Energy Transfer:

Laboratory for Primary Level Students

Student Manual

WS2

WOMEN SUPPORTING
WOMEN IN THE SCIENCES

Meet a Scientist

Joyce Elisadiki

Lecturer, Department of Physics, University of Dodoma
WS2 Co-Founder & Lab Kit Design Co-Lead, Heat Transfer (Primary)

About me:

In my ordinary level education, I opted for science subjects which later helped me to undertake Physics, Chemistry and Mathematics (PCM) combination in my advanced level secondary education, all in government schools. I received a Bachelor of Science with Education with two teaching subjects (Physics and Chemistry) and Master of Science in Physics from the University of Dar es Salaam and PhD in Sustainable Energy Sciences and Engineering from the Nelson Mandela African Institution of Science and Technology in Arusha, Tanzania. Prior to my current position, I completed a postdoctoral fellowship at the Botswana International University of Science and Technology. I am interested in doing research that will solve the problems of water and energy that are facing my community using energy efficient water purification technologies.

My advice for students interested in physics:

Most students think that Physics is a very hard subject, so they opt to drop it at their ordinary school education. By adding some effort to understand the underlying concepts, students will realize they can learn Physics!

Mission Statement

This laboratory will teach energy transfer concepts to a target audience of elementary/primary-aged students (ages ~6-12) through experiments related to energy transformation and energy absorption.

Contents

1. Introduction to WS2 Laboratories

1.1. Information about WS2

Women Supporting Women in the Sciences (WS2), an international organization unifying and supporting graduate and professional-level women and allies in science, technology, engineering, and mathematics (STEM), was awarded an American Physical Society (APS) Innovation Fund in 2020 to form international teams to design and distribute low-cost physics and materials science lab kits to 5000 primary and secondary school students, predominantly in eastern Africa. The lab kits are intended to utilize local resources and include topics that are especially relevant to young girls in order to spur their interest in STEM subjects. The international teams, which designed the content found in these laboratory manuals, worked with WS2 Partners in eastern Africa in order to successfully deliver and teach the science lab kits to their local communities through 2022. WS2 gratefully acknowledges the hard work of the teams in the creation of this lab kit content. For more information about WS2, please visit our website at ws2global.org.

WS2 is sponsored by the APS Innovation Fund, Northwestern University Materials Research Science and Engineering Center, and Northwestern University Multicultural Student Affairs. WS2 Partners receiving lab kits are representatives from Makerere University (Uganda), Masinde Muliro University of Science and Technology (Kenya), Mbeya University of Science and Technology (Tanzania), Mkwawa University College of Education (Tanzania), Nelson Mandela African Institution for Science and Technology (Tanzania), University of Dar es Salaam (Tanzania), University of Dodoma (Tanzania), and University of Rwanda (Rwanda). The APS, Materials World Modules, SciBridge, and Projekt Inspire have provided valuable input on WS2 lab kit design. WS2 especially thanks WS2 Partner representatives (John Bakayana, Pendo Bigambo, Daudi Mazengo, Lawrence Robert Msalilwa, Celine Omondi, Marcellin Rutegwa), Tom Coon and students of Haile-Manas Academy (Debre Birhan, Ethiopia), and Carla Johnston and students of Frank Bergman Elementary School (Manhattan, KS, USA) for piloting the lab kits with small focus groups in late 2021. WS2 also tremendously thanks the virtual lab kit design team that created the content for this lab manual.

1.2. Key Vocabulary

- Energy: The ability to do work
- Energy transfer: The movement of energy from one location or object to another
- Heat transfer: The movement of heat from one location or object to another (heat is always transferred from warm objects to cold objects)
- Atmosphere: The gases surrounding the Earth
- Greenhouse gas effect: When gases become trapped and heat up an environment

1.3. Key Questions

- What is heat transfer?
- What are greenhouse gases?
- How can greenhouse gases impact the Earth?

1.4. Purpose

The purpose of this lab is to demonstrate the impact of greenhouse gases in the environment and how energy transfer plays a role in our lives. Energy is part of our everyday lives; it is constantly changing and moving. Like when the Sun can heat up our bodies on a hot summer day, when we eat and digest food, or when we burn wood for fire, energy is transformed for practical purposes all around us every day,

2. Background on Main Topics

2.1. Energy and its Transfer

The Sun is an extremely powerful source of energy; for centuries people have used the Sun as a source of reliable and renewable energy to cook food and warm themselves. <u>Energy</u> is the ability to do work or make something move or change in some way. Have you ever been chilly in the shade or indoors, but when you go outside you feel an instant warmth? That is the power of the Sun's energy! The Sun's energy gets to you by <u>energy transfer</u>, which is the movement of energy from one location or object to another. This transfer of energy, especially thermal energy like heat, can occur in different ways.

<u>What is heat transfer?</u>

<u>Heat transfer</u> is when heat moves from one object to another. The heat always moves from the warmer object to the colder object. There are different types of heat transfer, including convection, conduction, and radiation (see Figure 1). You experience all three of these types every day! Convection is the transfer of heat through gas or a liquid in a pattern called a convection current. You may experience convection when it's windy near the ocean or sea, when water boils, or when the blood moves around your body. Conduction is the transfer of heat from one object to another by direct contact. Examples of conduction are when you heat a pan on a stove, your feet become hot when you walk on hot rocks or pavement, or when a spoon becomes hot in soup or tea. Radiation is the transfer of heat through space. You may experience radiation from sunlight or from feeling warm by a fire. As you may know from cooking foods or trying to cool off on hot days, some materials are better at getting hot than others. This means they are good at transferring heat.

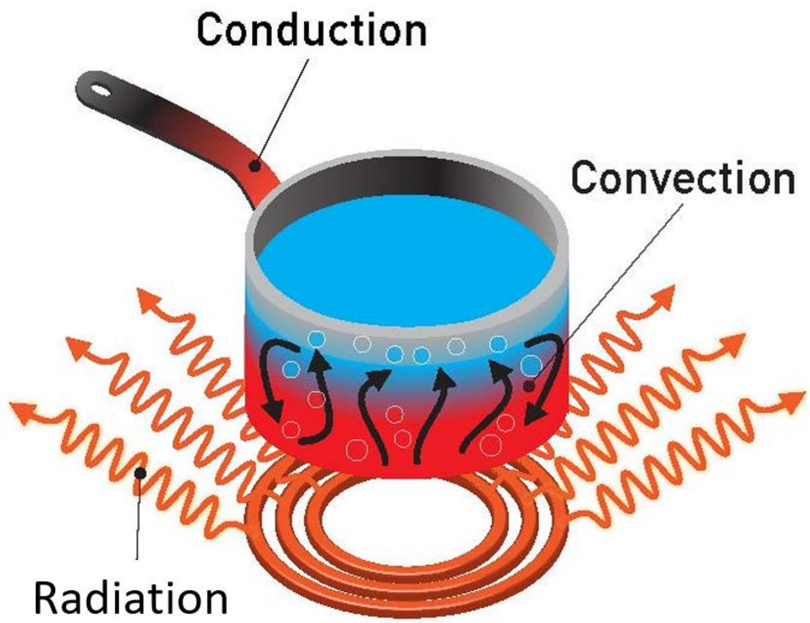

Figure 1. Conduction, convection, and radiation are three types of heat transfer. When you boil water in a pot, all three types are working to heat up the water and the pot! This Photo by Unknown Author is licensed under CC BY.

Do some materials transfer heat faster than others?

Everything around us is made from materials. Think of your home and the many materials the items in your house are made from like wood, metal, plastic (sometimes called polymer), ceramic, and maybe even living matter. Heat moves through different types of materials in different ways, making some materials better at heating up than others. For example, heat moves quickly through metals making them perfect as a container for boiling water or cooking food. Think again of your home and the containers you use for cooking food. Are they often made of metal?

How does heat transfer impact the Earth?

One example of how heat transfer impacts the Earth is related to its atmosphere, which is the blanket of gases surrounding the Earth. Gas is another material that can transfer heat. There are certain types of gases called greenhouse gases that trap energy from the Sun and lead to the greenhouse gas effect, which is the warming of the Earth's surface and the air above it. Have you ever heard of a greenhouse? This is a building made of glass which allows sunlight to pass through to heat the environment inside. A greenhouse stays warm enough to grow plants even in cool weather. Common greenhouse gases in our atmosphere are water vapor (the most abundant), ozone, carbon dioxide, methane, and nitrous oxide, all of which are naturally present. Some greenhouse gases, however, are not natural. Some are chemicals made by people and others result from burning fuel.

<u>So, what exactly is the greenhouse gas effect?</u>

When the Sun shines down on the Earth, the light passes through the layer of greenhouse gases on the way down to us at the Earth's surface. The Earth's surface heats up from the Sun's light, but at night the surface cools, and the heat is released back into the atmosphere. Some part of this energy passes back into space, but some

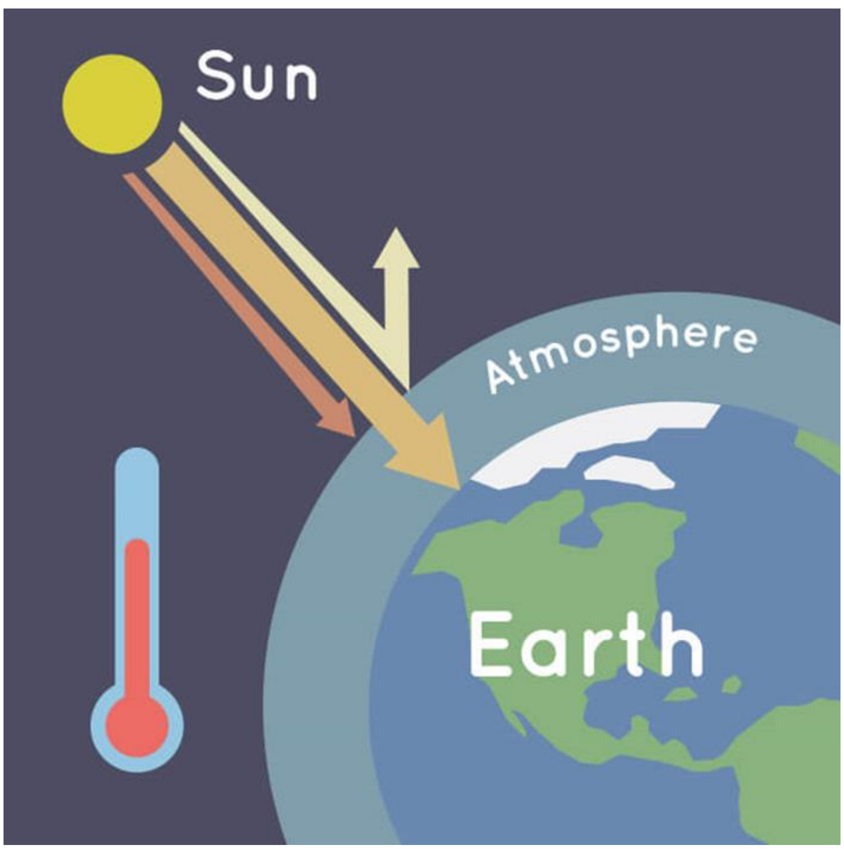

Figure 2. Sunlight hits the Earth, and these light rays can be absorbed into the atmosphere or reflected into space. The atmosphere traps some of the Sun's rays, which heats the Earth. Credit: NASA/JPL-Caltech.

stays trapped in the atmosphere by the greenhouse gases. This trapping of heat by the greenhouse gases in our atmosphere gives our world the heat we need to survive (see Figure 2)! The natural greenhouse effect has made the planet we call home good for growing food and housing all animals and plants. Without the natural greenhouse effect, Earth would be too cold for life to exist. It would be a solid ball of rock and ice—dropping from 14 °C (57 °F) to as low as -18 °C (-0.4 °F).

Can the greenhouse gas effect be harmful?

Yes! If there is too much of the greenhouse gas effect, the Earth will heat up and the temperature could rise more than what is comfortable or tolerable for animals and plants. If the temperature of the Earth rises by just a few °C, this could make parts of the planet too hot for humans to survive.

Unfortunately, human activities like pollution, cutting trees, and burning fuels add or contribute to extra greenhouse gases in the atmosphere. As humans make more of these gases, the temperature of the Earth rises. We call this global warming.

2.2. Sources

https://www.bulbapp.com/u/conduction-convection-and-radiation~1

https://scied.ucar.edu/teaching-box: Center for Science Education (UCAR) - includes NGSS for middle and high school students.

Climate Change Live. https://climatechangelive.org/index.php?pid=180

Solar Influence & Climate Change. https://cleanet.org/resources/43776.html

https://www.earthsciweek.org/classroom-activities/your-own-greenhouse

https://climatekids.nasa.gov/greenhouse-cards/

https://climatekids.nasa.gov/greenhouse-effect/

https://www.steampoweredfamily.com/activities/the-greenhouse-effect-experiment/

https://sciencing.com/homemade-alternative-baking-soda-vinegar-8509768.html

2.3. Supplies List

- 1 glass object, 1 metal object, 1 plastic object
    - Optional: Fabric, ceramics, rocks, plants, whatever materials you think may be fun to try!
- 5 glass or plastic jars
    - These can be used food or drink jars
- 1 marker for writing on the jars
- Plastic covering for the jars (can be plastic wrap, a plastic bag, or any other flexible plastic material)
- Elastic band or fabric strip to secure the plastic around the jar
- 1 measuring cup
- Two chemicals (one from Chemical 1 options and choose Chemical 2 based on Chemical 1) to make the greenhouse gas reaction occur
    - Chemical 1 options:
        - Vinegar
        - Ketchup
        - Soda (any carbonated beverage)
    - Chemical 2:
        - If Chemical 1 is vinegar or ketchup:
            - Baking soda
        - If Chemical 1 is soda:
            - Salt
- Thermometer (optional)

2.4. Safety Information

Before the students begin the laboratory, please take into consideration the following safety concerns:

- Students should be careful when heating objects in the Sun! Objects may become hot quickly.

3. Experiments

3.1. Part I. Heat Transfer

3.1.1. *Summary*

In this experiment, we are going to test how heat from the Sun is transferred to objects and how the material the object is made of matters.

3.1.2. *Pre-Experiment Questions*

1. What objects in your life heat up quickly?

2. Do you know what the objects are made of that heat up quickly?

3. What are some objects that you use that you want to heat up fast? What are these objects made of?

4. What are some objects that you don't want to heat up fast or at all? What are these objects made of?

3.1.3. *Materials*

- 1 glass object
- 1 metal object
- 1 plastic object
- Fabric, ceramic, rocks, plants, etc. (optional to test)

3.1.4. *Procedure (work in groups of 2-4)*

1. For the materials you have collected, record in the table in Results which you think will heat up the fastest and the slowest when placed in the sunlight. If you want to rank all of the materials in order as your prediction, you can rank them starting with "1" being the object you think will heat up the fastest, "2" being the next object to heat up the fastest, and so on.
2. Compare the temperatures of the glass, plastic, and metal objects (plus other objects you want to test) in your classroom. Record your results in the table. You can list words like "warm", "cool", "room temperature", etc.
3. Place the objects in the sunlight. This can be outside in the sunlight or an area of the classroom with lots of sunlight coming through a window.
4. After 5-10 minutes, feel the temperature of the objects with your hand or a thermometer. Record your observations in the table in Results. If you don't have a thermometer, use words like "cold", "chilly", "cool", "warm", "hot", and "very hot".
    a. Note: depending on the time of year and sunlight, this step may take longer than 5-10 minutes. If needed, you can move to Part II and come back to this step later.
5. Now, place the objects in the shade. This can be outside in the shade or in a shaded part of the classroom.
6. After 5-10 minutes, feel the temperature of the objects with your hand or a thermometer. Record your observations in the table in Results. If you don't have a thermometer, use words like "cold", "chilly", "cool", "warm", "hot", and "very hot".

3.1.5. *Results*

Object	Which object will heat up the fastest? Slowest?	Temperature of object in the classroom (or before placing in sunlight/shade)	Temperature of object after sunlight	Temperature of object after shade
Glass				
Plastic/Styrofoam				
Metal				

3.1.6. *Post-Experiment Questions*

1. Which object heated up fastest in the sunlight? Which object was the slowest to heat up in the sunlight? How did these results compare with your predictions?

    a. Extension question: Did the color of the object matter?

    b. Extension question: Based on the types of heat transfer you learned about in the Introduction, which type heated the objects in this experiment?

2. Why did you record the temperatures of the objects before placing them in the Sun?

3. Which object cooled fastest in the shade? Which object cooled slowest in the shade?

4. Consider a future experiment that tests how quickly other objects you don't currently have with you heat up in the sunlight. Predict how well these objects will transfer heat based on what they are made of. Be creative!

3.2. Part II. Make Your Own Atmosphere

3.2.1. *Summary*

In this experiment, we will simulate the greenhouse gas effect. Inside jars, we will see if we can create an environment that is like what happens on Earth when we burn wood or fuel for cars that generate greenhouse gases that cause the atmosphere to heat up. The air inside the jars represents the atmosphere of the Earth and the chemicals inside them represent things on Earth that when mixed together give off greenhouse gases. When two things (sometimes called "chemicals") are added together and give off gases and/or heat and produce a new thing (or new chemical), we call this a "chemical reaction".

3.2.2. *Pre-Experiment Questions*

1. What is the greenhouse gas effect?

2. What are examples of greenhouse gases?

3.2.3. *Materials*

- 5 glass or plastic jars
- 1 marker for writing on the jars
- Plastic covering for the jars (can be plastic wrap, a plastic bag, or any other flexible plastic material)
- Elastic bands or fabric strips to secure the plastic around the jar
- 1 measuring cup
- Two chemicals (one from Chemical 1 options and choose Chemical 2 based on Chemical 1) to make the greenhouse gas reaction occur
    - Chemical 1 options:
        - Vinegar
        - Ketchup
        - Soda (any carbonated beverage)
    - Chemical 2:
        - If Chemical 1 is vinegar or ketchup:
            - Baking soda

        - If Chemical 1 is soda:
            - Salt
- Thermometer (optional)

3.2.4. *Procedure (work in groups of 4)*

Note: A schematic of the jars you will prepare and measure in the following steps is shown in Figure 3.

1. Label the glass or plastic jars: "air", "1st chemical", "2nd chemical", "closed greenhouse effect", and "open greenhouse effect".
2. Cover the jar labeled "air" with plastic and secure it to the lid of the jar with an elastic band or a tied piece of fabric.
3. Record the temperature of the jar in "Temperature before sunlight" in the table in Results. Use your hands to describe the feeling or the thermometer to measure the temperature inside the jar.
4. Pour 60 mL (1/4 cup) of chemical 1 into the jar labeled "1st chemical". Cover the jar labeled "1st chemical" with plastic and secure it to the lid of the jar with an elastic band or a tied piece of fabric.
5. Record the temperature of the jar in "Temperature before sunlight" in the table in Results. Use your hands to describe the feeling or the thermometer to measure the temperature inside the jar.
6. Add 15 mL (1 tablespoon, or 1 spoonful) of chemical 2 to the jar labeled "2nd chemical". Cover the jar labeled "2nd chemical" with plastic and secure it to the lid of the jar with an elastic or a tied piece of fabric.
7. Record the temperature of the jar in "Temperature before sunlight" in the table in Results. Use your hands to describe the feeling or the thermometer to measure the temperature inside the jar.
    a. Note: The "air", "1st chemical", and "2nd chemical" jars act as "controls" in the experiment. A control is a part of an experiment that we can compare our results to that helps us learn.

Now, we will prepare the "closed greenhouse effect" jar. Each student will have a job:

8. Student 1: Measure 60 mL (1/4 cup) of chemical 1 and have it ready to add to the "closed greenhouse effect" jar. Don't add it yet!
9. Student 2: Measure 5 mL (1 tablespoon, or 1 spoonful) of chemical 2 and have it ready to add to the "closed greenhouse effect" jar. Don't add it yet!

10. Student 3: Have a piece of plastic and elastic band or piece of fabric ready to seal the jar.
11. Student 4: Feel the outside of the jar before we add any chemicals. Write down if it feels cold, cool, warm, or hot in "Temperature before reaction" in the table in Results.
12. Student 2: Add chemical 2 to the jar.
13. Student 1: Add chemical 1 to the jar on top of chemical 2.
14. Student 3: Quickly seal the jar with plastic! We want to keep the reaction (meaning the gases that are produced) inside the jar, so try to move quickly!!
15. Student 4: Feel the outside of the jar and record how it feels in the table in Results in "Temperature after reaction".

Finally, we will prepare the "open greenhouse effect" jar. Each student will have a job:

16. Student 1: Measure 60 mL (1/4 cup) of chemical 1 and have it ready to add to the "open greenhouse effect" jar. Don't add it yet!
17. Student 2: Measure 5 mL (1 tablespoon, or 1 spoonful) of chemical 2 and have it ready to add to the "open greenhouse effect" jar. Don't add it yet!
18. Student 3: Feel the outside of the jar before we add any chemicals. Write down if it feels cold, cool, warm, or hot in "Temperature before reaction" in the table in Results.
19. Student 3: Add chemical 2 to the jar.
20. Student 4: Add chemical 1 to the jar on top of chemical 2.
21. Student 4: Feel the outside of the jar and record how it feels in the table in Results in "Temperature after reaction".

Now, we will test if any gases we created in our jars (Earth's atmosphere) will be trapped and heated by the sunlight, similar to how greenhouse gases created on Earth are heated by the sunlight in our atmosphere.

22. Place all jars in the direct sunlight.
23. Wait 5-10 minutes after your jars have been left in the sunlight. If you have a thermometer, insert the thermometer carefully into the jar by poking a hole in the plastic covering of those jars covered in plastic. Record the temperature or the feeling of the jars in "Temperature after sunlight" in the table in Results.

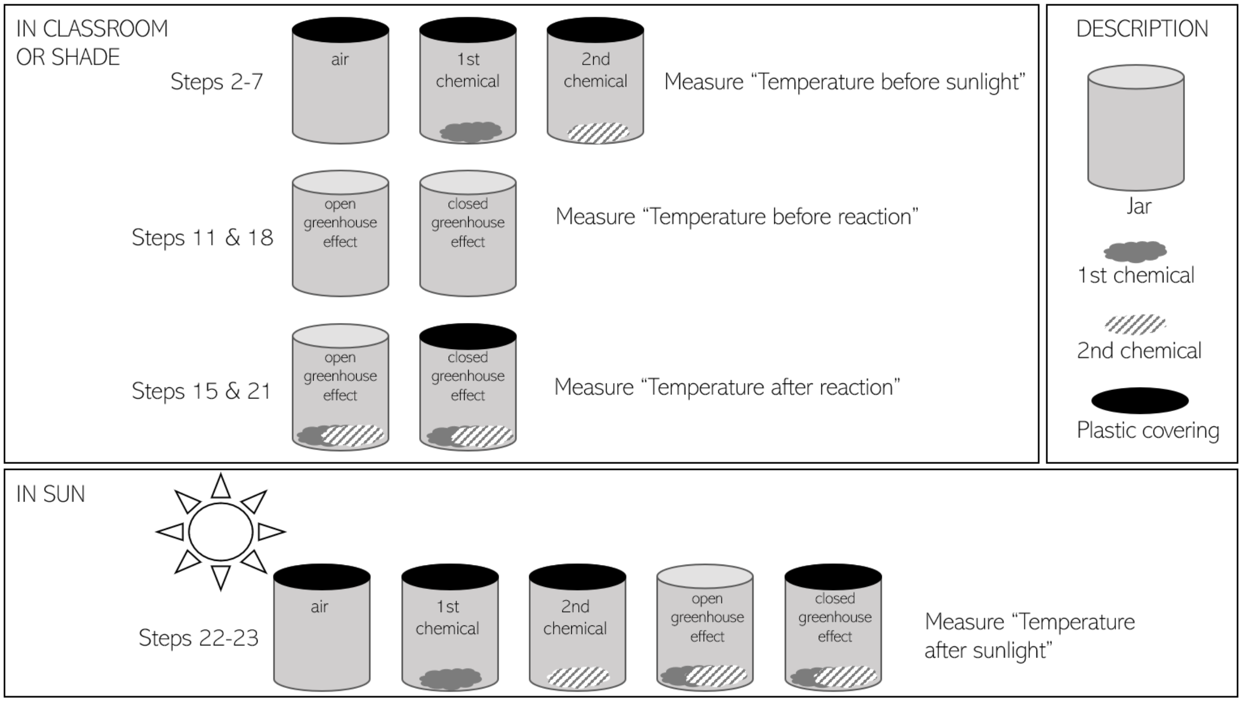

Figure 3. Schematic of the jars that the students will prepare with steps from Procedure. The upper left rectangle includes jar measurements taken in the classroom or shade. The bottom rectangle includes jar measurements taken in the sunlight. The upper right rectangle includes a description of the items in the Figure.

3.2.5. *Results*

Note: Those boxes with "X"s do not need to be filled in.

Jar	Temperature before reaction	Temperature after reaction	Temperature before sunlight	Temperature after sunlight
Air	X	X		
1st chemical	X	X		
2nd chemical	X	X		
Closed greenhouse effect			X	
Open greenhouse effect			X	

3.2.6. *Post-Experiment Questions*

1. Which jar warmed up the most after sitting in the sunlight? Why do you think this happened?

2. Why do you think the “closed greenhouse effect” jar became hotter than the “open greenhouse effect” jar?

3. Why do you think the “air”, “1st chemical”, and “2nd chemical” jars didn’t become as hot as the closed greenhouse gas effect jar?

4. Which jar in this experiment represents the earth heating up due to the greenhouse effect?

5. In the “closed greenhouse effect” jar, the release of gas (known as carbon dioxide) from the chemical reaction was trapped inside the jar as a greenhouse gas. Carbon dioxide is also formed when burning wood for fire, burning coal, driving cars (burning gasoline), and making new things in factories. What are some ways we can burn less carbon dioxide in our lives?

4. Design Challenge

<u>The Challenge:</u> Now that we have learned about heat transfer from sunlight and the greenhouse gas effect, it's time to use your knowledge to solve some hard problems! We know that if there is too much of the greenhouse gas effect, the Earth can heat up, and this temperature rise can lead to the changing of the Earth's climate and cause more extreme weather events like extreme heat and drought and intensity of storms. Can you design a house that may keep you comfortable and safe both now and as the Earth's climate changes?

4.1 Design Questions

Consider the following questions when designing your resilient home.

1. What weather events might you have to protect against?

2. What materials would you want your house to be made from? Are the materials different for the roof, walls, doors, and floor?

3. Do you want lots of windows and doors?

4. Do you want the Sun to shine into your house? Consider how this could be both a positive and a negative.

5. How could you make sure the stove does not heat up your house during cooking?

4.2 Design Sketch

Try out your design by sketching it on paper. You can also color it in with markers, pens, pencils, and crayons. Be creative!

<u>My resilient home:</u>