# Water Cycle: How 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 the first picture below), 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 second picture below), 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 the third picture below. Water vapor is responsible for humidity.

**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.**

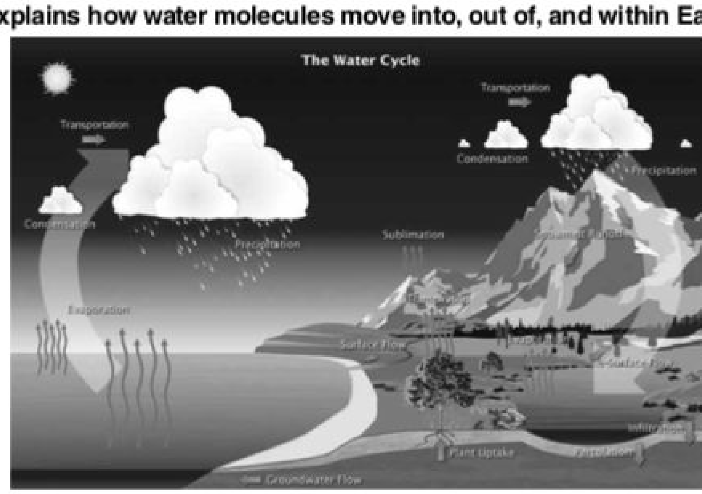
**a**

**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.

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




The water cycle, shown in the figure to the right, 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.

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

**Materials**

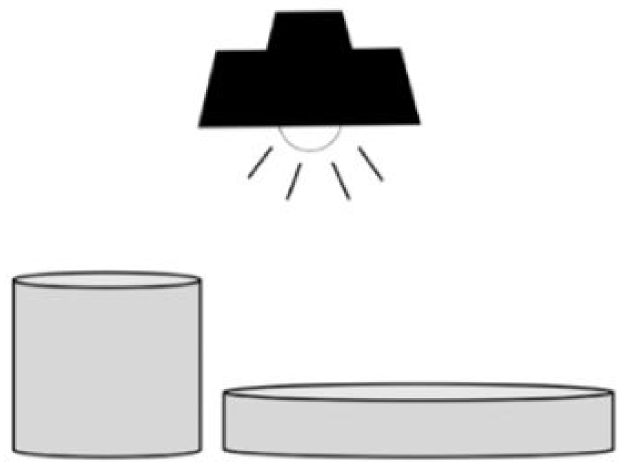
You may use any of the following materials during your investigation:

- Water
- Ice
- Containers of different sizes and shapes
- Balance
- Graduated cylinder (250 mL)
- Graduated cylinder (100 mL)
- Beaker (500 ml)
- Beaker (250 ml)
- Beaker (150 ml)
- Thermometer
- Hot plate or stove
- Ruler

**Getting Started**

You will need to design and carry out at least two different experiments to answer your guiding question for this lab. The figure to the right 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. The figure 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.

**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 <u>*what type of data you need to collect*</u>, 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 <u>*how you will collect your data*</u>, 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 <u>*how you will analyze your data*</u>, 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?

**Report**
Once you have completed your research, you will need to prepare an investigation report that consists of four sections (be sure to have section headings):

1. Introduction: Give some background information on the topic. Explain what question were you trying to answer and include a hypothesis. (Background info, research question and hypothesis)
2. Procedure: What did you do during your investigation and why did you conduct your investigation in this way? (How you collected and analyzed data)
3. Data: Include a data table and/or graph to show your results. Be sure to include a title for your table or graph with labels for the variables.
4. Conclusion: What is your argument? (Claim - Evidence - Reasoning) Include your conceptual model.

Your report should answer these questions in two pages or less. The report must be typed, and any diagrams, figures, or tables should be embedded into the document. Type your report on Google Docs (12 point font, double-spaced) and share it with your teacher. Your report will be graded based on the rubric in the class syllabus.