# Greenhouse Gases

<table>
<thead>
<tr>
<th># of Days</th>
<th>Prior Knowledge</th>
<th>Lesson Objective</th>
<th>Language Goals/Demands</th>
<th>Lesson Assessment</th>
<th>Changes for Next Time</th>
<th>Materials Needed</th>
<th>What Worked Well</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Students will have heard of greenhouse gases. They probably will know very little about energy balance.</td>
<td>Students will be able to identify greenhouse gases and their sources. Students will explain the role these gases play in the Earth's energy budget.</td>
<td>Reading 2.5, Listening 1.1, Speaking 2.2 b and c</td>
<td>Concept map on days 2-3, formative - connection of sources and sinks, Lab activity</td>
<td></td>
<td>Powerpoint, Materials for greenhouse gas effect activity; Resonance models with tennis balls, etc.; Gas Files Activity</td>
<td></td>
</tr>
</tbody>
</table>

## Time | Learning Task or Activity | Method & Notes |
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Day 1</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 min</td>
<td>BW: Study for the Quiz over LP 1 &amp; 2 Share/review last night's homework</td>
<td>INDIVIDUAL SEAT WORK</td>
</tr>
<tr>
<td>15 min</td>
<td>Quiz</td>
<td>INDIVIDUAL SEAT WORK</td>
</tr>
<tr>
<td>15 min</td>
<td>What do you already know? What are the greenhouse gases? Where do they come from? How do they work?</td>
<td>KWL Chart See 3.1.3 Greenhouse Gases Slide #2 Activating prior knowledge. Before naming the greenhouse gases, ask what students already know.</td>
</tr>
<tr>
<td>10 minutes</td>
<td>Greenhouse Gas Presentation - If the amount of energy that comes in is the same amount of energy that goes out, how can our planet stay warm? - The answer is greenhouse gases.</td>
<td>LECTURE/DISCUSSION See 3.1.3 Greenhouse Gases Slides #3-5 Use 3.1.4 Student Notes Handout</td>
</tr>
</tbody>
</table>
| 20 min | Resonance Model Demonstration  
- Show students different models of atmospheric compounds and how they resonate. Have students connect the different wavelengths with resonance. What would happen without greenhouse gases? Goldilocks slide. | LECTURE/DEMONSTRATION  
See 3.1.3 Greenhouse Gases Slides #6-10  
DEMONSTRATION - Follow 3.1.5a Task Card. Collect data by group on the board. Use 3.1.5 for instructions to make models.  
VIDEO: Resonance by Scott Denning  
http://www.youtube.com/watch?v=AIBk0pGV_BQ&feature=related |
| --- | --- | --- |
| HW | Students are to read the Carbon Dioxide and Greenhouse Effect and create 5 questions and an answer key. | HOMEWORK  
3.1.6 Reading on Carbon Dioxide and the Greenhouse Effect |
| **Day 2** | **INDIVIDUAL SEAT WORK** |
| 3 min | BW: What would happen if there were no greenhouse gases? | HANDS-ON LAB  
3.2.1 Greenhouse Gas Lab – written directions  
Greenhouse Effect Poster supplies |
| 35 min | The Greenhouse Gas Effect Activity and Poster  
- Students should work in groups to set up their labs. If they are successful at trapping CO₂ they should see a change in temperature in about 20 minutes.  
- While waiting/collecting data, students create a Greenhouse Effect Posters. Students work individually or with partners to create a poster to illustrate the path of sunlight as it radiates to the Earth (include pictures of Sun, Earth and representation of the terms radiation, reflection, absorption, and greenhouse gases). | DISCUSSION/LECTURE/Q&A  
See 3.1.3 Greenhouse Gases Slides #10-11 |
| 7 min | Debrief Lab and Discussion  
Debrief the lab, discuss the greenhouse effect and how the gas in the atmosphere does cause an increase in temperature. | DISCUSSION/LECTURE/Q&A  
See 3.1.3 Greenhouse Gases Slides #12 or 13  
Students continue working on the posters and share with classmates |
| 5 min | Energy Balance Diagram or Review of Resonance  
- Teachers and students will step through the different parts of the energy balance diagrams with students providing explanations for each of the arrows.  
- Students continue working on posters. | DISCUSSION/LECTURE/Q&A  
See 3.1.3 Greenhouse Gases Slides #12 or 13  
Students continue working on the posters and share with classmates |
| 5 min | Concept Map  
- Students will add to the concept map. Hand out the new words they should add to their maps. | INDIVIDUAL SEAT WORK  
Use 3.2.2 Concept Map Homework |
<p>| HW | Work on concept map |   |</p>
<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
<th>Task Type</th>
<th>Handouts/Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 min</td>
<td>BW: What do you think are the sources of greenhouse gases?</td>
<td>INDIVIDUAL SEAT WORK</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Check concept maps</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 min</td>
<td>Introduction to today’s activity: Sources and Sinks - Thought question about bathtub.</td>
<td>THINK/PAIR/SHARE</td>
<td>Use 3.3.1 Bathtub Thoughts Handout</td>
</tr>
<tr>
<td>25 min</td>
<td>Gas Files Activity</td>
<td>GROUP WORK</td>
<td>Use 3.3.2 Gas Files Activity</td>
</tr>
<tr>
<td></td>
<td>- Students look at data and graphs to determine the quantities and sources of the different greenhouse gases</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>- Examples will deal with CO₂, methane, nitrous oxide, and water vapor</td>
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<td></td>
</tr>
<tr>
<td>15 min</td>
<td>Mitigation Strategies</td>
<td>LECTURE/NOTES</td>
<td>3.3.3 Mitigation Strategies Slides</td>
</tr>
<tr>
<td></td>
<td>- Show the wedge diagram that will be used with the final assessment showing increases in greenhouse gases.</td>
<td></td>
<td>Use 3.3.3A for student notes during the presentation</td>
</tr>
<tr>
<td></td>
<td>- Talk about three or four wedges - ways to mitigate more carbon emissions</td>
<td></td>
<td>3.3.5 Pictures of Power Plants OPTIONAL</td>
</tr>
<tr>
<td>HW</td>
<td>Concept Map</td>
<td>HOMEWORK</td>
<td>3.3.4 Concept Map Homework</td>
</tr>
</tbody>
</table>
Greenhouse Gases and Energy Budget
LP3

3.0 List of Resources

3.1.1 blank
3.1.2 Quiz LP1 & LP2
3.1.3 Greenhouse Gases Slides
3.1.4 Student Notes Handout (for use during slides and resonance model activity)
3.1.5 Resonance Model Making Instructions
3.1.5a Resonance Model Task Card (to use with models)
3.1.6 Reading: Carbon Dioxide and Greenhouse Gases

3.2.1 Greenhouse Gas Lab WRITTEN
3.2.2 Concept Map Homework

3.3.1 Bathtub Thoughts Handout
3.3.2 Gas Files Activity
3.3.3 Mitigation Strategies Slides
3.3.3A Mitigation Notes Handout
3.3.4 Concept Map Homework
3.3.5 Pictures of Power Plants OPTIONAL

Supplies
Materials for greenhouse effect activity
   2L soda bottles, empty
   thermometers
   2 ways to make carbon dioxide
       Alka-seltzer tablets + water = carbon dioxide
       Vinegar + baking soda = carbon dioxide
   A heat source (light bulbs)

Resonance models with tennis balls (Instructions in 3.1.5)

Video: Scott Denning and Resonance:
http://www.youtube.com/watch?v=AIBk0pGV_BQ&feature=related

Video: Eco-Man explains Greenhouse Gases and Global Warming
http://www.youtube.com/watch?v=GBQ8-zEcE9w
3.1.2 Quiz LP1 & LP2
Questions and answers.

1. You have a friend that lives in the desert where it almost never rains. You talk to him on the phone and he says that it has rained for the last three days. He says that the climate must be changing. How do you respond?

   I would tell my friend that climate is weather that happens over a long period, often 30 years. He experienced some odd weather, but this is not evidence for or against climate change.

2. The energy that is emitted from the Sun travels in the form of:
   
   a. Short-wave radiation
   b. Long-wave radiation
   c. Non-wave radiation

3. The energy that is emitted from the Earth travels in the form of:

   a. Short-wave radiation
   b. Long-wave radiation
   c. Non-wave radiation

4. A volcano in Hawaii erupted and shot out a lot of ash. This ash formed huge thick clouds over Hawaii. What did this volcanic eruption do to the albedo over Hawaii?

   a. Increase the albedo
   b. Decrease the albedo
   c. Keep the albedo the same
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   a. Increase the albedo
   b. Decrease the albedo
   c. Keep the albedo the same
Greenhouse Gases and Energy Budget

LP 3

What are the greenhouse gases?

Where do they come from?

How do they work?

DAY 1 KWL CHART

Over the next few days we will be investigating the different greenhouse gases and where they are from. Start with a KWL chart in order to determine what students already know.
What is the greenhouse effect?

Students might also have experienced this feeling when they get into a car on a hot day. It feels much warmer inside the car because of the trapped air. So, it is different than the greenhouse effect but a connection to their experience. Students might be able come up with other examples as well.

Air in the car is trapped and can’t get out. On Earth, there is no physical boundary, so it is the gases that actually work to hold the heat. After these three slides students should be able to fill out the graphic organizer comparing and contrasting a greenhouse with the “greenhouse effect”

Composition of the Earth’s Atmosphere

- Nitrogen N₂ = 78%
- Oxygen O₂ = 21%
- Argon Ar = 0.9%
- Other = <0.1%
  - Carbon Dioxide CO₂
  - Methane CH₄
  - Nitrous Oxide NO₂
  - Ozone O₃
  - Hydrogen

DAY 1- RESONANCE MODELS

Most of our atmosphere is nitrogen and oxygen, neither of which is a greenhouse gas. Compare this to the Goldilocks effect. The GHGs in our atmosphere are less than 0.1% of the total amount of gas in the atmosphere and yet they are what make our planet inhabitable. Without the small amount of greenhouse gases, the average temperature on the planet would be 0 degrees F.

There is a major misconception that the hole in the ozone layer is the primary reason for climate change. It is correct to say that the ozone hole has a small effect on climate change, but is not the main cause. The other connection between these issues is that CFCs and their non-ozone-destroying replacements are very potent greenhouse gases, which also contribute to climate change. Students may or may not bring up these ideas in their discussion.
Greenhouse Gases

Resonance Models

RESONANCE MODELS—Show the tennis ball models of the gases
While this slide is up, students will complete the task card to use the models and discuss the following questions. Depending on your students it would also be possible to do this entirely as a demonstration.

Is there a frequency at which it is much easier to keep the model vibrating? At this frequency your model molecule better absorbs and retains your energy output. If there is such a frequency, determine what it is in vibrations per second by counting the number of vibrations in a 5-second interval and dividing by 5. Do at least three trials, letting different member of your group experiment and obtain the range of frequencies at which the maximum energy is absorbed. Repeat this procedure for all three models.

1. How do the resonant frequencies of the 3 models compare?
2. What hypothesis can you formulate to explain your observations?
3. Physicists tell us that the behavior of the models built from the tennis balls is a good analogy of the behavior of real molecules of carbon dioxide, methane, and nitrogen. From the observations of your models, can you explain why some gases in the atmosphere absorb infrared radiation and others do not?
4. Why do you think greenhouse gases absorb infrared radiation and do not absorb visible light?
The “Goldilocks” Principle

<table>
<thead>
<tr>
<th>Surface pressure relative to Earth (bars)</th>
<th>90</th>
<th>1</th>
<th>0.007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major greenhouse gases (GHG)</td>
<td>CO₂</td>
<td>H₂O</td>
<td>CO₂</td>
</tr>
<tr>
<td>Temperature if no GHG (°C)</td>
<td>-46</td>
<td>-18</td>
<td>-57</td>
</tr>
<tr>
<td>Actual temperatures (°C)</td>
<td>877</td>
<td>13</td>
<td>-47</td>
</tr>
<tr>
<td>Temperature change due to GHG</td>
<td>+825</td>
<td>+39</td>
<td>+10</td>
</tr>
</tbody>
</table>

Mars is too cold, Venus is too hot, but the Earth is just right!

Why is the greenhouse effect so important? This slide compares the temperatures on the three planets with and without greenhouse gases. All of them do experience warmer temperatures with the gases. The next slide is specifically the Earth and temperatures are reported in Fahrenheit (which might be more familiar to the students).

Recent calculations by NASA actually put the temperature change due to GHGs at only 20 degrees, not the 33 degrees in the chart. This is mostly because of using a different albedo number to consider the effects of solar and longwave radiation on the planetary albedo. The changed number is (-18 to -5) and is called the “atmosphere effect” of greenhouse gases, as opposed to the “enhanced atmospheric test” associated by the increase in greenhouse gases due to human activities.

### What if Earth did not have greenhouse gases?

<table>
<thead>
<tr>
<th></th>
<th>CO₂</th>
<th>H₂O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature without greenhouse gases</td>
<td>-5 °C (23 °F)</td>
<td></td>
</tr>
<tr>
<td>Actual Average Temperature</td>
<td>15 °C (59 °F)</td>
<td></td>
</tr>
<tr>
<td>Temperature change because of greenhouse gases</td>
<td>20 °C (36 °F)</td>
<td></td>
</tr>
</tbody>
</table>

This is an example of why we want to have greenhouse gases. They make our planet inhabitable and bring the temperature up to a level humans can live in. It does not mean that the temperature everywhere on everyday is equal to 59 degrees, but just that there is a dramatic change because of the greenhouse gases. We know this because we can look at other planets (Mars and Venus usually) and compare their temperatures and atmospheres to ours.
Use this slide to relate back to and debrief the lab. What are the comparisons between the greenhouse gas lab and this picture?
Ask students for similarities and differences. There is space on their lab notes to write their comments.

**Earth's greenhouse effect**
Some gases preferentially absorb certain wavelengths of radiation and are transparent to others. This is because of resonance. As we just saw with the amount of shaking in the GHG models, they shake more or less depending on how much energy you put into them. The long wave radiation happens to hit the greenhouse gases just right.

**OPTIONAL:**
This slide is not required. If you have time and inclination at this point, you could repeat the rope experiment from the other day. Students will see that different amounts of energy causes the rope to resonate at different frequencies.

**BACKGROUND**
Every object that is free to vibrate has its own natural frequency. If you vibrate an object near one of its natural frequencies, its motion may grow to quite large values, a process known as resonance. Molecules behave in the same manner: they absorb energy near their resonant frequencies and vibrate, creating heat. In this demonstration of model molecules of atmospheric gases, students can make observations about resonant frequencies.

Be sure that the students do not confuse the wavelength of the radiation (long and short wave) with the resonance frequency, although they are closely related. A molecule moves at a certain frequency and it is a certain wavelength of light that is absorbed by a specific molecule.
What are the percentages of different components of the atmosphere?

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td></td>
</tr>
<tr>
<td>Oxygen</td>
<td></td>
</tr>
<tr>
<td>Argon</td>
<td></td>
</tr>
<tr>
<td>Greenhouse Gases</td>
<td></td>
</tr>
</tbody>
</table>

What are some greenhouse gases?

What would happen to the Earth if the greenhouse effect did not exist?

Why is the small (less than 1%) amount of greenhouse gases so important to the average temperature of the Earth?

Where is one place where greenhouse gases are produced?
3.1.5 Resonance Model Making

Resonance and Greenhouse Gases

Background
Every object that is free to vibrate has its own natural frequency. If you vibrate an object near one of its natural frequencies, its motion may grow quite large, a process known as resonance. Molecules behave in the same manner: they absorb energy near their resonant frequencies and vibrate, creating heat. In this activity, you are going to build model molecules of atmospheric gases and make observations about their resonant frequencies.

Adapted from Operation Chemistry and Global Warming Activities for High School Science Classes, Rosenthal and Golden, 1991

Directions to Build Gas Models
Your team will build three molecules: carbon dioxide, methane, and nitrogen. These three gases are found in the atmosphere at different concentrations. You will use these models to figure out their resonance frequency which relates to the wavelength of light that they absorb.

Carbon dioxide model
1. Insert one 10-inch hacksaw blade through a carbon atom with two slits. Let it stick out about one inch on the other side.
2. Repeat the procedure with another hacksaw blade from the other side.
3. Add an oxygen atom to each end so that the distance between each oxygen and the center carbon is 5 inches.

Methane model
1. Insert one 10-inch hacksaw blade through the carbon atom with four slits so the end sticks out about one inch on the other side.
2. Repeat the procedure with another hacksaw blade from the other side.
3. Repeat steps 1 and 2 through the other pair of slits. You should now have a carbon atom with 4 arms.
4. Add one hydrogen atom to each of the arms so that the distance between each hydrogen and the central carbon is 5 inches.

Nitrogen model
1. Insert one short piece of hacksaw blade into each of the 3 slits in one of the nitrogen atoms.
2. Add the remaining nitrogen atom by inserting the 3 blade ends into its slits.
What to Do
Hold a gas model by the center atom and shake it (for nitrogen, hold one of the ends). Keep the amplitude of vibration (the shaking distance) less than 6 inches. First try very slow shaking (~2/second) and increase the speed of shaking. You are looking for the speed of shaking (frequency) that makes the molecule move the easiest, with the least jerky movements. Do this with all three gases.

Observations
Is there a frequency at which it is much easier to keep the model vibrating? At this frequency the model molecule absorbs and retains your energy output better. Less energy is lost to random movements. If there is such a frequency, determine what it is in vibrations per second by counting the number of vibrations in a 5-second interval and dividing by 5. Do at least three trials, letting different member of your group experiment and obtain the range of frequencies at which the maximum energy is absorbed. Repeat this procedure for all three models.

<table>
<thead>
<tr>
<th>Gas</th>
<th>Frequency (# of vibrations per second)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Trial 1</td>
</tr>
<tr>
<td>CO₂ – carbon dioxide</td>
<td></td>
</tr>
<tr>
<td>CH₄ – methane</td>
<td></td>
</tr>
<tr>
<td>N₂ – nitrogen</td>
<td></td>
</tr>
</tbody>
</table>

Record your group’s results on the board. Look at the results obtained by other groups and discuss how your results compare to those obtained by other members of the class.

1. Compare the resonant frequencies of the 3 models.

2. What hypothesis can you formulate to explain your observations?

3. Physicists tell us that the behavior of the models built from the tennis balls is a good analogy of the behavior of real molecules of carbon dioxide, methane, and nitrogen. From the observations of your models, can you explain why some gases in the atmosphere absorb infrared radiation and others do not?

4. Nitrogen is not a greenhouse gas, and carbon dioxide and methane are greenhouse gases. Why do you think greenhouse gases absorb infrared radiation and nitrogen doesn’t?
3.1.5a TASK CARD: Resonance Models – Carbon Dioxide, Methane and Nitrogen

You will be exploring three different greenhouse gases, each one represented by a model. Your group will use the models to make observations about the RESONANT FREQUENCY of each gas.

WHAT TO DO
Hold your model by the center atom and shake it (for nitrogen, hold one of the ends). Keep the amplitude of vibration (the shaking distance) less than 6 inches. Be sure to try very slow frequencies (~2/second) as well as fast ones.

OBSERVATIONS
When is it much easier to keep the model vibrating? At this frequency your model molecule better absorbs and retains your energy output. If there is such a frequency, determine what it is in vibrations per second by counting the number of vibrations in a 5-second interval and dividing by 5. When told rotate through different stations or switch models with other groups. Repeat this procedure for all three models.

DATA
Record your data on the back of your greenhouse gas notes and then add to the classroom data table.

DISCUSSION: As a group, discuss the following questions.
1. How do the resonant frequencies of the 3 models compare?

2. What hypothesis can you formulate to explain your observations?
The greenhouse effect is important. Without the greenhouse effect, the Earth would not be warm enough for humans to live. But as the greenhouse effect becomes stronger, it is making the Earth warmer than usual. Even a little extra warming can cause problems for humans, plants, and animals.

Carbon dioxide is currently responsible for over 60% of the enhanced greenhouse effect. This gas occurs naturally in the atmosphere, but burning coal, oil, and natural gas releases the carbon stored in these fossil fuels and increases the amount of carbon dioxide in the atmosphere. Deforestation, or cutting down trees to make more space for farms and homes, increases the amount of carbon dioxide in the atmosphere as well. Trees, like all living organisms, are made mostly of carbon; when forests are burned to clear land, the carbon in the trees is released as carbon dioxide.

Carbon dioxide produced by human activity enters the natural carbon cycle. Many billions of tons of carbon are exchanged naturally each year between the atmosphere, the oceans, and land plants. This exchange is known as the carbon cycle. The exchanges in this natural system are well balanced; carbon dioxide levels appear to have varied little for the 10,000 years before 1800. In the last 200 years, however, levels of carbon dioxide in the atmosphere have increased well above those levels.

The Carbon Cycle (image from kidsgeo.com) Adapted from Climate Change Information Kit and Climate Change 101: Science and Impacts
Greenhouse in a Jar Lab

Question: How does the presence of increased levels of CO₂ affect the temperature inside a bottle when exposed to heat?

Materials:
2 clear 2L soda bottles with labels removed
2 tin foil
2 thermometers (these should read at room temperature)
1 250 ml beaker + water
1 Alka-seltzer tablet
1 150 W light fixture
1 ruler
1 stop watch

Procedure:

1. Set up the lamp on the table so that it faces away from the rest of the class. Be careful as you work with the lamp, it can get very hot. Do not turn it on yet.
2. Place the 2 liter bottles next to each other side by side about 6 inches away from the lamp.
3. Add 200 ml of water to each bottle.
4. Hang the thermometer in the control bottle so that it is in the middle, the thermometer should not touch the water. Make sure you can see the temperature. Use tin foil to seal the bottle and also hold up the thermometer.
5. Break an Alkaseltzer tablet in half and place both pieces in the second bottle. Immediately hang the second thermometer and close the top with tin foil as with the first bottle. This is your experimental bottle.
6. Turn on the lamp and make sure it shines evenly on both bottles.
7. Using the recording sheet, record the temperature in both bottles every two minutes for the next twenty minutes.

8. When all data has been collected, clean up your lab station.
Data Collection:

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

<table>
<thead>
<tr>
<th>Time</th>
<th>Set up 1 = CONTROL</th>
<th>Set Up 2 = EXPERIMENTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Just Water</td>
<td>Water + CO₂</td>
</tr>
<tr>
<td>0 minutes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
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<tr>
<td>6</td>
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<td>8</td>
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<td>16</td>
<td></td>
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<td>18</td>
<td></td>
<td></td>
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<tr>
<td>20</td>
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</tr>
</tbody>
</table>

Results

Graph your results on graph paper.

Discussion Questions:

1. What is different in the two bottles?

2. Describe what is happening in the bottle that contains the CO₂.

3. How might you change this experiment if you wanted to know the effect of different concentrations of CO₂. Assume you have a method for measuring CO₂ concentration.
3.2.2 Concept Map and Homework

Continue to work on your Concept Map

Add the following words to your map.

Greenhouse gases
Carbon Dioxide
Water Vapor
Methane
Nitrous Oxide
Atmosphere
Temperature
Bathtub Thought Experiment

Imagine you have a 50-gallon bathtub. You want to keep it always exactly halfway full, at 25 gallons.

Besides turning off the tap and closing the drain as soon as it gets to 25 gallons and leaving it there --

List at least 2 ways you think of to put water into the bathtub

List at least 2 ways you think of to take water out of the bathtub

Now, imagine your bathtub is staying even at a steady state of 25 gallons. All of a sudden your friend comes over with a hose blasting at full speed.

What happens to your bathtub?

In this example there are SOURCES for water (hoses, taps, cups) and there are SINKS for water (ways to take water out, also buckets, hoses, drains). **There are also sources and sinks for greenhouse gases.**

Share with your partner and write down at least one source (place a greenhouse gas comes from) and one sink (a way a greenhouse gas can be used up or go away)

<table>
<thead>
<tr>
<th>SOURCE of Greenhouse Gases</th>
<th>SINK for Greenhouse Gases</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.3.2 Gas Files Activity

The Gas Files

Teacher Information:

There are 5 greenhouse gases that will be discussed in this activity. Students should have a task card, a recording sheet and the first 4 resource cards. Resource cards 5 and 6 show emission profiles by gas and source for developed vs developing countries and fossil fuel usage per capita. They can be used if you have the time and inclination.

More information on Greenhouse gases:

**Water vapor (H$_2$O).** The most abundant greenhouse gas. It acts as a feedback to the climate. Water vapor increases as the Earth's atmosphere warms, but so does the possibility of clouds and precipitation, making these some of the most important feedback mechanisms to the greenhouse effect.

**Carbon dioxide (CO$_2$).** A minor but very important component of the atmosphere (in terms of concentration). Carbon dioxide is released through natural processes such as respiration and volcano eruptions and through human activities such as deforestation, land use changes, and burning fossil fuels. Humans have increased atmospheric CO$_2$ concentration by more than a third since the Industrial Revolution began. This is the most important long-lived "forcing" of climate change.

**Methane (CH$_4$).** A hydrocarbon gas produced both through natural sources and human activities, including the decomposition of wastes in landfills, agriculture, and especially rice cultivation, as well as cattle digestion and manure management associated with domestic livestock. On a molecule-for-molecule basis, methane is a far more active greenhouse gas than carbon dioxide, but also one which is much less abundant in the atmosphere.

**Nitrous oxide (N O$_2$).** A powerful greenhouse gas produced by soil cultivation practices, especially the use of commercial and organic fertilizers, fossil fuel combustion, nitric acid production, and biomass burning.

**Chlorofluorocarbons (CFCs).** Synthetic compounds of entirely of industrial origin used in a number of applications, but now largely regulated in production and release to the atmosphere by international agreement for their ability to contribute to destruction of the ozone layer. CFCs are also greenhouse gases and so are the compounds we have made to replace them.
TASK CARD: The GAS Files

Greenhouse gases are invisible. They are in the atmosphere. They are produced both naturally and because of human activity. We call this either:

**NATURAL** - caused by nature or **ANTHROPOGENIC** - caused by humans

Using the resource cards as references, DISCUSS the following questions with your group:

1. What are the main greenhouse gases in the atmosphere? According to Resource Card 1 what is the most abundant greenhouse gas?

2. According to Resource Cards 1 and 2, there are many sources of greenhouse gases. On your table, record the 5 main greenhouse gases and give one natural and one human source for each one. These are **SOURCES** for greenhouse gases.

3. What trends do you notice in greenhouse gas emissions over time? (Resource Card 3) Why do you think this is happening?

4. For each of the 4 gases humans release (not counting water vapor), what is one thing that could be done to decrease the amount we are emitting?

5. Where are the major **SINKS** or places to store carbon? Is this natural or caused by humans? Some people are proposing that we capture and store carbon dioxide underground. Do you think this will work? Why? (Resource Card 4)

6. Using at least two graphs, give an example relating the graphs and explaining the evidence scientists use to support climate change.
RECORDING SHEET: The GAS Files

List the main greenhouse gases and at least two sources for each one. Divide the sources by **human** causes (anthropogenic) and **natural** causes. Not all may have both human and natural causes. (Resource Card 1 and 2)

<table>
<thead>
<tr>
<th>Greenhouse Gas</th>
<th>Human Cause - SOURCE</th>
<th>Natural Cause - SOURCE</th>
</tr>
</thead>
<tbody>
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</table>

Using Resource Card 3, what trends do you notice for greenhouse gases over time?

For each of the 4 gases humans release (not counting water vapor), what is one thing that could be done to decrease the amount we are emitting?

Where are the major SINKS or places to store carbon? Is this natural or caused by humans? (Resource Card 4)

What does Resource Card 5 show? Why is this important to understand?
In this figure, the top pie graph shows the total amount of annual greenhouse emissions from different sources.

The bottom three pie graphs show the breakdown for each of three greenhouse gases in comparison to the total. Seventy two percent (72%) of the total greenhouse gases emitted was carbon dioxide, 18% methane and 9% nitrous oxide. Use the color pattern in the upper pie graph to determine which source is represented in the lower pie graphs.
RESOURCE CARD 2: The GAS Files

Major Greenhouse Gases and their Sources

<table>
<thead>
<tr>
<th>Greenhouse Gas</th>
<th>Main sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Vapor (H₂O)</td>
<td>Water in the air as clouds or vapor</td>
</tr>
<tr>
<td>Carbon Dioxide (CO₂)</td>
<td>Burning fossil fuels, deforestation, land use changes, respiration, volcanic eruption</td>
</tr>
<tr>
<td>Methane (CH₄)</td>
<td>Decomposition of wastes in landfills, agriculture (especially rice production), cattle digestion, manure management</td>
</tr>
<tr>
<td>Nitrous Oxide (NO₂)</td>
<td>Soil cultivation practices (how we grow plants), use of fertilizers, burning fossil fuels, biomass burning, microbial denitrification</td>
</tr>
<tr>
<td>Chloroflorocarbons (CFCs)</td>
<td>Human made compound originally made to use as a coolant in refrigerators and air conditioners. Now regulated in production and atmosphere release because of international agreements to limit use.</td>
</tr>
</tbody>
</table>

Some Definitions:

Deforestation – cutting down trees

Land Use Changes – when what is on the land changes, a forest into a field, a grassy lot into a parking lot, a white glacier into brown dirt

Decomposition – the breakdown of something into something else

Biomass - plants
RESOURCE CARD 3: The GAS Files

Global Trends in Major Greenhouse Gases to 1/2003

Global trends in major long-lived greenhouse gases through the year 2002. These five gases account for about 97% of the direct climate forcing by long-lived greenhouse gas increases since 1750. The remaining 3% is contributed by an assortment of 10 minor halogen gases, mainly HCFC-22, CFC-113 and CCl4.
Where does carbon go?
Carbon is released from the respiration of plants and the burning of fossil fuels. It is stored in the atmosphere (the air), the biosphere (plants and soil) and the ocean.
RESOURCE CARD 5: The GAS Files

Fossil Fuel Usage per Capita
(world’s 20 largest populations)

Global Average
Mitigation Strategies

What and Why?

What is mitigation?

- To decrease force or intensity. To lower risk.
- Earthquake mitigation
- Flood mitigation
- Climate change mitigation

Some official definitions of mitigation: To moderate in force or intensity, to alleviate. To lessen in force or intensity. Elimination or reduction in frequency, magnitude or severity of exposure. To minimize risk.

An informal definition that could be used to discuss the idea: Basically to make something that could be very bad less bad.

Ask for examples of things people do to “mitigate” for the following environmental effects:

Earthquake – build houses to building codes, try to get people to have emergency kits, meeting points.
Floods – build houses on stilts, make walls so the water can’t get in. Create dams.
Climate Change – mostly involve decreasing the amount of greenhouse gases of all kinds in the atmosphere. For the most part, mitigation cannot reverse warming that has already occurred, it can only slow or stop what would come without any changes.
This is a famous graph called the Keeling Curve. Charles David Keeling started measuring CO₂ levels at the Mauna Loa Observation Laboratory in Hawaii in 1958. This graph shows only atmospheric carbon dioxide concentrations (not any other greenhouse gases). The annual cycle is due to changes in photosynthesis and respiration depending on seasonal fluctuations. The basic idea here is to show that CO₂ concentrations are increasing.

This graph is from The GAS Files and shows annual emissions per sector. The emissions are mostly anthropogenic (human causes) especially Carbon Dioxide. Use it if you think your students could benefit from more discussion of the sectors and where the emissions come from.
Connect Carbon Dioxide (CO₂) and Carbon Emissions to Climate

- The increased amount of carbon dioxide in the atmosphere is from human activities that emit carbon dioxide.
  - Burning fuel (wood, gas, coal)
- With more carbon dioxide in the atmosphere, the atmosphere is getting hotter and that is changing the climate.
- To mitigate (reduce the risk), carbon emissions need to be reduced to stop the increase of carbon dioxide in the atmosphere.

How? Why? What can we do?

We can't just stop emitting CO₂ immediately.

We actually need to bring emissions significantly lower than current levels in order to stabilize concentrations of CO₂.

These diagrams are a first introduction to the mitigation wedge strategy used as a final assessment. It shows historical emissions and then the amount that we need to decrease emissions in order to avoid doubling or tripling CO₂ concentrations over time. The flat path shows where we need to go to avoid doubling CO₂ values. However, we actually need to bring emissions to lower than current values in order to decrease actual CO₂ concentrations.

Bringing CO₂ values down this far will require a significant investment of money and resources. When we do the final assessment, students will be working in groups to make choices about how to decrease our total carbon emissions.

Ask students for ideas since they just finished the wedge activity and should have ideas about sources, sinks, what is happening. Notes at top to help remember questions: HOW CAN WE DECREASE CARBON EMISSIONS? WHY DO WE WANT TO? WHAT CAN WE DO?
Climate Change mitigation: actions we can take to reduce the concentrations of greenhouse gases. For this lesson we will be learning about 4 mitigation strategies. These strategies will help mitigate or reduce the amount of carbon dioxide that is released into the atmosphere.

This should be a review of earlier lesson

We know this from different sources like the ice cores that we just discussed.

If we want to avoid changing the earth even more, we need to cut down or mitigate the amount of carbon that we use.

At this point have students work in pairs or small groups for 5-7 minutes to come up with ways in which they could reduce carbon emissions in the sectors shown on the next slide.

WHAT WE KNOW

The level of greenhouse gases in the atmosphere have increased, causing the Earth’s temperature to rise.

One greenhouse gas in particular, carbon dioxide (CO2) has steadily increased over the past century largely due to human activity (anthropogenic).

We know that emissions have a significant impact on the world around us. How can we reduce the amount of carbon that is emitted?
How can we reduce carbon emissions?

- Work in pairs to talk about ways in which we could reduce (mitigate) carbon emissions in the following areas. Feel free to write your answers in the appropriate column on the board:
  - Transportation
  - Heating and Cooling Buildings
  - Industry Carbon Output
  - Electricity Use

Mitigation Strategy #1:
Transportation Efficiency

A car that gets 30 mpg releases 1 ton of carbon into the air for every 10,000 miles of driving.

Fuel efficient cars get more miles per gallon (mpg).

Increasing the fuel efficiency of cars will reduce the amount of CO₂ emitted into the atmosphere.

Quick formative assessment: make sure students remember what efficiency means.
Mitigation Strategy #2: Transport Conservation

With more cars on the road, the amount of CO₂ emitted steadily increases. Reducing the time and number of cars on the road will reduce emissions. Increasing the use of public transportation would reduce the amount of individual driving time.

Mitigation Strategy #3: Building Efficiency

Providing electricity, transportation, and heat for buildings produces high levels of CO₂ emission. Reducing heating and energy use would reduce the amount of carbon released into the atmosphere. Insulating buildings, using alternative energy sources, and solar water heating are ways to reduce emissions.
Mitigation Strategy #4: Efficient Electricity Production

25% of the world's carbon emissions come from the production of electricity at coal plants.

Since nearly 50% of electricity comes from coal combustion, improving coal plant efficiency will significantly reduce carbon emissions.

To do this requires alternative ways of using coal to produce electricity.
3.3.3A

Name:  
Date:  
Block:  

Action Notes on Mitigation

The level of __________________ in the atmosphere has increased, causing the Earth’s temperature to rise.

One greenhouse gas in particular, __________________ has steadily increased in the atmosphere over the past century largely due to __________________ activity.

Mitigation means:  
   a) to make less or reduce  
   b) to increase  
   c) to keep the same

Mitigation Strategies: What are four areas where we can reduce emission?

1)  
   one way to do this is to:

2)  
   one way to do this is to:

3)  
   one way to do this is to:

4)  
   one way to do this is to:
3.3.4 Concept Map and Homework

Continue to work on your Concept Map

Add the following words to your map.

Mitigation
Power Plant
Fossil Fuel
Sinks
Sources
Power Plants and How they Work

80% of all energy used in the US is formed in this way
There are many different ways to heat water to create steam.

Power Plants use energy to heat water.

Most commonly the power comes from burning coal.

Diagram of a Turbine

Steam from heated water turns the blades around a shaft. The turning creates electricity.

Most of our energy is created by somehow turning this turbine.
Coal Fired Power Plants

Mohave Power, Nevada
Photograph: Southern California Edison Co

Craig Power, Colorado
Photograph: Tri-State G&T Association

Natural Gas Fired Power Plant
Moss Landing, California Operator: Duke Energy
Photograph by Declan McCullagh
Solar Power Plant
Prescott, AZ  Operator: Arizona Public Service
Photograph courtesy of Power

Nuclear Power Plant
Diablo Canyon, California Operator: PG&E
Photo taken by Jim Zimmerlin, PG&E Employee
Wind Power Plants

Medicine Bow, WY
Operator: Platte River Power Authority
Photo: Greg Goebel

Spanish Fork Canyon, UT
Operator: Wasatch Wind LLC
Photo: Suzion