LAB 12

Lab Handout

Lab 12. Cycling of Water on Earth: Why Do the Temperature and the Surface Area to Volume Ratio of a Sample of Water Affect Its Rate of Evaporation?

Introduction

Water can be found as a liquid, solid, or gas on Earth. Lakes, rivers, and oceans contain liquid water. For example, Lake Tahoe (shown in Figure L12.1a), which straddles the border between California and Nevada, contains 36.15 cubic miles of liquid water. Polar ice caps and glaciers contain solid water. For example, the Perito Moreno glacier (see Figure L12.1b), located in western Patagonia, Argentina, is a huge ice formation that is 30 km in length, 5 km wide, and has an average height of 74 m. The atmosphere contains gaseous water vapor. Unlike the other two forms of water, gaseous water vapor is invisible. We can see water vapor only when it condenses to form visible clouds of water droplets such as in Figure L12.1c. Water vapor is responsible for humidity.

FIGURE L12.1

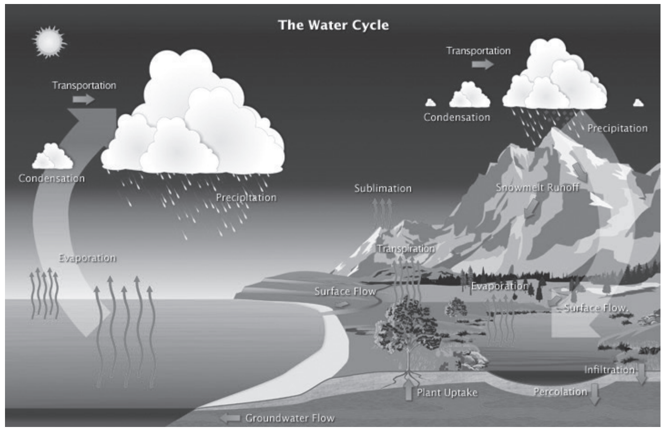
Water can be found in all three states on Earth. (a) Lake Tahoe contains liquid water. (b) The Perito Moreno glacier contains solid water. (c) Gaseous water is invisible unless it condenses to form clouds of water droplets, as seen in the Owakudani volcanic valley in Japan.

a b c

All water is made up of molecules that are composed of two hydrogen atoms and one oxygen atom. This type of molecule is called a water molecule. All water molecules have the same mass. Water molecules are also constantly in motion. Because water molecules have mass and are constantly in motion, they have *kinetic energy.* Temperature is a way we can measure the average kinetic energy of the molecules in any sample of water. A high temperature means that the molecules in the sample have high average kinetic energy and are moving quickly, while a low temperature means the molecules have low kinetic energy and are moving slowly. The three states of water are determined by temperature. At low temperatures (less than 0°C), water is a solid (ice); at room temperature, water is a liquid; and at high temperatures (more than 100°C), water is a gas.

FIGURE L12.2

The water cycle explains how water molecules move into, out of, and within Earth's systems



The water cycle, shown in Figure L12.2, is a model that scientists use to explain how water molecules move into, out of, and within Earth's systems. This process is driven by energy from the Sun and the force of gravity. When energy from the Sun heats liquid water, some of it transforms into gaseous water vapor and enters the atmosphere. This process is called evaporation. The water vapor rises into the air, where cooler temperatures cause it to condense into tiny liquid water droplets. A huge concentration of these droplets becomes visible to us as a cloud. Air currents move clouds around the globe. The water droplets in clouds collide, grow, and eventually fall to the ground as precipitation. Some precipitation falls as snow and can accumulate as ice caps and glaciers, which can store frozen water for thousands of years. Snowpacks in warmer climates often thaw and melt in the spring, and the melted water flows overland as snowmelt. Most precipitation, however, falls back into the oceans or onto land. On land, the water will flow over the ground as surface runoff because of the force of gravity.

A portion of the runoff will enter rivers in valleys in the landscape and move toward an ocean. Some of the runoff accumulates and forms freshwater lakes. Some of the water will also soak into the ground. This water is called groundwater. Some of the groundwater will move deep into the ground and create aquifers, which are underground stores of freshwater, and some will stay close to the surface. The groundwater that remains close to the surface will seep back into lakes or rivers as groundwater discharge or will create freshwater springs. Over time, though, all of this water keeps moving, and it eventually reaches an ocean or returns to the atmosphere through the process of evaporation.

Water can evaporate and enter the atmosphere from sources as vast as the ocean and as small as your pet's water dish. At any place where the surface of the water meets with the air, water molecules are able to leave the liquid water and enter the atmosphere. It might seem like evaporation makes liquid water disappear, but recall that the law of conservation of matter states that matter can never be created nor destroyed, but it can change form. When evaporation happens, the molecules are simply changing from a liquid phase, which is visible to us, to a gaseous phase, which we cannot see. Keeping this in mind, we can tell how much evaporation has happened by measuring changes in the mass or volume of the liquid water.

You may have noticed that bodies of water evaporate at different rates. For example, a rain puddle on the street can evaporate in a few hours, but water in a glass may take days or weeks to evaporate. There are many factors that may affect the rate that water evaporates:

- The amount of energy that water absorbs from the Sun
- The temperature of the water
- The *surface area to volume ratio* of the water; or the amount of the water's surface that is exposed to the air compared with its total volume

In this investigation, you will have an opportunity to determine how water temperature and the surface area to volume ratio of a sample of water contribute to the rate that water evaporates. Once you understand how these two factors affect how quickly a sample of water will evaporate, you will then develop a conceptual model that you can use to explain your observations and predict how quickly water will evaporate under different conditions.

Your Task

Use what you know about the properties of water, rates of change, and the importance of tracking the movement of matter into, out of, and within systems during an investigation to plan and carry out an experiment to determine how changes in the temperature and the surface area to volume ratio of a sample of water affect how quickly it will evaporate. Then develop a conceptual model that can be used to explain *why* these factors affect the rate that water evaporates. Once you have developed your conceptual model, you will need to test it using different water samples to determine if it allows you to predict how much liquid water will be lost due to evaporation under different conditions.

The guiding question of this investigation is, ***Why do the temperature and the surface area to volume ratio of a sample of water affect its rate of evaporation?***

Materials

You may use any of the following materials during your investigation:

Consumables
- Water
- Ice

Equipment
- Safety glasses or goggles (required)
- Chemical-resistant apron (required)
- Pyrex containers of different shapes and sizes
- Electronic or triple beam balance
- Graduated cylinder (250 ml)
- Graduated cylinder (100 ml)
- Beaker (500 ml)
- Beaker (250 ml)
- Beaker (150 ml)
- Thermometer (nonmercury)
- 2 Heat lamps
- Hot plate
- Ruler

Safety Precautions

Follow all normal lab safety rules. In addition, take the following safety precautions:

- Wear sanitized indirectly vented chemical-splash goggles and chemical-resistant, nonlatex aprons throughout the entire investigation (which includes setup and cleanup).
- Report and clean up spills immediately, and avoid walking in areas where water has been spilled
- Use caution when working with heat lamps and hot plates; they can get hot enough to burn skin.
- Never spray water on hot heat lamps—glass will shatter, producing dangerous glass projectiles.
- Use only GFCI-protected electrical receptacles for heat lamps and hot plates to prevent or reduce potential shock hazard.
- Handle all glassware with care.
- Handle glass thermometers with care. They are fragile and can break, causing a sharp hazard that can cut or puncture skin.
- Wash hands with soap and water when done collecting the data and after completing the lab.

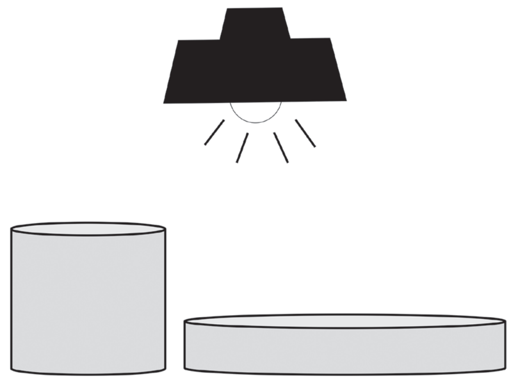
Investigation Proposal Required? ☐ Yes ☐ No

Getting Started

The first step in developing your model is to plan and carry out at least two experiments. Figure L12.3 (p. 300) shows how you can use a heat lamp to warm your different samples of water. The heat lamp will serve as the source of energy for each experiment. Your teacher may also allow you to set your water samples outside in direct sunlight depending on the time of year. Figure L12.3 also shows how you can use containers of different sizes and shapes to manipulate the surface area to volume ratio of a sample of water. You can use a hot plate to heat your water samples to different temperatures or to maintain the temperature of a water sample.

FIGURE L12.3

How to use a heat lamp to warm different samples of water



Before you begin to design your two experiments using this equipment, be sure to think about what type of data you need to collect, how you will collect the data, and how you will analyze the data. To determine *what type of data you need to collect,* think about the following questions:

- How will you track the flow of energy into each water sample?
- How will you track the amount of water loss from a sample?
- How will you measure the rate of water evaporation (change over time)?

To determine *how you will collect the data,* think about the following questions:

- What will be the independent and dependent variables for each experiment?
- What conditions will you need to set up for each experiment?
- How will you make sure you are only testing one variable at a time?
- How often will you need to take measurements during each experiment?
- What measurement scale or scales should you use to collect data?
- How will you make sure that your data are of high quality (i.e., how will you reduce error)?
- How will you keep track of and organize the data you collect?

To determine *how you will analyze the data,* think about the following questions:

- What type of calculations will you need to make?
- How will you determine if rates of change are the same or different?
- How could you use mathematics to document a difference between conditions?
- What type of table or graph could you create to help make sense of your data?

Once you have carried out your two experiments, you will need to develop a conceptual model. Your model needs to be able to explain why temperature and the surface area to volume ratio of a sample of water affect the amount of water lost due to evaporation in the way that these two factors do. The model also needs to account for the kinetic energy of water molecules and the conservation of matter.

The last step in this investigation is to test your model. To accomplish this goal, you can set up a third experiment to determine if your model leads to accurate predictions about the amount of water that will be lost from different containers of water under specific conditions (e.g., cold water, high surface area to volume ratio). If you are able to use your model to make accurate predictions about the way water evaporates under different conditions, then you will be able to generate the evidence you need to convince others that the conceptual model you developed is valid or acceptable.

Connections to the Nature of Scientific Knowledge and Scientific Inquiry

As you work through your investigation, be sure to think about

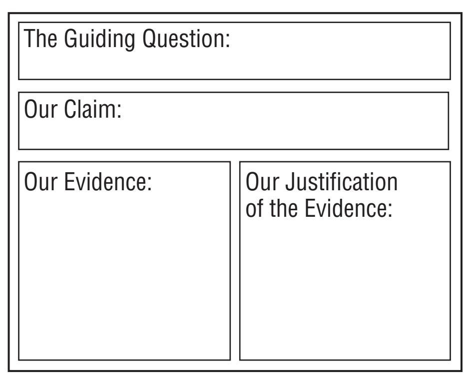
- the difference between observations and inferences in science, and
- the nature and role of experiments in science.

Initial Argument

Once your group has finished collecting and analyzing your data, your group will need to develop an initial argument. Your initial argument needs to include a claim, evidence to support your claim, and a justification of the evidence. The *claim* is your group's answer to the guiding question. The *evidence* is an analysis and interpretation of your data. Finally, the *justification* of the evidence is why your group thinks the evidence matters. The justification of the evidence is important because scientists can use different kinds of evidence to support their claims. Your group will create your initial argument on a whiteboard. Your whiteboard should include all the information shown in Figure L12.4.

FIGURE L12.4

Argument presentation on a whiteboard



Argumentation Session

The argumentation session allows all of the groups to share their arguments. One or two members of each group will stay at the lab station to share that group's argument, while the other members of the group go to the other lab stations to listen to and critique the other arguments. This is similar to what scientists do when they propose, support, evaluate, and refine new ideas during a poster session at a conference. If you are presenting your group's argument, your goal is to share your ideas and answer questions. You should also keep a record of the critiques and suggestions made by your classmates so you can use this feedback to make your initial argument stronger. You can keep track of specific critiques and suggestions for improvement that your classmates mention in the space below.

Critiques of our initial argument and suggestions for improvement:

If you are critiquing your classmates' arguments, your goal is to look for mistakes in their arguments and offer suggestions for improvement so these mistakes can be fixed. You should look for ways to make your initial argument stronger by looking for things that the other groups did well. You can keep track of interesting ideas that you see and hear during the argumentation in the space below. You can also use this space to keep track of any questions that you will need to discuss with your team.

Interesting ideas from other groups or questions to take back to my group:

Once the argumentation session is complete, you will have a chance to meet with your group and revise your initial argument. Your group might need to gather more data or design a way to test one or more alternative claims as part of this process. Remember, your goal at this stage of the investigation is to develop the best argument possible.

Report

Once you have completed your research, you will need to prepare an investigation report that consists of three sections. Each section should provide an answer for the following questions:

1. What question were you trying to answer and why?
2. What did you do to answer your question and why?
3. What is your argument?

Your report should answer these questions in two pages or less. You should write your report using a word processing application (such as Word, Pages, or Google Docs), if possible, to make it easier for you to edit and revise it later. You should embed any diagrams, figures, or tables into the document. Be sure to write in a persuasive style; you are trying to convince others that your claim is acceptable or valid.