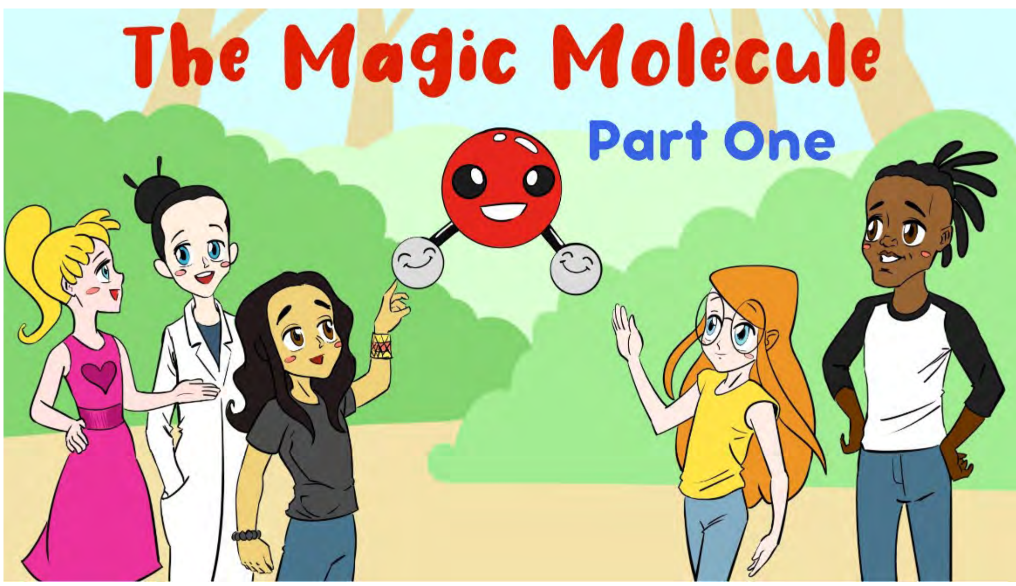
CO2 LEARNING CENTER

# Video Four Lesson Plan

## The Magic Molecule

***Part One***




***This lesson plan was produced by the CO2 Learning Center, a project of the CO2 Coalition.***

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***A note about our lesson plans:***

Our $CO_2$ Learning Center lesson plans all have the same format, which includes learning standards from the Next Generation Science Standards (NGSS), student learning objectives, background information on the science concepts covered in the book or video, suggested activities including labs to enrich the lesson and reinforce use of the scientific method, and formative and summative questions.

The NGSS are the standards on which most public-school systems have based their curriculum. We do not necessarily endorse the NGSS but have included the relevant standards for circumstances in which a teacher is required to use them. The lesson plans contain everything that a teacher might be required to submit in a formal lesson plan to a school administrator or science department head.

This lesson plan was created for the $CO_2$ Coalition's $CO_2$ Learning Center by Sharon Camp, Ph.D. Analytical Chemistry; B.S., Geology, using Next Generation Science Standards (NGSS).

Understanding NGSS:

LS: Life Science

PS: Physical Science

ES: Earth Science

1-5 indicates the standard for grade level (1-first grade, 2-second grade, 3-third grade, 4-fourth grade, 5-fifth grade)

MS: Middle School

*Please note that only the parts of the outline that are relevant to this lesson have been included. For example, if* LS1.A *and* PS3.D *are shown, these NGSS segments were included as relevant to this lesson for Life Science and Physical Science.*

# Lesson Plan: Video Four

## Grades K-8

## <u>Next Generation Science Standards (NGSS) Learning Objectives</u>

**MS-PS1-1. Develop models to describe the atomic composition of simple molecules and extended structures.**

- **PS1.A: Structure and Properties of Matter.** Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms.

**MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.**

- **PS1.A: Structure and Properties of Matter.** Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.

**MS-PS1-4. Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.**

- **PS1.A: Structure and Properties of Matter**
  - Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. (MS-PS1-1)
  - Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. (MS-PS1-2),(MS-PS1-3)
  - Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. (MS-PS1-4)
  - In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations. (MS-PS1-4)
  - Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals). (MS-PS1-1)

- The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter. (MS-PS1-4)

- **PS1.B: Chemical Reactions**

  Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. (MS-PS1-3)

- **PS3.A: Definitions of Energy**
  - The term "heat" as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and the transfer of that thermal energy from one object to another. In science, heat is used only for this second meaning; it refers to the energy transferred due to the temperature difference between two objects.

**MS-ESS2-4. Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity. [Clarification Statement: Emphasis is on the ways water changes its state as it moves through the multiple pathways of the hydrologic cycle. Examples of models can be conceptual or physical.]**

- **ESS2.C: The Roles of Water in Earth's Surface Processes**
  - Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downhill flows on land.
  - Global movements of water and its changes in form are propelled by sunlight and gravity.

*Source:* https://www.nextgenscience.org

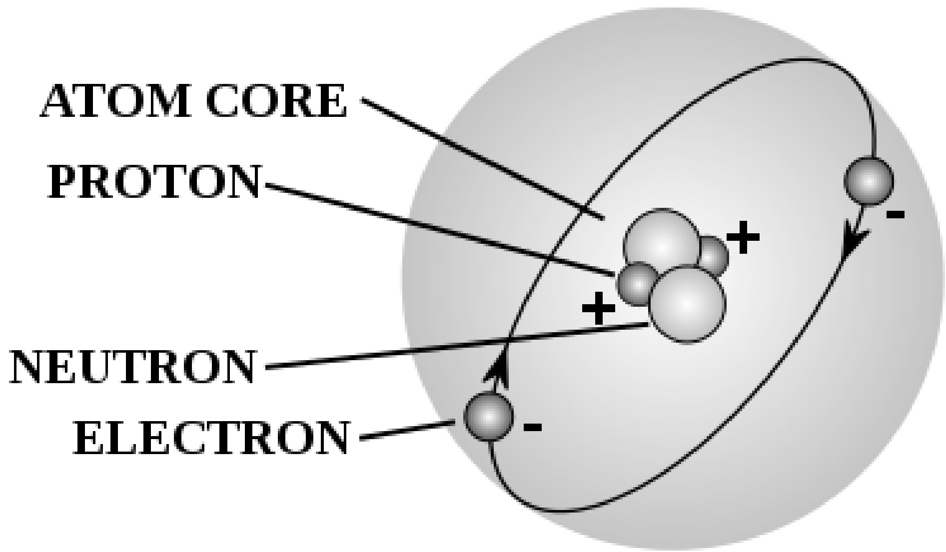
## Student Learning Goals

After watching *The Magic Molecule: Part One*, students will be able to:

- Explain that molecules are composed of atoms.
- Describe the structure of an atom.
- Explain how oxygen and hydrogen atoms combine to form a water molecule.
- Explain what a hydrogen bond is and how it is different from the covalent bond that holds a water molecule together.
- Explain how water changes when it loses energy (freezes).
- Explain how water changes when it absorbs energy (vaporizes).
- Describe the benefits to lakes and oceans when water freezes.
- Explain why solid water (ice) floats instead of sinking.
- Explain how clouds form.

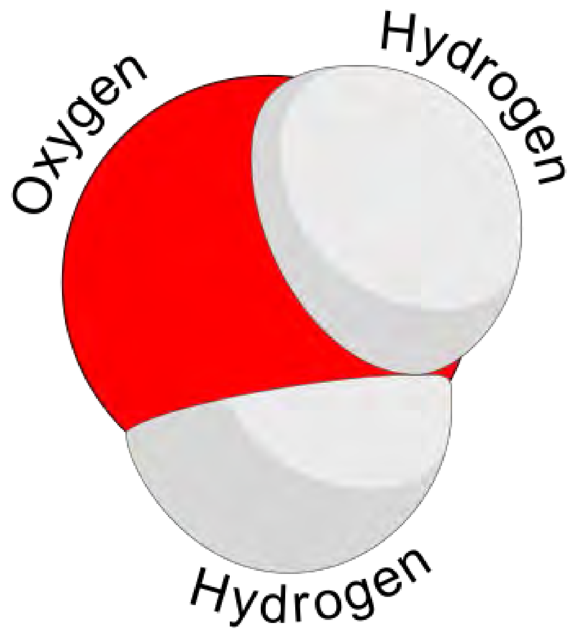
- Explain what a solvent is and why water is called the “universal solvent.”
- Explain what surface tension is and give examples of how the high surface tension of water can benefit many different organisms in various ways.
- Explain what capillary action is and why it is important to plants.

## Background Information



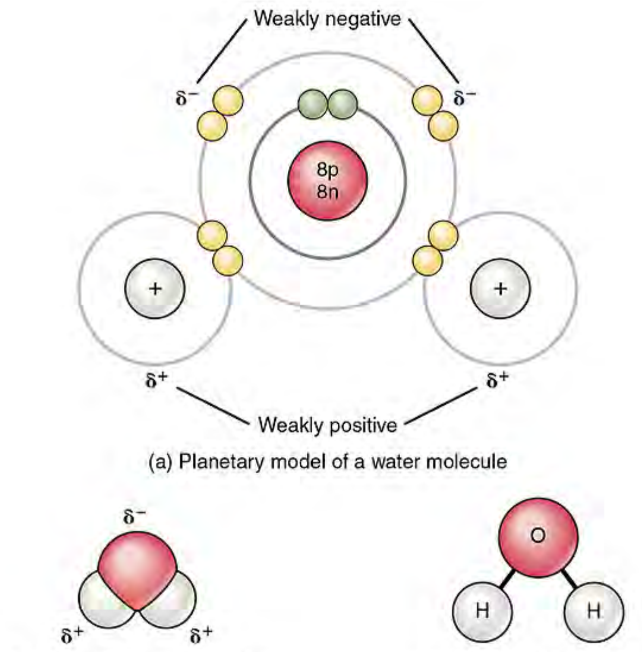

*Source: AhmadSherif, Public domain, via Wikimedia Commons, https://commons.wikimedia.org/wiki/File:Atom-struc.svg*

Atoms are the building blocks of matter and are the simplest particle of an element. Each naturally occurring and synthetically produced element is listed in the Periodic Table. An understanding of the specifics of the Periodic Table is not necessary for this lesson because only the elements hydrogen (atomic number 1) and oxygen (atomic number 8) are discussed in this video. It is, however, important that students understand that elements are made of only one kind of atom and compounds are made of a combination of different kinds of atoms bound together to form a single particle. The students should also understand that the new substance has new properties that are unlike any of the properties of the individual elements.




*Source: Booyabazooka at English Wikipedia, Public domain, via Wikimedia Commons, https://commons.wikimedia.org/wiki/File:Water_molecule_(1).svg*

Water is composed of two atoms of hydrogen chemically bound with one atom of oxygen. This type of bond is called a covalent bond, which occurs when atoms share electrons. Each hydrogen atom shares one electron with the oxygen atom, and the oxygen atom shares one electron with each hydrogen. This sharing of electrons provides stability to atoms that are not stable when they exist as single atoms. The atoms do not share the electrons evenly, however. Because of a property called electronegativity, the oxygen atom has a stronger pull on the electrons than either of the hydrogen atoms. This uneven sharing of electrons means that the oxygen will have a slight, or partial, negative charge, while each hydrogen has a partial positive charge.



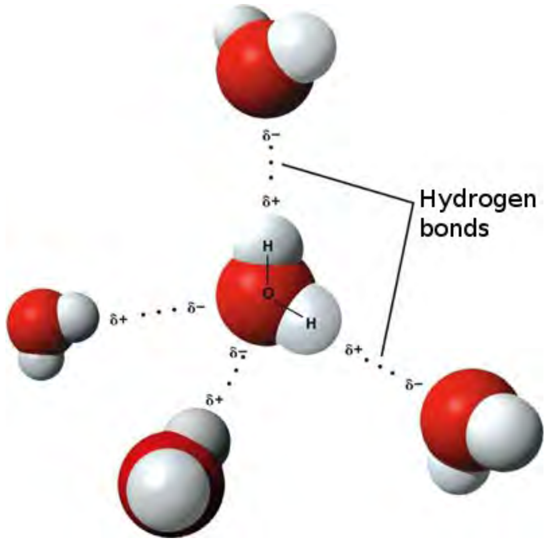
(a) Planetary model of a water molecule

(b) Three-dimensional model of a water molecule

(c) Structural formula for water molecule

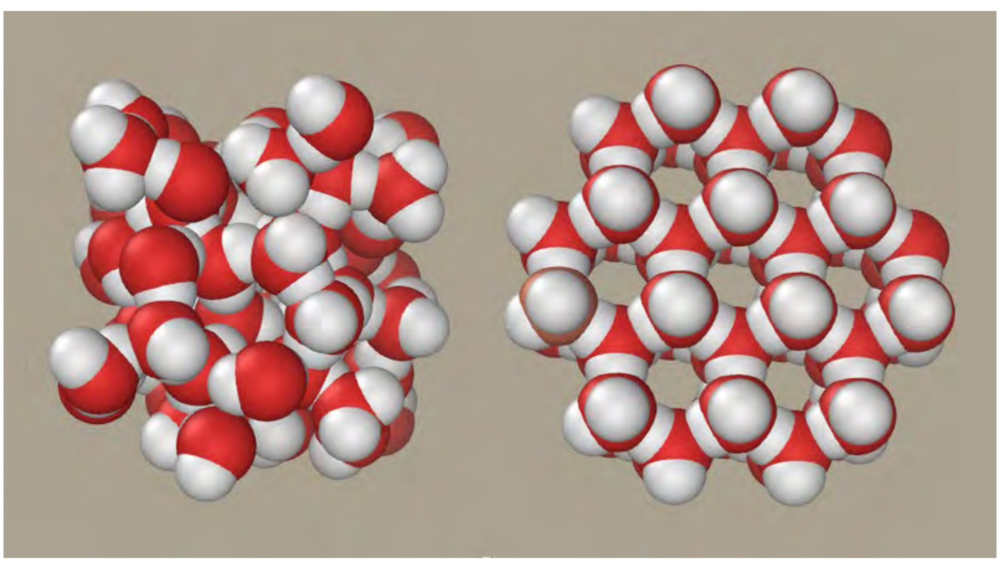
*Source:*
https://commons.wikimedia.org/wiki/File:209_Polar_Covalent_Bonds_in_a_Water_Molecule.jpg, *OpenStax College, CC BY 3.0 <https://creativecommons.org/licenses/by/3.0>, via Wikimedia Commons*

The bent shape of the molecule results in a molecule that has a positive side and a negative side and is said to be a polar molecule. This is similar to a magnet having a north and south pole; the north pole of one magnet is attracted to the south pole of another magnet. As in magnets, the opposites of molecules attract each other; the positive side of one water molecule is attracted to the negative side of another molecule. This attraction is called a hydrogen bond, which is really a misnomer because this attraction is not a true bond. Just as two magnets can be pulled apart, so can two water molecules. But this attraction among water molecules is so strong that it determines almost all of water's physical properties.




*Source:* https://commons.wikimedia.org/wiki/File:3D_model_hydrogen_bonds_in_water.jpg*, translated by Michal Maňas (User:snek01), Public domain, via Wikimedia Commons*

The three states of matter – solid, liquid, and gas – are affected by temperature or the movement of energy from one system to another. When energy is removed from liquid water, the water molecules move more slowly and can attach to one another forming a crystalline structure. Therefore, it changes from a liquid to a solid (freezing). This structure is less dense than liquid water, so frozen water (or ice) floats on top of water. Water is the only substance in which the solid state is less dense than the liquid state. This amazing property protects aquatic ecosystems from cold temperatures. Imagine if lakes and oceans froze from the bottom up!



*Liquid water on left; solid water (ice) on right. Source:* https://commons.wikimedia.org/wiki/File:Liquid-water-and-ice.png*, P99am, CC BY-SA 3.0 <https://creativecommons.org/licenses/by-sa/3.0>,via Wikimedia Commons*

When energy is absorbed by liquid water, the water molecules move more rapidly and break the attractive forces among the molecules, then move out into the atmosphere and form what is called water vapor. In vapor form, water molecules exist singly. Clouds form when water molecules condense onto tiny particles, such as dust, to form water droplets. This occurs when the temperature of the air is reduced, allowing the water vapor to change back into a liquid form or condense. If these water droplets get heavy enough, they fall out of the cloud in the form of rain. If the air is cold enough, the water molecules will form ice crystals instead of water droplets and fall in the form of snow. One source of water vapor in the atmosphere is from the oceans, although there are many other sources, including trees.

Water is called the universal solvent because it can dissolve almost any substance, including certain minerals (even though it will dissolve them in very tiny amounts). Water will dissolve other substances that are polar, such as different types of salts. Since sugar molecules are polar, they are easily dissolved by water. Gases are dissolved by water as well. Oxygen is critical for aquatic animals and is available to them because oxygen dissolves. Carbon dioxide also dissolves, which allows us to make fizzy drinks and allows ocean animals to make shells of calcium carbonate.

Surface tension is a physical property of liquids. When a liquid has a high surface tension, it appears as if the surface of the liquid is covered with a thin film of clear plastic. The surface tension of water is very high because the water molecules stick together like magnets, making the surface stronger than it would appear.

*Water Strider. Source:* https://pixabay.com/photos/water-striders-water-flea-animal-4443535/

This surface tension allows water striders to glide across the surface of a pond or creek. It is also the reason why the front of a watercraft has a wedge-shaped bow; the wedge shape makes it easier for the boat or ship to cut through the water. The surface tension of water also holds small amounts into a sphere or droplet. These droplets can contain small organisms, including bacteria, and can travel by wind for long distances. The strong attraction among water molecules allows capillary action, where water molecules will stick to each other like a chain of magnets. The attractive forces among these molecules are strong enough to allow them to be pulled up through the veins in a tree to reach the top. Evaporation of water from the leaves provides the pulling motion that brings the water up from the ground throughout the whole tree.

Rainbows form when tiny droplets of water bend, or refract, light waves as a prism does, separating the light from the Sun into different wavelengths that we perceive as color. The energy stored in large bodies of water also drives weather, which will be discussed in the next video.

*Double rainbow over a lake in Jackson, WY. Credit: Sharon Camp*

## For Further Information


1. https://chem.libretexts.org/Bookshelves/Introductory_Chemistry/Introductory_Chemistry_(CK-12)/15%3A_Water/15.01%3A_Structure_of_Water
2. https://www.usgs.gov/special-topics/water-science-school/science/facts-about-water
3. https://climatekids.nasa.gov/cloud-formation/
4. https://zoom.earth/
5. https://www.usgs.gov/special-topics/water-science-school/science/water-universal-solvent
6. https://www.scientificamerican.com/article/how-do-large-trees-such-a/
7. https://www.usgs.gov/special-topics/water-science-school/science/surface-tension-and-water
8. https://www.usgs.gov/special-topics/water-science-school/science/capillary-action-and-water
9. https://www.weather.gov/fgz/Rainbow

## Suggested Activities

**1. Water Kit Model:**


This model kit from 3D Molecular Designs is one of the best on the market. With this kit, the student can understand the difference between the covalent bonds that hold the hydrogen and oxygen atoms together, and the hydrogen bonds that are really attractive forces among the molecules. Capillary action and surface tension can also be modeled with this kit as can the attractions between the water molecules and another polar substance, sodium chloride (or table salt). Their website also includes free teacher materials, student handouts and videos with no purchase necessary. It might be possible to find this kit at a lower price from another source, but it is an excellent investment.

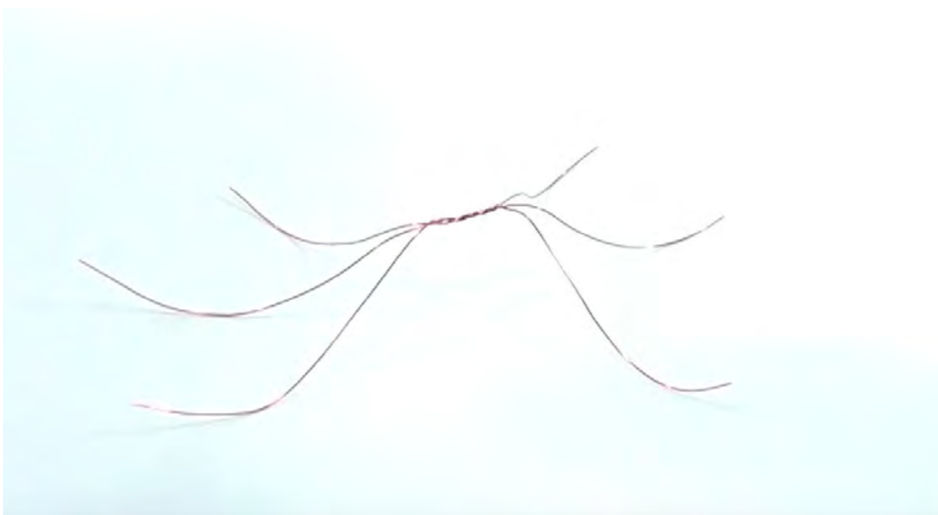
https://3dmoleculardesigns.com/classroom_resources/water-kit/#teacher-guides

**2. Make a Cloud in a Bottle:**


By using only 3 materials (a liter bottle, water and a match), a cloud can be easily made in a bottle. Younger children will need to have this activity demonstrated because of the match, but older children should be able to do this individually or as a group. To start, ask students if they think it is possible to create a cloud in a bottle. Record their answers. Start by filling a 1-liter bottle three quarters of the way full with warm water. Put the cap on the bottle and squeeze it several times: no cloud will form. Next, take a match, light it, blow it out so that it is smoking and put it in the bottle, putting the cap on rapidly afterward. Now squeeze the bottle several times; a cloud should form in the bottle. Now ask the students why the burning match made a difference. Also ask the students why squeezing the bottle was necessary for the cloud to form. The reason is because of two gas laws: Boyle's Law, which states that decreasing the volume of a gas will increase its pressure, and Gay-Lussac's Law, which states that increasing the pressure of a gas will also increase its temperature. Both the increase in temperature and pressure are necessary to force the water to both vaporize and condense.

https://www.youtube.com/watch?v=G70y90BVes4

**3. Make a water strider:**



This project can be as simple as just making the strider or as complicated as an experiment with variables. The variables could be the gauge of the wire or adding substances such as rubbing alcohol or dish soap to the water.

**Materials:** thin wire, scissors, shallow bowl, water, possibly wire strippers if using wire coated with insulation.

**Procedure:** Cut three pieces of wire, each about 8-10 centimeters long. Tightly twist the wires together in the middle to form your bug's body. The ends of the wires should form the bug's six legs, three on each side. Spread the legs out to evenly distribute the water strider's weight. Curve each of the water strider's legs into a long, shallow "U" shape. When the water strider is placed on a flat, solid surface, it should rest evenly on all 6 legs (e.g. none of the legs should be sticking up in the air), with the body up off the ground. Adjust the legs if necessary. Gently place the water strider into the bowl/tray of water.

**Critical Thinking:** If the students are having trouble getting their water strider to float, get them to make a list of factors that contribute to the ability of the real insect to float. Have them keep a list of changes they made to get the constructed water strider to change its shape so that it would float. *Experiment 1*: Have the students make several water striders from increasingly larger gauge wire. Have them first hypothesize what they expect the results to be (e.g., the larger the gauge, the less likely the strider will float). Have the students design their experiments, collect data, and use the data to draw their conclusions. The conclusions should include addressing the hypothesis (what was the initial expectation), a statement of whether the hypothesis was supported or disproved using the data, and an explanation of what happened and why. *Experiment 2*: Have the students explore the effect of additives to the water to see if the surface tension is affected. Possible examples would include rubbing alcohol, liquid dish detergent, vegetable oil, or anything else the students may think of. The students should determine at least two different liquids to add to the water as variables, and the experiment with plain water will serve as a control. The same strider should be used for all variations of the experiment (a constant). Groups of two to three students could also do the experimentation instead of single students. The students should develop their hypothesis first, design their experiment to test their hypothesis, and collect their own data. Afterward, they should either write a lab report or give a class presentation on their experiment, the results, whether the hypothesis was supported by the data, and why they received the results they obtained.

Source: https://www.sciencebuddies.org/stem-activities/build-a-water-strider

**4. How much energy does it take to melt ice to form water?**

*Source:* https://pixabay.com/photos/ice-melt-frost-melting-frozen-570500/

The amount depends on how much water is present. Water, as does other substances, has a property called heat of fusion, which is defined as the amount of energy required to melt 1 gram of ice to form water. Water's heat of fusion is equal to 80 cal/g. If you had 1 gallon of ice (3785g), how much heat would be required to melt it? The calculation is simple: multiply 3785g x 80 cal/g. The answer is 302,000 cal, which equals 302 food calories. If the ice melts, it will absorb the same amount of energy from the environment, cooling it off. Conversely, water will absorb about 540 cal/g when it evaporates. So, the amount of energy absorbed from the environment when 1 gallon of water evaporates is found by multiplying 3785g x 540 cal/g. The answer is 2,044,000 cal, or about 2000 food calories, close to the number of calories the average person should consume in one day. The amount of energy stored in water is called the latent heat of water and is released into the atmosphere when water evaporates.

**Materials:** two small bowls, water, rubbing alcohol, eye droppers or dropper pipets, tablespoon.

**Procedure:** First pour a tablespoon of rubbing alcohol into one of the bowls, and pour a tablespoon of water into the other bowl. Have the students take the eye dropper and drop several drops of water onto the back of their hands. They should rub the water over their skin. W*hen the water touches their skin, how does it feel?* Then, blow on the wet hand. Does their skin feel any different when blowing on the water? Can they sense a difference in temperature while blowing? How does it feel? Next, take the eye dropper and put several drops of alcohol on the back of the other hand, and rub the alcohol over their skin. Does the alcohol feel different when it touches their skin? How? Again, ask them to blow over the area on their hand where they put the alcohol. What sensation do they feel this time? Does their hand feel warmer or colder compared to water when blowing on the liquid? Can they think of a reason why?

**Critical thinking:** Can the students think of a reason why water fountains are frequently found in towns and cities where the summer temperatures get very high? What service do they provide? Can the students think of a reason why farmers will spray their crops with water just before a freeze? (Hint: it's not because the crops will be protected by the ice.) Can the students think of a reason why forests are always cooler than the areas around them? (Hint: it's not because they provide shade.) Lastly, can the students think of a reason why sweating helps to control body temperature? If desired, the students can be assigned finding the answers to these questions instead of having them guess in class.

Source: https://www.sciencebuddies.org/stem-activities/evaporative-cooling-with-liquids

## Formative and Summative Questions

1) Molecules are made of atoms. What are some examples of atoms? What are some examples of substances that are made of molecules? What chart lists all the known elements?

2) Oxygen and hydrogen combine to form a water molecule. How does this happen?

3) Why are hydrogen bonds not considered to be true bonds? What are some properties of water that are caused by hydrogen bonds?

4) What happens to the energy of a water molecule when it evaporates? What happens to its energy when it freezes?

5) Why is it a good thing that ice floats on top of lakes and oceans when it freezes instead of sinking? Why does ice float instead of sink?

6) Water is always evaporating from oceans and lakes, but sometimes there are no apparent clouds in the sky. What two things do clouds need to form? Why does precipitation (rain and snow) form sometimes and not others?

7) Why is water called the "universal solvent?"

8) Why can some insects "walk" on top of water?

9) How can trees get water from their roots to their tops even if they are hundreds of feet tall?

**$CO_2$ Coalition Senior Education Advisor** Sharon R. Camp, Ph.D., Analytical Chemistry; B.S., Geology

**What is the CO2 Coalition?**

The $CO_2$ Coalition was established in 2015 as a 501(c)(3) for the purpose of educating thought leaders, policy makers, and the public about the important contribution made by carbon dioxide to our lives and the economy.

The $CO_2$ Coalition is a group of the top scientists, engineers and energy experts who study and report on the important contribution made by carbon dioxide to our lives and the economy.