Name\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

## Factors Affecting Average Global Temperature

**Purpose:** The purpose of this lab is to investigate three of the many factors that affect Earth’s average global temperature; the greenhouse effect, cloud cover, and albedo.

**Background:**

Earth’s atmosphere is made of up many gases, mostly nitrogen N₂ and oxygen O₂ gases, but also carbon dioxide CO₂, water vapor H₂O, and methane CH₄, among other compounds. Gases that absorb and reemit infrared light are greenhouse gases. Gases that do not interact with infrared light are not greenhouse gases. The **greenhouse effect** makes temperatures favorable for life on Earth but makes other planets, like Venus, uninhabitable.

**Albedo**is the fraction of light that a surface reflects. A surface that reflects 100% of light has an albedo of 1, while a surface that absorbs 100% of light has an albedo of zero.

**Instructions:** For each part, follow the instructions to set up each scenario in the simulation and answer the corresponding questions.

**Part 1: Greenhouse Gases**

Go to <https://phet.colorado.edu/sims/html/molecules-and-light/latest/molecules-and-light_all.html>

In this simulation, you will observe how different wavelengths of the electromagnetic spectrum interact with different molecules of gas. Try passing photons of infrared and visible light through molecules of each of the gases listed in the table below. Describe the interaction for each.

|  |  |  |
| --- | --- | --- |
| Gas | Visible | Infrared |
| Nitrogen |  |  |
| Oxygen  |  |  |
| Carbon Dioxide |  |  |
| Methane |  |  |
| Water |  |  |

1. Based on your observations, which gases are greenhouse gases.

The remaining parts of the lab, you will use the following simulation.

<https://phet.colorado.edu/sims/html/greenhouse-effect/latest/greenhouse-effect_en.html>.

**Part 2: Modeling the Greenhouse Effect with Absorbing Layers**

In the Layer Model module, set the albedo to 0.3 to approximate Earth’s current average albedo. Click on *Flux Meter.* Drag the flux meter to just above the surface. Click on *Start Sunlight*, and let the sim run until the surface temperature stabilizes. The **Earth absorbs the sunlight** photons (yellow) and then, **radiates infrared** photons (red). From the *Flux Meter*, record the units of both incoming and outgoing sunlight radiation in the table below. Do the same for the infrared radiation. Then, calculate the total incoming and outgoing radiation.

Add one absorbing layer, and make sure the flux meter is below the absorbing layer. Let the simulation run until the surface temperature stabilizes and record the data in the table below.

1. How do the sunlight photons interact with the absorbing layer?
2. How do the infrared photons interact with the absorbing layer?

Add another layer and record the data. Finally, add a third layer and record the data.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| # of Layers | Sunlight In | Infrared In | Total In | Sunlight Out | Infrared Out | Total Out | Surface T |
| 0 | 4 | 0 | 4 | 1 | 3 | 4 | -18°C |
| 1 |  |  |  |  |  |  |  |
| 2 |  |  |  |  |  |  |  |
| 3 |  |  |  |  |  |  |  |

1. How did the surface temperature change as you added absorbing layers? Explain why this happens.

**Part 3: The Greenhouse Effect on Earth**

Click on the Photons module. Set the greenhouse gas concentration to none. Uncheck *Cloud*. *Start Sunli*ght and let the simulation run until the surface temperature stabilizes.

1. With no greenhouse gases in the atmosphere or no clouds, what is the temperature at the surface of the Earth?

Slowly move the greenhouse gas concentration slider upward and stop at the middle.

1. Observe the behavior of the infrared photons. Explain what is happening.
2. When the slider is in the middle, what is the surface temperature? How does this compare to the temperature when there are no greenhouse gases present.
3. An increase in greenhouse gas concentration leads to a(n) (**increase** or **decrease**) in surface temperature.

Reset the simulation. Under *Greenhouse Gas Concentration*, click on the calendar. Set the conditions to *Ice Age*. Note the greenhouse gas concentrations in the table below. Run the simulation until the temperature stabilizes. Record the surface temperature in the table below.

Complete the table below by running the simulation for the remaining time periods.

|  |  |  |
| --- | --- | --- |
| Time Period | Greenhouse Gas Concentrations | Temperature |
| CO₂ | CH₄ | N₂0 |
| Ice Age |  |  |  |  |
| 1750 |  |  |  |  |
| 1950 |  |  |  |  |
| 2020 |  |  |  |  |

1. From the Ice Age to 2020, how much did the global average temperature change? Based on the table above, what was one of the contributing factors to this temperature change?

**Part 4: Effect of Clouds on Temperature**

Reset the simulation. Again, start with the greenhouse gas concentration at zero. This time check *Cloud* in order to simulate the presence of clouds. *Start Sunlight*. Allow the surface temperature to stabilize.

1. How are the sunlight photons interacting with the cloud?
2. How are the infrared photons interacting with the cloud?
3. Did the surface temperature increase, decrease or stay the same? (compare to the temperature in Part 3 Question #1)

For the following questions, use the internet to research.

1. How can clouds affect surface temperature **on a local scale** during the day?  What about at night?
2. What is the net effect of cloud cover on Earth's global temperature today?

**Part 5: Albedo**

**Albedo**is the fraction of light that a surface reflects. A surface that reflects 100% of light has an albedo of 1, while a surface that absorbs 100% of light has an albedo of zero. Keep in mind that a perfect absorber is also a perfect emitter.

Click on the Layer Model module. Set the surface albedo to zero. Click on *Flux Meter.* Drag the flux meter to just above the surface. Click on *Start Sunlight*, and let the sim run until the temperature stabilizes. The **Earth absorbs the sunlight** photons (yellow) and then, **radiates infrared** photons (red).

1. Compare and contrast the *Energy Flux* sunlight and infrared arrows. Relate your observation to the fact that you set the albedo to 0.
2. What is the surface temperature in this scenario?

Reset the simulation. Set the albedo to 0.3 (30%), which is the current average albedo of Earth’s surface. Click on *Start Sunlight* and let the sim run until the temperature stabilizes.

1. Observe the *Energy Flux* sunlight and infrared arrows. Explain why they look the way they do.
2. What is the temperature and why is it colder than the temperature with zero albedo?

While the sim is running, slowly increase the albedo of Earth’s surface.

1. Observe the *Energy Flux* arrows for sunlight and infrared radiation. What happens to the temperature? Explain why.

**Closing Questions:**

1. Do you think Earth’s albedo was more or less during the Ice Age than it is now? Would this affect global temperature? Explain.
2. Explain how the greenhouse effect works at Earth’s surface IN YOUR OWN WORDS.
3. Use the internet to research the heat island effect. Briefly explain the heat island effect and why it occurs.