - What happened to the CO_2 when the bottle cap was opened? [It began to come out of solution and escape into the air.]

3. Now you want to focus your students on the state of matter, getting them to think about the idea that gas can dissolve in water by leading a brief discussion on states of matter.

- For example, ask the students:
  - What are the states of matter? [gas, liquid, solid]
  - What state of matter is water? [liquid]
  - What states of matter can dissolve in water? [all]
  - Do you think that gases can dissolve in water? [The idea of a gas dissolving may seem strange to students, but this demonstration will help them realize that gases can dissolve in water. In the case of carbonated beverages, pressure is used dissolve large amount of CO_2 in the liquid.]

Carbon Dioxide & Heat: Mythbusters Video, Time-Elapse Video

4. At this point, refer back to the information students shared in the K column of the KLEW chart, referencing some connection to greenhouse gases, warming temperatures, or carbon dioxide and warming temperatures. Explain that scientists like to test different ideas using controlled experiments and investigations, and that the Mythbusters decided to conduct a controlled investigation to test if carbon dioxide really did retain heat. Remind students that we just learned about CO_2 in different states of matter, and that it is in the atmosphere (we just wanted it get released in our bubbles).

Show the three-minute Mythbuster's video "Mythbusters tests global warming theory – does CO_2 really warm air?": https://youtu.be/pPRd5GT0v0I. Ask students what it could mean for Earth's temperatures if more and more CO_2 is in the atmosphere. Tell students that they'll be acting just like the Mythbusters and real scientists to by developing their own investigations to answer a question about CO_2.

5. Summarize, or have the class help to summarize, the major points discovered so far:

- CO_2 can be a gas, a solid, or a liquid.
- CO_2 dissolves in water and is in the atmosphere and air around us.
- CO_2 retains heat.

Have all students raise one hand in a "thumbs up" position and level their thumbs so they are not pointed up or down. Tell students if they agree with this statement, they should give the statement a "thumbs up" and if they disagree with the statement, they should give it a "thumbs down". Say, "records from the late 1800s to the early 2000s show the average temperature of the Earth is increasing." After students vote, show the time elapse video of the earth warming "3-Watch 131 Year of Global Warming in 26 Seconds" (http://www.climatecentral.org/blogs/131-years-of-global-warming-in-26-seconds). You may need to show the video several times, as well as have an explicit discussion of what the colors mean (blue means cooler, yellow means hotter). This video should help illustrate that the earth (including oceans) is indeed getting warmer. Students should recognize that the data used to make this video was collected and recorded by scientists and people (thermometers, weather reports, etc.). Point out that the colors are changing over the oceans as well as the continents.

Have students update their KLEW charts by beginning to record information in the “L” and “E” columns. Introduce the **driving question**, “Will warm oceans be better or worse at absorbing CO_2?”

Explore

Gassy World Climate Change Bingo

6. *Gassy World Climate Change Bingo* encourages students to explore and is designed to allow students to gain a broader understanding of carbon dioxide as it relates to climate change.

Cool It! Cards Background Information

The Cool It! game was designed by the Union of Concerned Scientists as a tool to provide an opportunity for learners to talk about global warming in an engaging and approachable way. The game allows learners to understand how the choices humans make contributes to or reduces the effects of global warming. A comprehensive guide to the Cool It! cards including a teacher’s guide and how to play can be found in the link below:

https://www.nestanet.org/cms/content/int/newsletter/corners/2598

In this lesson, the Cool It! cards will be used to expand student knowledge on carbon dioxide and specifically how it relates to climate change. The chart in Appendix C is an overview of each of the Cool It! Cards used in Cool It! Bingo.

How to Play Climate Change Bingo

Each student will be given one Cool It! card. Each card is numbered on the front of the card in the bottom right hand corner. Cards numbered one through twenty-five are unique and answer every question on the bingo board. Cards numbered twenty-six through thirty-five are duplicates and should be used when there are more than twenty-five students playing the game. Explain that each card contains information about climate change. The Climate Change Bingo board has two types of questions on it: red and purple. The answers to the questions written in red can be found on the Cool It! cards. The squares written in purple are ‘prior knowledge’ squares. The answers to these questions are not found on the Cool It! cards, but rather from what a student may have already learned about climate change. Because these questions may be more challenging for students, some prior knowledge squares are worth two spaces instead of just one.

Students must work with their peers to find the answers to the questions (for both the red Cool It! squares and the purple prior knowledge squares). The goal can be to get six squares with correct answers in a row, or to complete as many squares as possible. It is possible to get six in a row without having any prior knowledge about climate change. Allow students to get up and walk around the room to find the answers for the Climate Change Bingo questions with their peers.

Have the class share their answers so they can review what they found and summarize information to serve as a formative assessment. Encourage students to share something they learned that surprised them.

7. After Climate Change Bingo, take a moment and have students fill out the "L" and "E" column of their KLEW chart.

Lab Design

8. Remind students of the driving question: <u>Will warm oceans be better or worse at absorbing CO_2?</u> and tell them they will begin to design a fair test (investigation) to answer the driving question. Be sure guide the students to consider the idea that they will need to know how temperature affects water's ability to absorb CO_2. Remind students why we're interested in water absorbing CO_2 (oceans as a sink for carbon emissions). You may need to make sure that students understand the terms absorb and retain and that if the oceans absorb and retain the CO_2, they prevent it from remaining in the atmosphere and contributing to global warming.

9. Ask students to brainstorm in their small groups (either pairs, or two sets of pairs) how they would design a fair test (an investigation) to answer the question of how water temperature affects its ability to absorb and retain CO_2. You want them to get to the idea that they could measure and compare how much CO_2 is in, that is, been absorbed by, similar volumes of warmer water and colder water, but you do not want to directly tell them this. This is very likely to be a task at which many students struggle. This task is meant to be challenging and allowing students an opportunity to meet this challenge on their own (with appropriate scaffolds) is an important part of the development of scientific investigation skills. Note that at this point all they need to have thought about it the general idea of comparing absorption in warm water versus cold water. They do not yet need to come up with the specific protocols for their investigations.

10. Once they have the idea that they will want to be able to compare the amount of CO_2 being absorbed and retained in different temperature water, you can use the following demonstration to give them an idea for a source of CO_2.

- Ask the students where can we get CO_2 from for this investigation?
  - They might answer carbonated drinks (since that is what we used before, or blowing into the water). You can say we could compare the amount of bubbles in warm and cold soda, but it would be hard to know if you were starting with the same amount of CO_2 since it would also be very difficult to count all the bubbles and the bubbles

might not all be the same size. Likewise, blowing into the water would not necessarily result in an equal amount of CO_2 in each trial as bubble size and number can vary and student level of activity directly correlates to the amount of CO_2 in exhalations.

  - Hand out Alka-Seltzer tablets (half a tablet per group) and cups of room temperature water and ask them what state of matter does the tablet represent? [solid]

- Have students place tablet into water and make observations.
  - What happened? [Bubbles, fizzing.]
  - What do you think the bubbles are made of? [CO_2]
  - Where do you think the CO_2 in the bubbles came from? [CO_2 molecules are released from the chemicals in the Alka-Seltzer tablet as a result of a chemical reaction that occurs when the tablet dissolves in water.]
  - Where did the CO_2 go? [CO_2 bubbles rose to surface and popped, releasing CO_2 into the air.] This is a good time to revisit what we mean by 'absorb,' 'retain' and 'release' with respect to CO_2 in water. CO_2 bubbles rise to the surface and are released into the air. Some CO_2 from the chemical reaction didn't become a bubble and stayed in, was absorbed by, the water. Fewer bubbles popping at the surface means less CO_2 is being released and, therefore, more is being absorbed by the water.
  - What happened to the tablet? [It dissolved.] Here, you can also talk about term "solubility."
  - Ask the students how do you suppose you could use these Alka-Seltzer tablets to help you determine how much CO_2 is retained in warm versus cold saltwater, which is what they are going to do in lab today. Help the students understand that they will be making an investigational model to test what happens in the real world with CO_2 and the oceans and the atmosphere. Make sure they understand the connection between CO_2 from the Alka-Seltzer tablet to CO_2 in the atmosphere. Point out that scientists often test ideas with models.

11. Show PowerPoint slide (see thumb drive) with materials pictured and put samples of materials available in lab on their tables. Have students think about how they could use these materials to run an investigation to find out whether cold or warm water absorbs more CO_2. They can examine and manipulate the items, but cannot use any water or Alka-Seltzer tablets at this point. We would like them to arrive at the conclusion they can put balloons over the top of Erlenmeyer flasks filled with warm and cold water and an Alka-Seltzer tablet, trap the CO_2 not being absorbed by the water and measure the amount that wasn't absorbed. Note that there are different ways one can quantify the amount of CO_2 released from water. If you want to allow students to use different methods, that is fine, but we only provide materials for the balloon method. If students do come up with a plausible way to do it, but you want them to use the balloon method instead, just make sure to explain that their idea would have worked, it's just that you don't have the equipment available to make it happen, as we want to encourage creativity and the idea that there are many different ways to test an idea in science.

- Have students put their ideas on the whiteboards.
- Students write their final plan on their worksheet.

Scaffolding the Investigation

Two scaffolds are available to help students plan and carry out their investigation. One is an Experimental Design Graphic Organizer, and one is a set of Experimental Design Picture Steps. These scaffolds can be used for students who are new to planning investigations or who are struggling to get started with writing their protocol. These scaffolds can also be used in the interest of time. Both scaffolds can be found in Appendix D. The scaffolds are not included in the student pages, as they are optional. If you decide to use the Graphic Organizer scaffolds, you will need to print the template (found in Appendix D) in addition to the regular student pages. The picture steps are included in the materials sent with the kit.

Conducting the Investigation

12. Conducting the investigation.

Students will need to have a solid idea of their investigational procedure before beginning the lab portion of the activity. We use the peer review process to help students strengthen their investigational procedure before they usually begin collecting data. Have each small group of students (2-3 students/group recommended) design and write out their investigational procedure. Then, have them meet with another group and take turns sharing their ideas. Tell each group it is their responsibility to ask questions and respectfully critique the procedures. This is an important step and allows students an opportunity to think through their procedure and to practice communicating as scientists. Once they have had a chance to give and receive feedback, give students additional time to make any necessary revisions to their procedure (there is space provided in the student worksheets for initial procedures and revisions).

The materials supplied in this activity allow students to do this test using the following general method:

- They will use the Alka-Seltzer tablet to generate CO_2 in flasks containing warm and cold saltwater.
- Please do not allow students to pour hot water directly from the hotpot that is provided. The water is extremely hot and poses a risk to students.
- We suggest giving each student a limited supply of materials. If they need additional materials (i.e., more CO_2 or more balloons), ask them to come and trade in the old balloons (or the CO_2 wrappers) for new supplies. This helps keep students on task and can prevent students from too much unfocused 'play' in the lab or from using too many Alka-Seltzer tabs in one flask at a time.
- They will use the balloons to measure how much CO_2 is escaping from the flask, and thus is not absorbed by the water. But what we really want to know is how much was 'absorbed' by the water. We can only infer the amount absorbed by assuming both started with the same amount and measuring how much escapes. Therefore, the bigger

the balloon, the more CO_2 was released and the less that was absorbed by the water. This is likely to be confusing to the students. This confusion might make itself evident during the actual lab activity, but most likely will become clear during the data analysis phase using Claim-Evidence-Reasoning chart (bigger balloons, mean LESS was absorbed by the water).

- They can measure how big the balloons are in several ways:
  - Qualitatively (bigger versus smaller);
  - Measure the circumference of each balloon using a string or the diameter using a ruler and use that as a quantitative measure of the amount of gas released;
  - Calculate the approximate volume of the balloon ($V = 4/3\pi r^3$) after measuring the circumference using the string and calculating the radius since the circumference is known $r = C/2\pi$);
  - Calculate the approximate volume by immersing the balloon in water and measuring the volume of the displaced water.
- Hints for adding Alka-Seltzer tablets to the water
  - There are many different ways the Alka-Seltzer tablets can be added to the water. The challenges include having the reaction of the water with the tablets run for the same amount of time, and getting the balloon on top of the Erlenmeyer flasks quickly, without allowing too much gas to escape. One solution to this challenge would be to break Alka-Seltzer tablet into small pieces and add the pieces to the balloon, and then place the balloon on the top of the Erlenmeyer flask. Once the balloon is securely fastened to the cylinder, you can tip the balloon up and allow the broken Alka-Seltzer table to fall into the Erlenmeyer flasks. Another solution would be to add Alka-Seltzer to one Erlenmeyer flask at a time, and using a timer to ensure all trials are the same length. Allowing students to struggle with these types of 'problems' and come up with their own solutions is important, so don't be overly prescriptive about the 'help' that you give the students.

Explain

Analysis & Conclusions: Graphs, C-E-R

13. Once students have collected their data, they need to analyze it and draw conclusions. They should make a bar graph that shows the amount of CO_2 released from warm water versus cold water. This graphing opportunity is useful practice as students continue developing their graphing skills. If they have done multiple trials, they can use averages; however, if they have only gotten qualitative measures of amount absorbed (e.g. smaller vs larger balloon size) then they will not be able to produce a numerical average. The students will likely struggle at this point with understanding that the bigger balloon actually means the water absorbed less CO_2.

14. After students make their graph, they need to construct a scientific explanation using the Claim-Evidence-Reasoning (C-E-R) framework. There is a C-E-R graphic organizer in their student handout or the C-E-R can be done as a poster, and the class can do a gallery walk at the end of the activity to compare results. If you and your students are not familiar with the Claim-

Evidence-Reasoning framework, see the C-E-R appendix of this manual for additional information. A rubric for assessing scientific explanations is also provided in the appendix. Note that students often struggle with providing appropriate evidence and reasoning for claims, and the students may require additional scaffolding as they learn to develop scientific explanations.

15. Have students fill out the analysis questions on their student worksheet.

16. Have students return to the KLEW chart, and add to learned and evidence columns any new information. They should also take time to fill out the 'wondering's column, as a big part of science is developing new questions and areas to study based on what was learned.

Elaborate

17. Ask students what warmer oceans, due to global warming, will mean for the amount of CO_2 that is entering the atmosphere and contributing to the greenhouse gas effect? (Question 13 on student worksheet).

18. Discuss question 14 on the student worksheet "What can you do to reduce the amount of CO_2 being released into the atmosphere to help prevent global warming and climate change?" You'll want to leave students with ideas about what is being done to address climate change, and what they can do in their lives to address the issue.

Evaluate

19. You could ask students to predict which will fizz more, a cold bottle of soda or a warm bottle of soda and explain why they think that and how they would know. Consider having them answer using the Claim-Evidence-Reasoning format. You can have a demo so show them after they submit their prediction.

- Cold soda would retain more CO_2, so it would have fewer bubbles rising to the surface.

20. Student learning is formatively evaluated throughout the lab activity (KLEW chart, student worksheets, discussions, etc.)

<table>
<tr><th colspan="6">Cool It! Bingo: Answer Key</th></tr>
<tr>
<td>What is an example of a biofuel?

Wood chips, grass (transportation solution: clean fuel from plants)</td>
<td>How is sprawl related to global warming?

People live far away from where the work, drive a lot and burn a lot of gas; gas produces CO2 (transportation problem: sprawl)</td>
<td>How many gallons of gasoline would a gas guzzler use to drive 10,000 miles? A regular car?

1,100; 450 (transportation problem: gas guzzlers)</td>
<td>How much less CO2 is produced in an electric car than a typical gas powered car?

Half as much (transportation solution: electric cars)</td>
<td>Why do hybrid cars release less CO2 into the atmosphere?

Has a battery and a gas engine, so the gas engine is not needed as often (transportation solution: hybrid cars)</td>
<td>How are humans adding carbon dioxide to the atmosphere?

Burning too much fossil fuel, cutting down trees</td>
</tr>
<tr>
<td>When a couple rides a bus instead of driving, what percent less gas do they burn?

70% (transportation solution: bus lines)</td>
<td>How does growing coffee underneath tropical trees reduce the effects of climate change?

Trees are not cut down, releasing CO2 (threatened forest solution: shade grown coffee)</td>
<td>How much less energy do compact florescent lightbulbs use than filament lightbulbs?

75% (energy solutions: better lightbulbs)</td>
<td>How much carbon dioxide does wind power create?

None (energy solution: wind power)</td>
<td>What is coal? How does coal produce CO2?

Hardened carbon from plants that have been buried in the ground for a long time; burning coal produces CO2 (energy sector)</td>
<td>The sea level is rising as a result of climate change. True or False?

True</td>
</tr>
<tr>
<td>How many tons of CO2 is released from cutting 1 acre of forest?

About 160 tons (threatened forest problem: clear cutting for farmland)</td>
<td rowspan="2">Where is carbon dioxide found in non-living parts of the earth?

Air, oceans, fossil fuels</td>
<td>Trees are made mostly out of what?

Carbon (threatened forest sector)</td>
<td>Every second of every day, and area of tropical forest the size of a <u>football field</u> is destroyed.
(threatened forest problem: clear cutting pastures)</td>
<td>How many acres of forest has brazil designated as protected?

62 million (threatened forests solution: protected forests)</td>
<td>How does carbon capture work?

Capture CO2 and pump it underground so it's not released into the atmosphere (energy solutions: carbon capture and storage)</td>
</tr>
<tr>
<td>How do solar cells work? How much CO2 does it create?

Capture the suns light and turn it into energy; none (energy solutions: solar power plants)</td>
<td>How does deforestation lead to increased levels of CO2 in the atmosphere?

Fewer trees to absorb CO2</td>
<td>What is geothermal heating and cooling?

Using the more stable temperatures underground for heating and cooling (energy sector solution: geothermal heating and cooling)</td>
<td>Do oceans absorb carbon dioxide?

Yes</td>
<td>How much less electricity does an Energy Star- certified refrigerator use than other refrigerators?

20-40% less (energy solutions: energy efficient appliances)</td>
</tr>
<tr>
<td rowspan="2">What is the greenhouse effect? How does it relate to carbon dioxide?

Gasses in the atmosphere retain heat from the sun and trap it on earth instead of being released into space. CO2 is a greenhouse gas</td>
<td>How did Sidwell Friends School cut its energy use by 60%?

By designing the building to let the sun heat it (energy sector solution: passive solar buildings)</td>
<td>Why are protected forests important?

Stops forests and trees from being destroyed and releasing CO2 (threatened forests solution: protected forests)</td>
<td>Oil is liquid carbon that forms from what?

Decaying plant and animal matter (transportation sector)</td>
<td>What is forest-smart farming?

Growing crops without cutting down forests (threatened forests solution: forest-smart farming)</td>
<td>What do smart meters do?

Let people know when energy is more or less expensive (energy solutions: smart meters)</td>
</tr>
<tr>
<td>In the United States, what percent of CO2 comes from heating, cooling, and powering homes?

38% (energy sector problem: old buildings)</td>
<td>True or false: carbon dioxide traps heat and makes the earth warmer.

True</td>
<td colspan="2">What is a carbon sink? Give an example.

Places where carbon is stored for a long time. Oceans, forests, fossil fuels</td>
<td>What is one of the main ways heat-trapping CO2 gets into the atmosphere?

Burning coal (energy sector problem: new coal plants)</td>
</tr>
</table>

Answers to Student Analysis Questions

Q1. What specific question are you trying to answer with your investigation?

The driving question of the whole activity is "Will warm oceans be better or worse at absorbing CO_2?" The specific question they are asking in their investigation is likely to be "Does warm water or cold water absorb more CO_2?

Q2. Why are you using Alka-Seltzer tablets? What happens when you place them in water?

They are the source of CO_2 for the model we are using to examine the effects of temperature on the ocean's ability to absorb CO_2. When they are placed in water, they release bubbles contain CO_2 gas. This is an excellent opportunity to discuss with your students about the scientific practice of "developing and using models". Scientists often use models to make and test predictions. You can read more about how scientists use models in Appendix F of the Next Generation Science Standards which can be found at www.nextgenscience.org.

Q3 and Q4. Planning your investigation.

The planning of the investigation is a major focus of the lab. The expectation is that the students, themselves, will plan the investigation, rather than follow a series of cookbook steps. Allowing students the space and time to engage in this scientific practice is critical. All students may not come up with the exact same procedure, and that is ok. You can scaffold the process for students by asking them guiding questions, but refrain from telling the students exactly what to include. For example, if students don't include multiple trials in their investigational set-up, you could ask leading questions that get them to consider the importance of multiple trials. Additionally, if they don't at first state they will be using equal volumes of water, you can prompt them to consider if it is a 'fair test' if both Erlenmeyer flasks don't have the same amount of water. Similarly, the amount of Alka-Seltzer tablet each flask gets needs to be the same.

Sharing their ideas with other groups is a way to get them to consider good investigational design components they may not have come up with on their own.

Remember, students need opportunities to try and fail, and try again to learn the important skills of science.

Q5. Make a prediction about what you think the results of your investigation might be and make sure to explain why you think this.

This is a good opportunity for students to learn that scientists don't often make random guesses, predictions, or hypotheses, but rather base their predications on their prior knowledge or experience. If students are having trouble answering this question or, more specifically, having trouble providing a reason for their prediction, you might ask them to think about if they ever experienced a difference in the amount of CO_2 in warm soda (less) than in cold soda (more). You can also discuss that 'flat' sodas have lost their CO_2.

Q6. Designing a Data Table

Having students design their own data tables is an important skill that requires practice to develop. Reasons why students need practice designing their own data tables include:

- Many students have never have been asked to design their own data tables before (data tables are almost always provided for students).
- Some students may not fully understand the investigation, therefore they do not know what data they will be collecting.
- Some students do not readily see how to organize their data.

Q7. Conducting the investigation

This is likely to be the most fun for the students. Encourage their excitement. Give them some time and space to practice and become familiar with the equipment. For example, getting the balloons on the Erlenmeyer flasks quickly and securely takes practice, so they may need to try it several times before they are ready to collect data. At the same time, make sure to maintain control and check in with each group to see that they are remaining focused and accomplishing their task. Students need to be reminded to write down the data they collect even if they are surprised by their data. Their data are their data—there is no such thing as 'wrong' data, but encourage students to record any factors which could influence the data unfairly (i.e., not getting the balloon on fast enough or forgetting to time equally).

Q8. Graphing

The graphs the students will produce will depend on the type of data they collect (qualitative versus quantitative). You will need to decide and provide some direction for your students depending on the type of data they have collected.

Q9. Claim-Evidence-Reasoning Chart

A Claim-Evidence-Reasoning (CER) chart is an excellent way for students to learn to construct scientific explanations. If you have never used CER before, you can read more about it at this link: http://www.edutopia.org/blog/science-inquiry-claim-evidence-reasoning-eric-brunsell.

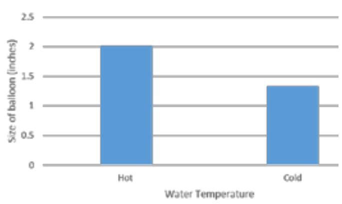
Claim (a statement that answers the question):

Answers may vary depending on the data from each investigation.

One possible answer: Cold water absorbs more CO_2 than warm water.

Evidence (the scientific data you collected that support your claim)

Evidence should be in the form of a graph or table.



Reasoning (your explanation for how the evidence supports your claim)

Examples of appropriate reasoning include:

- The size of balloons increases due to CO_2 being released from water in the Erlenmeyer flask.
- The balloon on the Erlenmeyer flask filled with warm water was bigger because it contained more CO_2 gas than the balloon on the Erlenmeyer flask filled with cold water.
- This indicates that more CO_2 gas was absorbed by the cold water (and less was released into the balloon).
- Warmer water increases the speed of the CO_2 molecules, allowing them to escape into the atmosphere (balloon) faster.

Examples of inappropriate reasoning could include:

- No reasoning given.
- Students repeat the results from their investigation.
- Student incorrectly conclude that bigger balloons mean more CO_2 absorbed, or otherwise demonstrate they do not understand the idea that bigger balloon size means more CO_2 escaped, and therefore less CO_2 was absorbed by the water.

Q10. Our driving question for this activity is "Will warmer oceans be better or worse at soaking up CO_2?" Provide your answer to that question here.

Warmer oceans can absorb less CO_2 than oceans with cooler temperatures.

Q11. Why do we need some greenhouse gases, like carbon dioxide (CO_2) in the atmosphere?

They keep the earth warm enough to sustain life.

Q12. What happens if people add extra greenhouse gases, like carbon dioxide (CO_2) to the atmosphere?

The earth gets warmer, causing changes in the global climate which will change our local weather patterns. Some students might mention that changes in global climate can have far-reaching effects, such as increased occurrences of extreme weather events (tornados, hurricanes, droughts, flooding). These consequences will have serious impacts on human health and on economies.

Q13. How does the ocean affect the amount of CO_2 in the atmosphere?
The ocean acts as a sink, absorbing some of the CO_2 that is being released into the atmosphere. Therefore, oceans are helping to mitigate the effects of all the CO_2 being released by humans burning fossil fuels. But the oceans can only hold so much CO_2, and warmer oceans will hold less CO_2. As the oceans get warmer, some of the CO_2 currently being retained by them is expected to be released increasing the amount in the atmosphere.

Q14. If warmer oceans soak up less CO_2, what effect do you think rising ocean temperatures will have on the amount of CO_2 in the atmosphere?
Warmer oceans will not be able to absorb as much CO_2. Therefore, there will be more CO_2 in the atmosphere, leading to increased global warming.

Q15. What can you do to help prevent global warming and climate change?
Answers will vary and may include: Decrease the amount of fossil fuels being burned to reduce the amount of CO_2 being released into the atmosphere. Use less energy, and try to substitute energy derived from fossil fuels with alternative sources (wind, solar, etc.). Reduce, reuse and recycle materials.

Next Generation Science Standards

NGSS connections
www.nextgenscience.org

It's A Gassy World
Middle School

Performance Expectations: Students' ability to complete the following performance expectations will be supported by participation in this activity. **MS-ESS2-1:** Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process. **MS-ESS2-5:** Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions. **MS-ESS2-6:** Develop and use a model to describe how unequal heating an rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climate. **MS-ESS3-3** Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment. **MS-ESS3-4** Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems. **MS-ESS3-5** Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century. **MS-PS1-4** Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed. **MS-PS1-1:** Develop models to describe the atomic composition of simple molecules and extended structures.		
Dimension	**NGSS code or citation**	**Corresponding student task in activity**
Practice	Planning and Carrying Out Investigations • Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and	Students will design an investigation to determine if water temperature affects its ability to retain carbon dioxide gas. Students will share their draft procedures with peers, and make revisions based on feedback. Students will then conduct their investigation.

	how many data are needed to support a claim. • Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation. • Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.	
	Analyzing and Interpreting Data • Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships. • Analyze and interpret data to provide evidence for phenomena.	Students will construct a graph to look for patterns in their data. Students will use this data as evidence to support their claims.
	Constructing Explanations • Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past	Students will construct a scientific explanation that includes their evidence and reasoning to support their claim that answers the question "Does warm water or cold water absorb more carbon dioxide gas? Students will consider the role that oceans play in absorbing excess carbon dioxide and how

	and will continue to do so in the future. • Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real world phenomena, examples, or events.	warming oceans might affect their ability to act as carbon sinks.
	Engaging in Argument From Evidence • Respectfully provide and receive critiques about one's explanations, procedures, models, and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail.	Students share their investigational procedures with classmates for peer review. They are then expected to revise their procedures based on the peer feedback.
Disciplinary Core Ideas	**ESS2.D Weather and Climate** • Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. • Greenhouse gases in the atmosphere absorb and retain the energy radiated form land an ocean surfaces, thereby regulating Earth's average surface temperature and keeping it habitable.	Students will view a Mythbuster's video that demonstrates that carbon dioxide gas retains heat.
	ESS3.C Human Impacts on Earth Systems • Human impacts have significantly altered the biosphere, sometimes	Students will view and discuss a short video that shows that the Earth's surface, and surrounding

	damaging or destroying natural habitats and causing the extinction of many other species. But changes to the Earth's environments can have different impacts (negative and positive) for different living things. • Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth, unless the activities and technologies involved are engineered otherwise	oceans, have been warming over the past 200 years. During Climate Change Bingo, students will use Cool It! cards, a game that discusses the role of humans in increasing the levels of CO_2 in the atmosphere.
	ESS3.D Global Climate Change • Human activities, such as the release of greenhouse gas emissions from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities.	Students explore their current understanding of the words/phrases "Climate Change", "Global Warming" and "Carbon Dioxide" as they fill in the KLEW (What they know, what they learned, what is the evidence, what they want to know". This initial activity serves to elicit student prior knowledge on the topic. At this point, teachers are not expected to address or correct misconceptions or incorrect ideas, rather they should address these ideas as they come up throughout the activity. Students will explore these ideas in the Climate Change Bingo activity.

	PS1.A Structure and Properties of Matter • Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide.	Students will observe a bottle of carbonated water, before and after it is opened. Students will discuss how the bubbles that appear after it is opened are from carbon dioxide gas that has been dissolved in the water to give it it's 'fizzy' properties. Students can make connections between the results of their investigation (cold water retains more CO2 than hot water) and the kinetic-molecular theory (warmer water increases the speed of molecules, allowing them to escape into the air at a faster rate).
Crosscutting Concepts	Cause and Effect - Cause and effect relationships may be used to predict phenomena in natural or designed systems.	Students will explore the causal relationship between increasing greenhouse gas emissions and increasing temperatures.
	Systems and System Models - Systems may interact with other systems; they nay have subsystems and be a part of a larger complex system.	Students will explore how affecting one system (increasing ocean temperatures) can affect, and be affect by, another system (the amount of CO2 in the atmosphere).
	Energy and Matter: Flows, Cycles, and Conservation - Within a natural or designed system, the transfer of energy drives the motion and/or cycling of matter.	Students will consider the cycling of carbon, as well as the cycling of energy in the atmosphere and oceans.
	Stability and Change of Systems - Small changes in one part of a system might cause large changes in another part.	Students will consider how changes in ocean temperature can affect the amount of CO2 in the atmosphere. They will also consider how

	- Stability might be disturbed with by sudden events or gradual changes that accumulate over time.	increasing carbon emissions are creating large disturbances in global climate.

Nature of Science

- Scientific knowledge is based on empirical evidence
    - Scientific knowledge is based on logical and conceptual connections between evidence and explanations.
- Science Addresses Questions About the Natural and Material World
    - Science knowledge can describe consequences of actions but is not responsible for society's decisions.

Connections to Common Core State Standards

English Language Arts/Literacy:	Mathematics:
RST.6-8.3	MP3
RST.6-8.4	MP5
RST.6-8.7	MP6
W.6.1	6.SP.B.5.c
W.7.1	
W.8.1	

Appendix A: Common Climate Change Misconceptions related to *It's a Gassy World!*

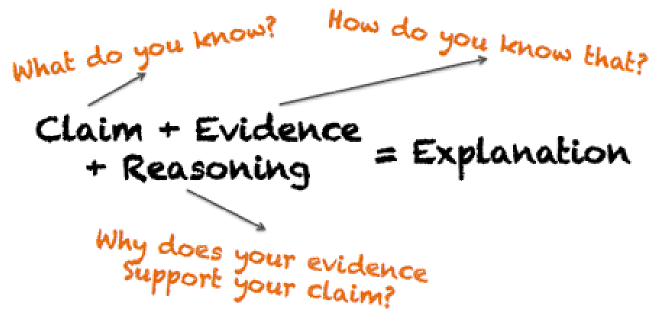
Climate change misconception	**Scientifically Accepted Relevant information**
Global warming is caused by the ozone hole, created by the release of chemicals in aerosol cans, because the hole lets in more radiation.	The ozone hole, which occurs high in the atmosphere, is an important environmental problem and it has been addressed as the chemicals responsible for the problem were globally banned. However, the ozone hole is *not* responsible for global warming. Global warming is not associated with any change in radiation being received at the earth's surface, rather it is due to an increase in greenhouse gases which re-radiate heat back to earth rather than let it escape into space.
The atmosphere is large and small amounts of carbon dioxide or a few degrees of temperature change can't make much difference.	The amount of carbon dioxide that has been added to the atmosphere since 1900 is about 40% of the total that is present; the same amount of change as if a 100 lb. person gained 40 pounds, a BIG change. So the change is relatively large. In addition, carbon dioxide released into the atmosphere remains there for 100 years. The difference in temperature between our current earth and the earth during an ice age is only about 5°C. It is also important to remember that human civilization only arose about 10,000 years ago and the large changes in earth's climate [ice ages and tropical periods] were much, much earlier.
Climate has changed many times in the distant past, before humans began burning coal and oil, so humans burning coal, oil, and natural gas cannot cause the current warming.	There are several drivers that cause climate to change, and some of the key drivers have both natural and human sources. Recent increases in global temperatures result mostly from higher levels of heat-trapping gases in the atmosphere, which have been increasing because of human activities. These recent changes are also occurring rapidly, whereas those in the distant past took thousands of years to occur. It should also be noted that they occurred before there was advanced human civilization to suffer their impact.
Carbon is destroyed when fossil fuels are burned and CO_2 is released into the atmosphere. Carbon released from combustion doesn't have an impact on the climate system.	Carbon stored in plants and fossilized into oil or coal does *not* disappear when it burns. Burning is a chemical process that follows the law of conservation of matter. The process of combustion combines oxygen with carbon, releasing the greenhouse gas, CO_2. The observed increase in global average temperatures since the latter part of the 20^{th} century is likely due to documented increases in human-induced greenhouse gas concentrations, primarily from the burning of fossil fuels.

Fossil fuels have been around since the origins of the Earth.	Fossil fuels are "buried solar energy" originally captured by living organisms. Photosynthesis is the mechanism by which plants, the base of the food chain, capture the sun's energy and turn carbon dioxide into biomass. Oil, natural gas and coal come from energy captured long ago from the sun by organisms that had been buried for millions of years and retained their 'captured carbon dioxide' until burned by us.
The last few years have been cooler, so global warming can't be real. Global warming stopped in 1990's. The world has been cooling for the past decade.	The climate is defined by long-term averages in global temperatures and other climate metrics, and those are still increasing. Local cool temperatures do not reflect global averages. Winter of 2014-2015 was 'abnormal' (both colder or warmer) than typical in different parts of the USA http://www.wunderground.com/news/strange-weather-early-snow-cold-heat-quiet-tropics-20140910
In the past CO_2 did not initiate warming but it did amplify the warming. In fact, about 90% of the global warming *followed* the CO_2 increase.	Climate systems are complex and in the past CO_2 was observed to increase along with warming *but* just because it increased as things warmed *does not* mean it did not initiate the warming. Warming itself from excess CO_2 leads to the increase in CO_2 in several ways. For example, as ocean temperature rises, oceans release dissolved CO_2 into the atmosphere. This additional release of carbon dioxide amplifies the warming trend, leading to yet more CO_2 being released and so on. This is known as a positive feedback loop.
Greenhouse gases are bad for the environment.	Greenhouse gases are critical for maintaining heat in our atmosphere. These gases keep our earth at an average temperature of 59°F. Without greenhouse gases the earth's temperature would be 0°F. However, while a certain level of GHG is critical for biological life as we know it, when the level of greenhouse gases increases beyond this minimum their impact can become detrimental. Currently the atmospheric concentration of CO_2 is rising as a result of humans burning of fossil fuels and deforestation.

References and additional climate misconceptions resources:
Common Misconceptions about Climate and Climate Change: http://cires.colorado.edu/education/outreach/climateCommunication/CC%20Misconceptions%20Handout.pdf
Common Misconceptions about Polar Weather and Climate:
http://beyondpenguins.nsdl.org/issue/column.php?date=June2008&departmentid=professional&columnid=professional!misconceptions
Climate Misconceptions: A Top 10 List: http://beyondpenguins.nsdl.org/issue/column.php?date=June2010&departmentid=professional&columnid=professional!misconceptions
Greenhouse Gas Overview: http://www.epa.gov/climatechange/emissions/index.html
http://www.pewclimate.org/science-impacts/realities-vs-misconceptions

Appendix B: C-E-R Framework

Explanations in Science: Claim, Evidence, Reasoning



After students are engaged in an investigation, how can they make sense of their data and construct a scientific explanation in which they justify their claim? One way is to introduce the Claim, Evidence, Reasoning (C-E-R) framework (McNeill and Krajcik, 2011). "An explanation includes a <u>claim</u> that relates how a variable(s) relates to another variable or set of variables. A claim is often made in response to a question and in the process of answering the question, scientists often design *investigations* to generate *data*." Explanations rely on <u>evidence</u> and provide the "how" or "why" phenomena occur (<u>reasoning</u>). *NGSS Appendix F*

Components of an Explanation – What does a good scientific explanation look like?

1. Claim
   - A conclusion that answers the question about a phenomena or a solution to a problem.
   - A statement of what you understand or a conclusion that you have reached from an investigation(s) or text(s) you have read.

2. Evidence
   - Scientific data that supports the student's claim.
   - Must be appropriate and sufficient.
   - Can come from an investigation or other source that may include:
     - Observations
     - Information found in texts
     - Archived data
     - Information from an expert

3. Scientific Reasoning
   - Justification that links the claim and evidence.
   - Shows why the data counts as evidence to support the claim, using appropriate scientific principles.

Scaffold the Process in Your Classroom

- Explicitly define the elements of the C-E-R Framework
- Provide a graphic organizer that explains the parts of the framework
- Connect to everyday examples
- Provide opportunities for oral discourse of claim, evidence and reasoning before writing
- Use teacher questioning or feedback during oral presentation
- Model and critique examples
- Engage students in peer critique

- Provide students with feedback

Student Challenges

- **Using evidence to support their ideas** – Students may tend to rely on their own opinion(s) and have difficulty using sufficient evidence.
- **Explaining why the evidence supports their ideas (justification/reasoning)** – Students may have difficulty articulating this link and/or using scientific principles.
- **Considering multiple explanations or solutions** – Students may have difficulty revising explanations and solutions based on evidence or scientific knowledge.

The following rubric can be used by both students and teachers to assess their scientific arguments and explanations. Rubric developed and adapted from material at http://slider.gatech.edu/student-edition.

C-E-R Element	**Zero (0)**	**Early (1pt)**	**Emerging (2pts)**	**Sophisticated (3pts)**
1) Claim	Does not make a claim that responds to the question.	The claim responds to the question, but is inaccurate claim.	Makes an accurate but incomplete claim in response to the question.	Makes an accurate and complete claim in response to the question.
2a) Evidence Use of data	No evidence is provided.	The evidence contains **some** of appropriate data from an observation.	The evidence contains **most** of appropriate data from an observation.	The evidence contains **all** appropriate data from an observation.
2b) Evidence Interpretation of data	Does not interpret any evidence.	Interprets only some data accurately.	Interprets **most** of the data accurately.	Interprets **all** of the data accurately.
3a) Reasoning General Statement	Does not provide any reasoning.	Answers why or how the evidence supports claim with **no relevant** scientific principles (disciplinary core ideas).	Answers why or how the evidence supports claim with **insufficient relevant** scientific principles (disciplinary core ideas).	Answers why or how the evidence supports claim with **sufficient relevant** scientific principles (disciplinary core ideas).
3b) Reasoning Use of pieces of evidence	Uses no evidence or relevant big ideas accurately to explain the relationship between claim and evidence.	Uses **some** piece(s) of evidence and relevant disciplinary core ideas accurately to explain the relationship between claim and evidence.	Uses **most** pieces of evidence and relevant disciplinary core ideas accurately to explain the relationship between claim and evidence.	Uses **all** pieces of evidence and relevant disciplinary core ideas accurately to explain the relationship between claim and evidence.
4a) Persuasion Complete sentences	**No** sentences are complete.	**Only few** sentences are complete.	**Most** sentences are complete.	**All** sentences are complete.
4b) Persuasion Grammatical Choices	**Most** of CER contains many grammatical errors.	CER contains **some** grammatical errors.	CER contains **few** grammatical errors.	CER contains **minimal** grammatical errors.

Resources

McNeill, Katherine L. and J. Krajcik. *Supporting Grade 5-8 Students in Constructing Explanations in Science: The Claim, Evidence, and Reasoning Framework for Talk*: New York, Pearson, 2011. Print.

Sampson, Victor, P. Enderle, L. Gleim, J. Grooms, M. Hester, S. Southerland, K. Wilson. *Argument-Driven Inquiry in Biology: Lab Investigations for Grades 9-12*: Arlington, NSTA Press, 2014. Print.

http://learningcenter.nsta.org/products/symposia_seminars/nsta/files/howdoyouknowthat--helpingstudentswriteaboutclaimsandevidence_12-12-2012.pdf

http://slider.gatech.edu/student-edition

http://www.activatelearning.com/claim-evidence-reasoning/

https://www.nestanet.org/cms/content/int/newsletter/corners/2598

Appendix C: Cool It! Cards Overview

The chart below describes the cards used in Cool It! Bingo.

Card number	Card Overview	Card Details
1 & 26	Hybrid Cars	Gas & electric motor; burns less gasoline and releases less CO_2
2 & 27	Clear-cutting for farmland	Cutting down forests to grow crops releases CO_2; Forest destruction happens because of farming; cutting one acre of forest releases about 160 tons of CO_2
3	Shade-grown coffee	Coffee growers cut down trees to make room for coffee plants (destroying trees releases CO_2); coffee can be grown in shade without having to cut down trees
4 & 32	Threatened Forests Sector	Trees are made of mostly carbon; when they are burned CO_2 is formed, which traps heat and makes the earth warmer. Tropical forests are a big source of carbon and destroying them could release a lot of CO_2 into the atmosphere
5	Better lightbulbs	Compact fluorescent lightbulbs use 75% less electricity than filament light bulbs and last 10 times longer. Reduces the amount of coal produced at power plants
6	Bus lines	Easier and cheaper to get around; burn 70% less fossil fuel when you ride a bus as opposed to driving. New hybrid that use both an electric and gasoline motor can reduce amount of gasoline burned by another 25-30%
7	Electric cars	Run on batteries; produces about half as much CO_2 as a typical gasoline powered car. If recharged with wind or solar power, almost no CO_2 emissions
8	Gas guzzlers	Someone who drives more than 10,000 miles per year in a gas guzzler uses more than 1,100 gallons of gasoline; average car would use 450 gallons. Burning less gas means putting less CO_2 into the atmosphere
9 & 29	Sprawl	When people live far from where they work, they drive a lot and burn a lot of gasoline. Each gallon of gas burned in a car produces 20 lbs. of heat trapping CO_2, which causes global warming
10	Old buildings	In US, 38%of CO_2 comes from energy used to heat, cool, and power homes/ buildings. Older buildings let heat escape in winter and cool air in summer (waste energy)
11	Smart meters	Electric companies charge different prices for electricity at different times of day; smart meters let people know when electricity is more or less expensive
12	Forest-smart farming	Farmers often burn and cut down tropical forests to clear land for farming; destroying trees releases CO_2into atmosphere and traps heat. Farmers in tropical countries can grow some crops without cutting down forests
13 & 33	Transportation Sector	Gas comes from oil, which is liquid carbon. Using gas in cars produces CO_2, which traps heat and makes the earth warmer
14 & 34	Protected forests	Make laws protecting forest lands so they can't be destroyed

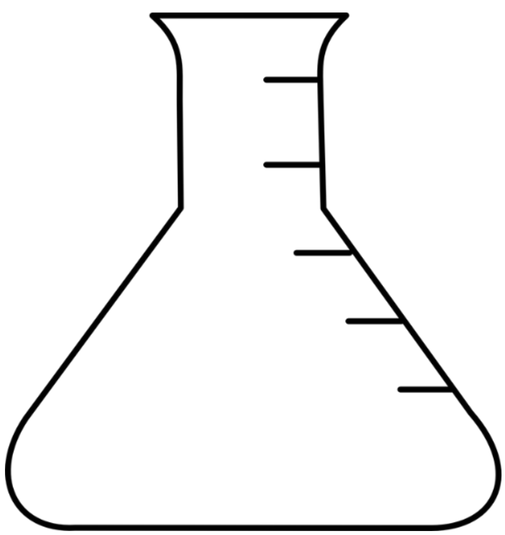
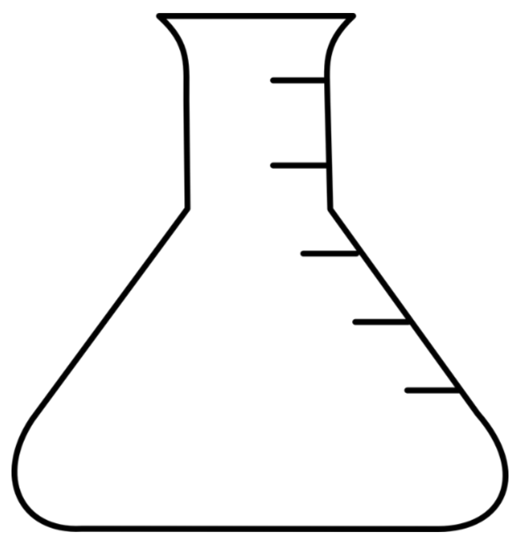
15	Passive solar buildings	Buildings designed to let the sun heat them
16 & 28	Clean fuels from plants	Biofuels made from woodchips and grass create 80% less heat-trapping emissions than gasoline when used in cars; can also be made from garbage
17 & 30	Wind power	Magnets make turbines spin and create electricity; wind power doesn't create CO2
18	New coal plants	Burning coal to make electricity is one of the main ways CO2 gets into atmosphere. Building new coal power plants that will burn coal for many years in the future will make it hard to reduce amount of CO2
19	Energy Efficient appliances	Refrigerators use a lot of energy; efficient ones use 20-40% less electricity
20	Geothermal heating and cooling	Temperature underground is more stable than above (around 50-60 F); can be used for heating in the winter and cooling in the summer
21 & 35	Solar power plants	Capture the suns light and turns it into electricity; doesn't create an CO2
22	Carbon capture and storage	Capturing CO2 from coal fired power plants and pump it underground so it doesn't go into the atmosphere and warm the earth more
23	Protected forests	Make laws protecting forest lands so they can't be destroyed
24	Clear-cutting for pastures	Farmers clear cut forests and turn them into grasslands for grazing cattle; Every second of every day, and area of tropical forest the size of a football field is destroyed; 60-70% of amazon deforestation is a result of clear cutting for cattle pastures
25 & 31	Energy Sector	Much of the energy used for electricity comes from burning coal at power plants. Burning coal produces CO2, which traps heat and makes the earth warmer

Appendix D: Scaffolding the Investigation

Scaffold #1: Experimental Design Graphic Organizer

The Experimental Design Graphic Organizer scaffold helps students visualize their investigation while also encouraging them to consider key elements of an investigation such as variables and controls.

The Experimental Design Graphic Organizer can be found on the following page.

<table>
<tr><td colspan="2">What question is your investigation going to help you answer?</td></tr>
<tr><td>Independent variable:</td><td rowspan="3">Questions to consider while planning your investigation:
Are you including information on amounts used?
Are you including labels, explanations, and the order you will conduct the steps?
How many times will you test your hypothesis?</td></tr>
<tr><td>Dependent variable:</td></tr>
<tr><td>Control:</td></tr>
<tr><td colspan="2">Use the images below to illustrate and label the steps of your investigation.
 </td></tr>
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Scaffold #2: Experimental Design Picture Steps

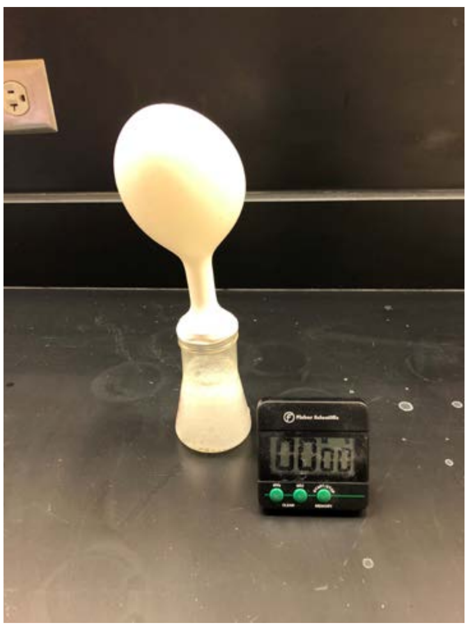
Picture steps include a picture of every step of the investigation. Students are given the pictures and instructed to put them in an order that reflects a logical sequence. Students should be able to articulate what each picture represents and why they placed the pictures in the order that they did.

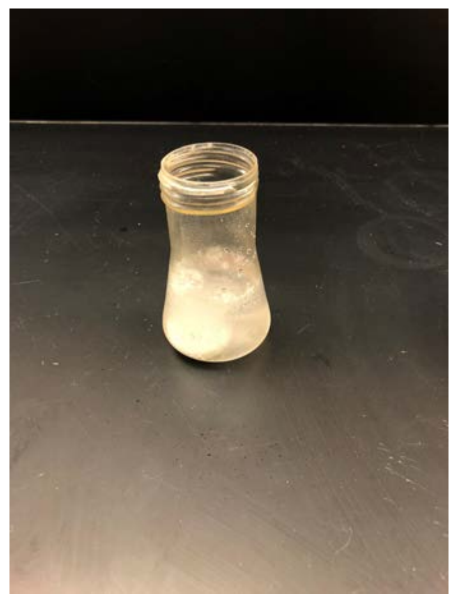
The chart below describes each picture step. Pictures can be found on the following two pages.

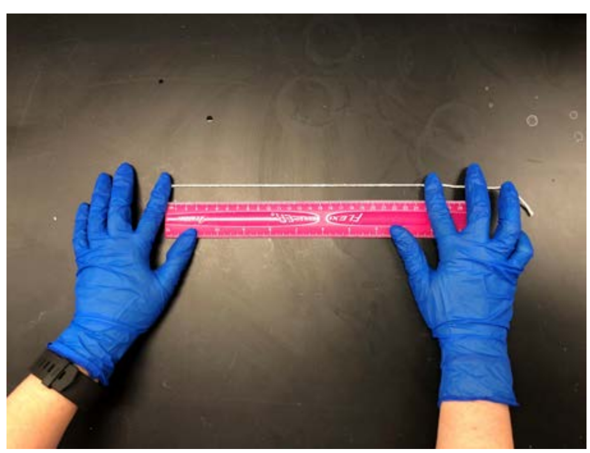
Step #	Picture Description	Reasoning
1	Two Erlenmeyer flasks, labeled hot and cold water	Testing how Alka-Seltzer reacts in both hot and cold water
2	Two Erlenmeyer flasks, labeled hot and cold water, two Alka-Seltzer tabs	Alka-Seltzer tabs represent CO2 and should be placed in both the hot and cold water flasks
3&4	Erlenmeyer flask with Alka-Seltzer tab in flask	Two of the same picture; one represents hot water, one represents cold water
5&6	Erlenmeyer flask with balloon on top and timer	Two of the same picture (for hot and cold); balloon is used to trap CO2 for a specific amount of time (timer)
7&8	String around balloon on top of Erlenmeyer flask	Two of the same picture (for hot and cold); string is used to measure the inflation of the balloon
9&10	String and ruler	Two of the same picture (for hot and cold); measure the string to determine how much the balloon inflated
11	Data table	Students should have a plan of what information they will record during the investigation
12	Reminder Card	Card asks 'What are we trying to determine in our investigation?' to encourage students to consider how the investigation they are planning relates to the driving question.

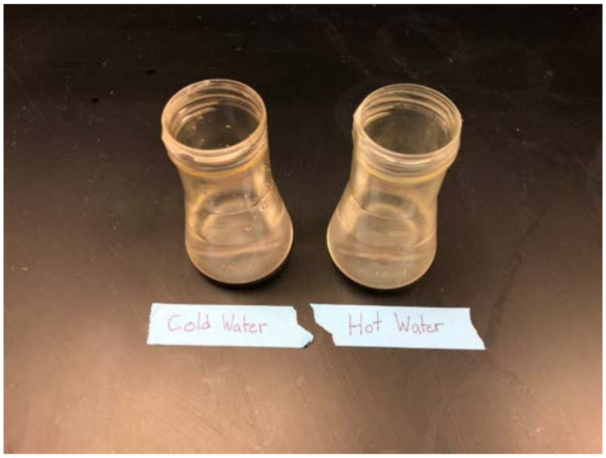
It's a Gassy World!

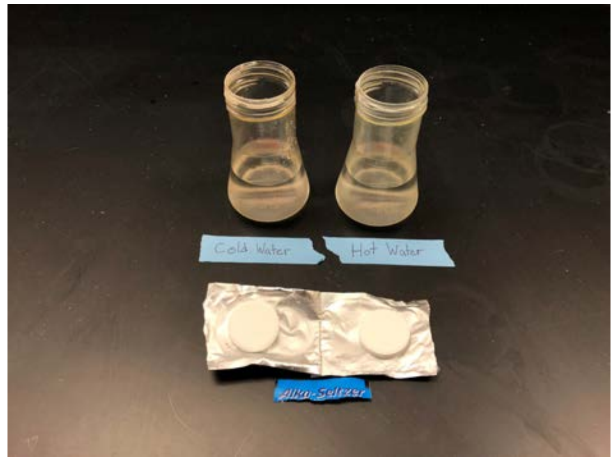
What are we trying to determine in our investigation?

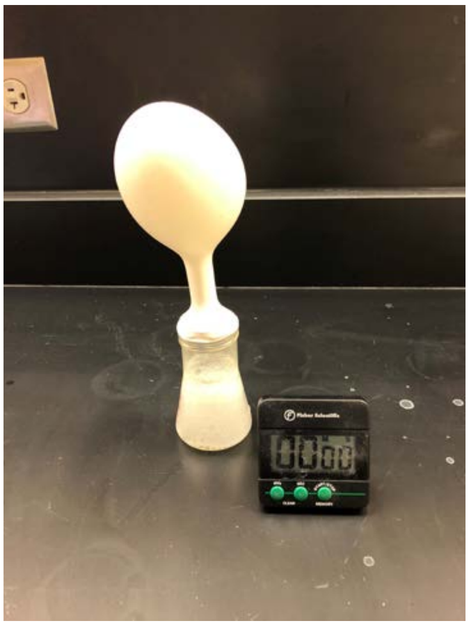


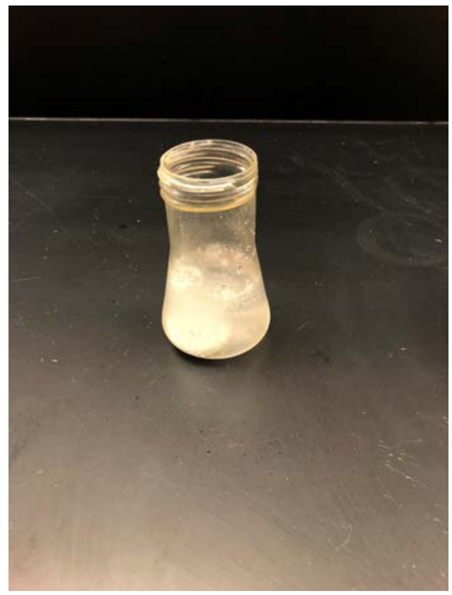


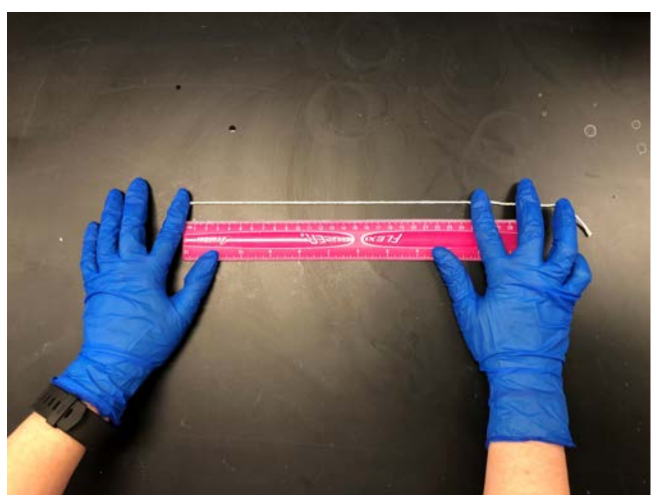



Cold Water
Hot Water


Cold Water
Hot Water
Alka-Seltzer







Appendix E: Student Worksheets

Student worksheets begin on the next page and are number S-1 through S-8. They correlate with both the lab activity and the PowerPoint presentation available on the web and on the thumb drive. The

Name: ______________________________

What do you know about Global Warming and Climate Change and Carbon Dioxide (CO_2)?

K-L-E-W Chart

What do you know?	What did you learn?	What is your evidence?	What are you wondering?

Driving Question: Will warm oceans be better or worse at absorbing CO_2?

<table>
<tr><th colspan="6">Cool It! Bingo</th></tr>
<tr><td>What is an example of a biofuel?</td><td>How is sprawl related to global warming?</td><td>How many gallons of gasoline would a gas guzzler use to drive 10,000 miles? A regular car?</td><td>How much less CO2 is produced in an electric car than a typical gas powered car?</td><td>Why do hybrid cars release less CO2 into the atmosphere?</td><td>How are humans adding carbon dioxide to the atmosphere?</td></tr>
<tr><td>When a couple rides a bus instead of driving, what percent less gas do they burn?</td><td>How does growing coffee underneath tropical trees reduce the effects of climate change?</td><td>How much less energy do compact florescent lightbulbs use than filament lightbulbs?</td><td>How much carbon dioxide does wind power create?</td><td>What is coal? How does coal produce CO2?</td><td>The sea level is rising as a result of climate change. True or False?</td></tr>
<tr><td>How many tons of CO2 is released from cutting 1 acre of forest?</td><td rowspan="2">Where is carbon dioxide found in non-living parts of the earth?</td><td>Trees are made mostly out of what?</td><td>Every second of every day, and area of tropical forest the size of a ________ ________is destroyed.</td><td>How many acres of forest has brazil designated as protected?</td><td>How does carbon capture work?</td></tr>
<tr><td>How do solar cells work? How much CO2 does it create?</td><td>How does deforestation lead to increased levels of CO2 in the atmosphere?</td><td>What is geothermal heating and cooling?</td><td>Do oceans absorb carbon dioxide?</td><td>How much less electricity does an Energy Star-certified refrigerator use than other refrigerators?</td></tr>
<tr><td rowspan="2">What is the greenhouse effect? How does it relate to carbon dioxide?</td><td>How did Sidwell Friends School cut its energy use by 60%?</td><td>Why are protected forests important?</td><td>Oil is liquid carbon that forms from what?</td><td>What is forest-smart farming?</td><td>What do smart meters do?</td></tr>
<tr><td>In the United States, what percent of CO2 comes from heating, cooling, and powering homes?</td><td>True or false: carbon dioxide traps heat and makes the earth warmer.</td><td colspan="2">What is a carbon sink? Give an example.</td><td>What is one of the main ways heat-trapping CO2 gets into the atmosphere?</td></tr>
</table>

Driving Question: Will warm oceans be better or worse at absorbing CO_2?

1. What specific question are you trying to answer with your investigation?

2. Why are you using Alka-Seltzer tablets? What happens when you place them in water?

3. Planning your investigation: Using the materials listed below, design a fair test investigation that will allow you to determine how the temperature of water affects the amount of CO_2 gas it can absorb. You will need to write the steps you will do in your investigation. Make sure to include enough information so that a classmate could follow your procedure.

Some things to consider:

- What things do you need to keep the same to make sure it is a fair test?
- How many times do you need to perform each test?
- How are you going to determine the amount of gas that is released from the water?

Materials Available:

- 50-ml Erlenmeyer flasks
- Warm saltwater
- Cold saltwater
- Alka-Seltzer tablets
- Balloons
- String
- Ruler
- Thermometer

Investigational

Driving Question: Will warm oceans be better or worse at absorbing CO_2?

4. Explain your investigational procedure to another group and listen to their investigational procedure. After sharing your ideas, take time to revise your original idea based on your discussion. You can cross out, erase and add to what you wrote in the space above, or you can write it again with your changes in the space below:

Revised Investigational Procedure:

5. Make a prediction about what you think the results of your investigation might be. Make sure to explain why you think this.

6. Now that you know what you are going to do, you need to design a data table to organize the data you will be collecting. Make sure to have a place to write all your results.

- Hint: If you are going to test something more than once (a good idea in science) make sure to have space to write the results for each time you test it.

Data Table:

Driving Question: Will warm oceans be better or worse at absorbing CO_2?

7. Conducting your investigation

Now you're ready to conduct your investigation. Before you begin, here are some hints that will help you get started.

- You may need to stretch the balloons a few times to begin, so they inflate easier
- Practice getting the balloon onto the Erlenmeyer flask a few times- it's tricky!
- Don't fill your Erlenmeyer flasks more than ½ full
- Remember to enter your data on your data table!

8. Make a graph using the data you collected.

Graph

Driving Question: Will warm oceans be better or worse at absorbing CO_2?

9. Use the data from your graph to answer the question "Does warm water or cold water *absorb* more CO_2?" Create a scientific explanation to answer this question using the Claim-Evidence-Reasoning chart below.

Claim: Statement that answers your question: *Does warm water or cold water absorb more CO_2?*	
Evidence: The scientific data you collected that support your claim. This is a good place for a graph of your results.	**Reasoning.** Your explanation for how the evidence supports your claim.

Driving Question: Will warming oceans be better or worse at absorbing CO_2?

Student Analysis Questions:

10. Our driving question for this activity is "Will warm oceans be better or worse at absorbing CO_2?" Provide your answer to that question here.

11. Why do is it good to have some greenhouse gases, like carbon dioxide (CO_2), in the atmosphere?

12. What happens if people add extra greenhouse gases, like carbon dioxide (CO_2), to the atmosphere?

13. How do the oceans affect the amount of CO_2 in the atmosphere?

14. If warmer oceans absorb less CO_2, what effect do you think rising ocean temperatures will have on the amount of CO_2 in the atmosphere?

15. What can you do to help prevent global warming and climate change?