Greenhouse Gases and the Atmosphere
ASTR 1010

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Overview:
In this activity you will study the greenhouse effect. You will first determine what atmospheric molecules are potentially greenhouse gases. Next, you will see how greenhouse gases trap heat and how they are thus able to raise the surface temperature of a planet.

Objectives:
After completing this activity, students will be able to:
• Explain how greenhouse gases raise surface temperatures.
• Understand how humanity has impacted climate equilibrium.
• Calculate the relative percentage change.

Definitions
Here are some terms from lecture that we will be using today in lab:

• **Light**: a form of electromagnetic radiation. It consists of photons, which are particles that carry energy and travel in waves. The most familiar form of light is what we can see – "visible light".

• **Heat**: a form of energy that is transferred between objects due to a temperature difference. It flows from a hotter object to a cooler one until thermal equilibrium is reached.

• **Thermal Equilibrium**: a state where two or more objects that are in contact with each other reach the same temperature, and therefore there is no net flow of energy (heat) between them.

• **Greenhouse Gas:** a gas in the Earth's atmosphere that absorbs and radiates heat.

• **Greenhouse Effect:** where greenhouse gases trap heat from the Sun, thereby warming the planet's surface by absorbing and re-emitting radiation.

• **Albedo:** a measure of the reflectivity of a surface, specifically how much sunlight (solar radiation) is reflected by that surface compared to how much is absorbed. An albedo of 0 indicates complete absorption while an albedo of 1 is when the surface reflects all incoming solar radiation.

• **Flux:** the flow or transfer of energy, particles, or other quantities per unit area over time. For our purposes, flux will measure the relative energy in versus energy out.

• **Energy In:** the amount of energy entering a system – in our case sunlight hitting the Earth.

• **Energy Out:** amount of energy leaving the system – in our case heat radiating away from the Earth.

Part 1: Molecules in your Atmosphere
You may have thought the air you breath is basically oxygen, but the truth is air is composed of different molecules. In fact, air is about 78% nitrogen, 21% oxygen, 0.9% argon, and a mere 0.04% carbon dioxide, along with trace amounts of other molecules. We will now observe how different wavelengths of light interact with different molecules of gas and determine which of these molecules are **greenhouse gases**. Go to the simulation here:

https://phet.colorado.edu/sims/html/molecules-and-light/latest/molecules-and-light_all.html

Press the green button on the flashlight to start the simulation. Pass photons (light) of both infrared and visible light through the molecules of each of the gases listed below in the table. Describe the interaction for each. Determine which molecules are greenhouse gases.

GAS	Visible	IR	Greenhouse Gas?
N_2	Photons pass through	Photons pass through	No
O_2	Photons pass through	Photons pass through	No
CO_2	Photons pass through	Absorb -> re-emit	Yes
CH_4	Photons pass through	Absorb -> re-emit	Yes
H_2O	Photons pass through	Absorb -> re-emit	Yes

Part 2: Many Layered Atmosphere
For this next part we will explore how greenhouse gases affect temperature. Go to the simulation here:

https://phet.colorado.edu/sims/html/greenhouse-effect/latest/greenhouse-effect_all.html

Click on Layer Model.
Set the albedo to 0.3 to approximate Earth's current albedo. Solar Intensity should be set to "Our Sun". Check "Flux Meter" (lower right). To start the simulation click on **Start Sunlight**. We will record what we observe in the table below. To make sure you are on the right track, some of the table is completed for you – verify that you are observing the same results, and do not forget to complete the remaining cells for the first row.

# Layers	Sunlight In	Sunlight Out	IR In	IR Out	Total In	Total Out	Surface T (ºC)
0	4	1	0	3	4	4	18
1	4	1	3	6	7	7	30.3, -17.9
2	4	1	6	9	10	10	62.7,30.3,-17.9
3	4	1	9	12	13	13	87.8,62.7,30.3,-1

Now, add 1 absorbing layer and record your results in the table.
→ **Make sure to let the simulation reach thermal equilibrium before recording your measurements.**
Finally, do the same thing for 2 and 3 layers.

1)How do the sunlight photons interact with the absorbing layer?
The sunlight photons remain the same as they interact with the absorbing layers.

2)How do the reflected IR photons interact with the absorbing layer?
The IR photons going in are increasing by 3 starting from 0 with zero layers. The IR photons going out are increasing by 3 starting from 3 with zero layers.

3)Explain why adding "absorbing layers" increases the surface temperature. Also, what exactly are these "absorbing layers"?
The absorbing layers are infrared radiation. The more there are, the more greenhouse gases are trapped, increasing the surface temperature accordingly.

Part 3: Greenhouse Earth
Using the same simulator, we will now explore the greenhouse effect on Earth.
Click on Photons.
Complete the table below. The surface temperature should be in ^{o}C once equilibrium has been reached.

Greenhouse Gas Concentration	**Temperature (No Cloud)**	**Temperature (Cloud)**
None	-9.3	-17.9
Middle	13.8	4.4
Lots	36.0	25.8

4)Explain the (perhaps surprising) role the cloud had on the surface temperature and why?
The cloud plays the role of decreasing the surface temperature because it reduces the amount of sunlight coming in.

5)Explain whether clouds would continue to cool the Earth, or heat the Earth, at night?
The clouds would heat the Earth at night because they ' re absorbing the emitted IR, thus becoming warmer.

In the "Greenhouse Gas Concentration" widget **click on the calendar icon**. Notice that CO_2 is given as "ppm" which is parts-per-million while the other two gases are in "ppb" or parts-per-billion. The last Ice Age was obviously pre-industrial revolution, which started around 1750. There were a number of factors that resulted in the last ice age which ended some 11,700 years ago. For our purposes, we shall concentrate on what humanity has done. The formula for relative percentage change is given by:

$$P = \frac{X_2 - X_1}{X_1} \times 100$$

Where X_2 is the final value, X_1 the initial value. So if you get a value of 10 that means that the initial amount has increased by 10%.

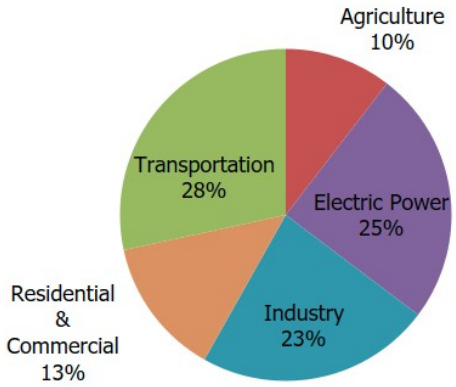
6)Calculate the relative percentage change from 1750 to 2020 for CO_2 and CH_4.
Show your work.

The CO2 in 1750 is 277 ppm and the CH4 is 694 ppb. The CO2 in 2020 is 413 ppm and the CH4 is 1889 ppb. The percentage change in CO2 is (413 ppm - 277 ppm)/277 ppm x 100 = 49.1%. The percentage change in CH4 is (1889 ppb - 694 ppb)/694 ppb x 100 = 172.2%.

7)Now calculate the relative percentage change in surface temperature from 1750 to 2020.
Show your work.

The surface temperature in 1750 was 13.6 C and 14.9 C. The percentage change is (14.9 C - 13.6 C)/13.6 C x 100 = 9.6 %.

What could be causing the increase in surface temperature? Over long periods of time, from 10,000 to millions of years, nature can certainly play a role. However, in just a few hundred years the answer is clearly humans. Now you may have heard of a term called the **carbon footprint** which is the total amount of greenhouse gases, primarily carbon dioxide, that are emitted directly or indirectly by an individual, group, organization, etc. The total sources of greenhouse gas emissions can be found here: https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions
Below is a summary of the total greenhouse gas emission:



8)In what ways do you think you contribute to the increase in greenhouse gases? For example, you might think you don't contribute to "Agriculture", but greenhouse gas emissions from agriculture comes from livestock – so if you eat chicken or beef, you are contributing! To a lesser extent, the same is true for rice and other crops. To answer this question fully, you may want to look at the link provided above.

In terms of agriculture, I consume rice every day and chicken every week along with the general vegetables. In terms of transportation, I commute to campus two days a week and take out the car once during the weekends. I cut down my power use however along with using mostly LED lights. In terms of residential and commercial, I very rarely turn on the heating and cooling, opting for blankets or shorter clothes instead. For electric power, I cut down on my use of power both at home and outside.

9)Now that you have considered your carbon footprint, what do you think people could do as a whole to release fewer carbon emissions?

People as a whole could first start learning more about their impact and others around them. Comparing statistics will help identify sources that can be cut down.

Part 4: Runaway Venus, Runaway Earth?

10) As you likely learned in lecture, Venus is the canonical example of a "runaway greenhouse". That said, Venus was almost certainly once very much like Earth – it had oceans and was likely a habitable planet, for a time. However, Venus is also closer to the Sun and receives more radiation. Return to the **Layer Model** and keep the albedo at 0.3, but increase the Solar Intensity to 200% which is approximately what Venus receives. With 3 Absorbing Layers, what is the surface temperature of Venus?

30.3 C, 87.7 C, 126.3 C, 156.0 C

11) Based on your answer to Q10, explain what happened to all of Venus' water and how this paved the way to a runaway greenhouse?

With the increasing temperatures, it ' s clear that all of Venus ' water evaporated, paving the way for a hotter and IR emitting runaway greenhouse.

12) Most scientists do not believe Earth will become another runaway Venus. However, there is no doubt that the added carbon emissions are leading to severe climate impacts – leading to extreme heat and fires, rising sea levels, and disrupted ecosystems. How important a problem do you feel this to our civilization?

Although I don ' t believe Earth will become another runaway greenhouse—and even if it does stand a chance, it probably won ' t happen until billions or years later—I think that the rising climate impacts are certainly a problem large enough for civilization to address.

13) Some people have advocated the following to help fight climate change: reduced energy consumption including using less electricity and less driving. Limiting consumption – for instance, reusing clothing more often and far less purchasing of disposable goods such as shoes, clothes, etc. Eating more plant-based foods and consuming less dairy and especially less meats. Lastly, many have argued that there needs to be a smaller world population. What are your thoughts on all of this?

Despite all the activism and people changing their diets and routines, it has shown only a small percentage of change. The largest contributors to climate change are corporate-owned factories and tech servers—seeing this, my thoughts are that people should focus more on using their time to protest against these companies. Although our personal efforts are having a good impact, it ' s still practically nothing when compared to the negative consequences from these corporations.