**Pre-Lab Activity**

**Climate Change: The Gas Phase**

**Materials Per Pair**

2 Computers *(We recommend one computer displaying the instructions and one displaying websites)*

1 molecular model kit

**As a Class – Greenhouse Gases**

1. Watch the following video together: <http://tinyurl.com/sdenningvid> As you watch the funny antics of this climate scientist, use your model kits to build the greenhouse gas molecules that he describes.
2. At the end of the video, capture the points you *didn’t already know* about greenhouse gases. Discuss these points with your group and summarize below:
3. With a group of 4, discuss this image in relation to the video: <http://tinyurl.com/greenhsimg>
4. Decide whether you wish to watch the video again to ensure the new points you learned are clarified.
5. As you learned in *Society’s Fuels: Past and Future Quests for Energy*, the emission rate of CO2 into the atmosphere due to human activities, and the length of time it lasts in the atmosphere, help make it the most worrisome and often discussed greenhouse gas. However, methane concentrations *have more than doubled since the mid-1800s*! Each person builds a methane molecule: <http://tinyurl.com/methanegg>
6. Time to learn about methane as a greenhouse gas…Learn how scientists make estimates about methane gas emissions. Open this image: <https://tinyurl.com/MethaneAtlas>
   1. Have a few class members survey the image as a think-aloud, paying attention to the directions of the arrows and their relative size, the colors, and the 5 source categories.
   2. Revisit the statistics definitions of *mean, max*. and *min*. values. In this visual, the main number is the mean, and the values in parentheses are min. and max. The values are determined through a variety of calculations.
   3. Follow along as a few class members take turns reading the caption below the image.
   4. Certain bacteria in wetland soils make methane naturally, as long as the temperatures are warm enough, like they are in Southeast Asia. Use your model kits to construct the reactant and convert it to the products:

**C6H12O6 🡪 3CO2 + 3CH4**

(The sugar reactant is derived from cellulose in wetlands plants)

Sometimes a chemical *sink* acts like a trap, holding the chemical for long periods of time. Soils are also home to bacteria that *remove* methane from the atmosphere, making soils a methane sink as well as a source.

* 1. Do human (*anthropogenic*) or natural activities account for most of the methane in the atmosphere? Which particular activities? Use the diagram to find evidence for your answer and discuss!
  2. A *sink* generally describes processes such as chemical reactions that remove the chemical (methane), often by changing its form. Methane can react with OH- to form mainly H2O and CO2. Represent an initial reaction in this series using your model kits:

**CH4 + OH- 🡪 [CH3]- + H2O**

This reaction is one of the biggest sources of water vapor in the atmosphere—and water vapor is the most abundant greenhouse gas. From there, the following reaction proceeds quickly. Build it, being sure to build both reactants first:

**[CH3]- + O2 🡪 + [CH3O2]-**

Many reactions occurring simultaneously create *formaldehyde* (CH2O) and other products, including more CO2. Interestingly, data from Mars rover *Curiosity* are making NASA scientists contemplate possible methane sources and sinks on Mars! https://tinyurl.com/MethaneMars Build one of the molecules you see in the Mars diagram.

What are sources of atmospheric methane on Mars?

How can studying Mars help us learn about Earth[[1]](#footnote-1)?

* 1. Back to methane emissions as a greenhouse gas on Earth…Since gases swirl around the dynamic atmosphere, it can be difficult to determine how much of a given greenhouse gas is present, and where those gases originate.

Scientists use a variety of data collection methods, which tends to produce a range of data rather than a single value. This can make it difficult to decide how much to regulate industries, or specific facilities, that emit a greenhouse gas into the atmosphere.

1. *Top-down strategies* take measurements from different regions of the atmosphere using devices on satellites, planes, and towers. Researchers use advanced models to back-track these measurements to land-based regions responsible for emissions (14 in the data visualization below). It is difficult to pinpoint specific facilities using this strategy, but all sources of the gas are accounted for.
2. *Bottom-up strategies* begin on land, at sources of the emission, such as fossil fuel production and agriculture (5 categories in this visualization). Researchers used advanced models to determine how these emissions contribute to the atmosphere. It is difficult to account for all sources of a given gas, but easier to tell how much a given source is contributing[[2]](#footnote-2).
3. Based on these general definitions, which strategy involves some *extrapolation*? (Hint: The Post-Lab Activity questions in your GUD I *Bacterial Study* lab can refresh your memory).
4. Which strategy affords more *accuracy* in determining the source of the emission?
5. As a class, view this video from 2:57 to 10:55 to hear about these strategies from Dr. James W.C. White from the National Academies of Sciences in Engineering and Medicine in the USA. This is an overview of a 2018 report: https://tinyurl.com/NASMethane2018
   1. Open this related interactive data visualization: https://tinyurl.com/MethaneAtlasViz

Use your mousepad to slowly roll over the 14 land regions on the left, and the 5 human source categories on the right.

We are destroying wetlands. How will this impact methane concentration in the atmosphere?

Evaluate the combination of the two visuals and the researcher’s explanation—does it help you understand global sources and sinks of methane? Discuss.

**With a Partner – Photon Absorption Simulation**

1. Now it’s time to see how certain gases ‘trap’ heat to warm the planet. Hint: it’s about more than sheer *abundance*! Go to <https://phet.colorado.edu/en/simulation/greenhouse> and click DOWNLOAD. Check your download folder for the file if you don’t see it. Open the simulation.
2. First, go to the Photon Absorption tab at the top. You have 5 gases to test with both the infrared and visible photons. Play with the simulation for a few minutes to see what it tests. Think about what data might be interesting to collect.
   1. Based on your knowledge of the EM spectrum and the previous lab, define *infrared* and *visible light photons*:
   2. Create a data table to capture data for both types of photons and all 5 gases. Insert your data table below. Before you proceed, raise your hand to discuss your data collection table with the teacher:
3. Use your collected data as evidence to answer these questions:
   1. Which gases are greenhouse gases? Explain how you know.
   2. Does this evidence confirm or disprove the information you learned from Dr. Denning in the video? Explain.
   3. At the molecular level, describe the possible outcomes when a greenhouse gas encounters an infrared photon.
   4. From this simulation, which gases seem most effective at absorbing infrared photons?
   5. Chemically speaking, methane is 28 times more effective than CO2 in absorbing infrared photons in the atmosphere! Right now, CO2 remains in the atmosphere for far longer and there is more of it. But if the amount of methane increases, more OH- is removed through chemical reactions. This leaves more intact methane in the atmosphere for longer periods of time. Further, increasing temperatures on land can also lead to increased release of methane via the bacterial reactions in soils!

If we don’t stop putting methane into the atmosphere, describe 2 possible effects (discuss first, then draw or write your reasoning below):

* 1. Raise your hand when finished and the teacher will listen to your reasoning before continuing to the next step.

1. Now click the **Build Atmosphere** radio button in the Photon Absorption tab. With your partner, discuss HOW you want to build your atmosphere and why. Don’t just randomly pick numbers of molecules, THINK about what you want to SIMULATE.

Record your final atmospheric composition here, and explain why you composed your atmosphere this way:

1. Run your atmospheric simulation, noting what happens.
2. As a class, come together to discuss the results of the atmospheric simulation.

**With a Partner – Greenhouse Effect Simulation**

1. Now click the Greenhouse Effect tab in the same simulation. Review the menu items on the right side to orient you to the simulation. NOTE: You cannot see the greenhouse gases, only the photons.
2. Create a second data table to capture your observations. Then complete the table.
   1. Note the greenhouse gas composition at each time period (Today, 1750 and Ice Age). This simulation shows 388 ppm, but as of October 2018, Earth was at 406 ppm atmospheric CO2!!
   2. Describe infrared photon activity at each time period.
   3. Describe sunlight photon activity at each time period.
   4. Note temperature range (°C) at each time period.
3. Click the radio button **Adjustable concentration** and move the slider between None and Lots. What slider position most closely resembles “Today?”

**As a Class – Human-accelerated Greenhouse Effect and Climate Change**

1. Discuss your findings from this simulation. Summarize by describing any relationships you discovered:
2. Society’s quest for energy has left a footprint on the entire planet. Global atmospheric concentrations of CO2 over time describe this footprint. Interpret the data in this CO2 movie and discuss what that footprint shows: https://tinyurl.com/ESRLCO2

Silently as an individual, use Google Draw to sketch a curve on x-y axes that shows an extrapolation of these data, if no action is taken by 2020 to reduce CO2 emissions. Share with a partner and discuss as a class.

1. Humans have accelerated global warming on our planet by increasing the emissions of CO2, methane and other greenhouse gases. View this movie, or drag the slider yourself, to view the change in global temperature since 1884: https://tinyurl.com/temptimemachine
2. However, **increase in global temperature is not equal to climate change**. It is an indicator, but not the whole picture. According to the USA Global Change Research Program,

*[Climate change* may be described as] changes in average weather conditions that persist over multiple decades or longer. Climate change encompasses both increases and decreases in temperature, as well as shifts in precipitation, changing risk of certain types of severe weather events, and changes to other features of our climate system.

See this model of the climate system: <https://tinyurl.com/ClimateSystemComponents>

1. So, how do climate scientists arrive at their predictions about the future of the planet, and *are they correct*?

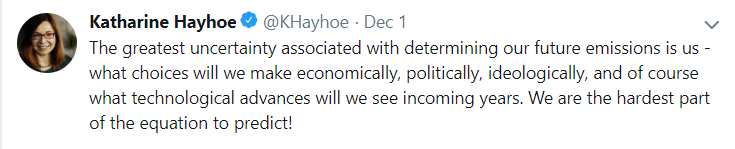
We can’t know future *measurements* for certain. But we can combine recent and historic measurements with scientific understanding natural phenomena—such as our understanding of the greenhouse effect—and *assume* that human-caused climate change will persist if left unchecked. Swift, forceful action must be taken in order to alter current trends.

Climate scientists publish annual reports based on possible future *scenarios* modeled using *several* variables—from GHG emissions, to national policies to sea level rise. We need to use several variables because *climate* is a dynamic system of interacting abiotic and biotic factors. Download this Figure, presented in the 2018 National Climate Assessment report, which is consistent with internationally accepted models[[3]](#footnote-3). Insert it in the space below: https://tinyurl.com/2018scenarios

Have a volunteer read the following caption aloud as you study the graphs:

**Simplified caption**: The black curve in both graphs represents the actual measurements we have to date. The colored curves represent 3 different possible future scenarios. The “Higher Scenario” represents a pathway of unchecked emissions of GHGs, which is consistent with current human activities. If we do nothing to check fossil fuel combustion and land use activities (including agriculture, industrial processing and deforestation), the “Higher Scenario” shows how both global carbon emissions and global average temperature change increase markedly. In fact, global average temperature (shown on the right) *depends* on the emissions scenarios (shown on the left). This cause-effect relationship also is demonstrated in the “Lower” and “Even Lower” Scenarios. Note that human activities cause the shifts in global carbon emissions scenarios. The Paris Agreement now has 195 signatories, committing them to the “Lower Scenario” that limits the increase in global average temperature change to ~1.5 °C. One reason this temperature threshold is important is that it correlates with increased impacts on many other climate system variables: drought risk, wildfires, risk of coral bleaching, and extreme weather events, etc. However, impacts of climate change are happening now and scientists are urging policymakers and citizens to take immediate action.

1. How do these climate scientist scenarios compare to your extrapolations? Discuss this and other reflections on the scenarios as a class.
2. Dr. Katharine Hayhoe is a Canadian scientist working in the USA, and one of the authors of the 2018 report that presented these scenarios, shown above. Read this Tweet from December 1, 2018:



What is her underlying message? Do you think human activities related to GHG emissions are difficult to predict, 20-50 years into the future? Explain and discuss as a class.

**Learning More about Climate Action**

1. Watch this video of a 20-year-old Australian woman responding to questions about why she is taking action for the climate: https://tinyurl.com/AussieProtest2018
2. With a partner, discuss your reactions to her response. How would *you* have responded?
3. Engage with the online dialogue to see what others are saying: Follow one or more groups taking action on climate change on Twitter to get news feed until the end of this lab. Try these: @UNFCCC, @KHayhoe, @ThisZeroHour, @NASAGISS, @ClimateCentral, @IYCM, @UN4Youth.
4. Download the **NASA Visualization Explorer** App on your Smart phone or computer. It is available here: <https://svs.gsfc.nasa.gov/nasaviz/index.html> or by searching the title in the AppStore or GooglePlay.

Once downloaded, search for *Warm World of 2017* and view the visualizations. Discuss as a class. The visualizations on this app are updated regularly and will be useful to you as you explore this lab and others.

1. Check out this 2018 Special Report by the Intergovernmental Panel on Climate Change (IPCC): https://tinyurl.com/IPCC2018SR

1. Read this NASA news release for more information (optional): https://tinyurl.com/JPLMarsMethane [↑](#footnote-ref-1)
2. This researcher explains how he used both strategies, and some of the math involved, in his research on methane and carbon dioxide emissions in California, USA (optional video): https://tinyurl.com/TDBUAir [↑](#footnote-ref-2)
3. The figure may be found inside the full report, with its original caption, here (optional): https://tinyurl.com/2018scenarioscap [↑](#footnote-ref-3)