Chapter 4

Hydrosphere

Why can't we drink most of the water on Earth?

Standard 4: Students will understand the dynamics of the hydrosphere.

Standard 4, Objective 1: Characterize the water cycle in terms of its reservoirs, water movement among reservoirs and how water has been recycled throughout time.

Terms to know

- condensation
- evaporation
- fresh water
- groundwater
- hydrologic (water) cycle
- precipitation
- natural purification
- reservoir
- transpiration
- water vapor
- aquifer

Section 1: The Distribution of Water on Earth

Lesson Objectives

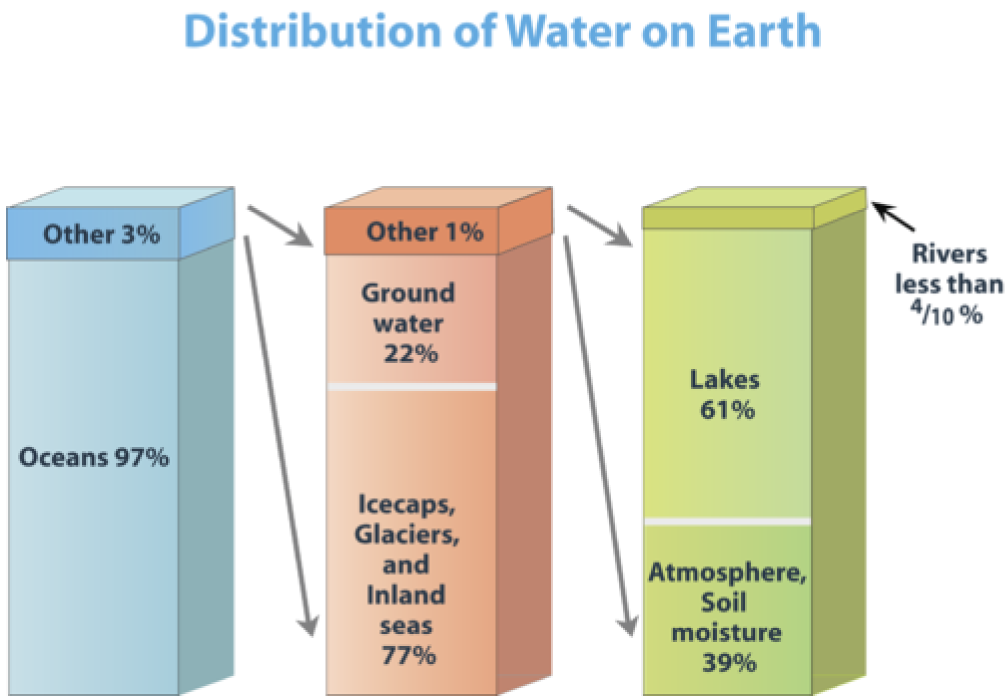
- Describe how water is distributed on Earth.
- Describe what powers the water cycle and how water moves through this cycle.
- Understand how water is purified

Introduction

Water is simply two atoms of hydrogen and one atom of oxygen bonded together. Despite its simplicity, water has remarkable properties. Water expands when it freezes, has high surface tension (because of the polar nature of the molecules, they tend to stick together), and others. Without water, life might not be able to exist on Earth and it certainly would not have the tremendous complexity and diversity that we see.

Distribution of Earth's Water

Earth's oceans contain 97% of the planet's water, just 3% is fresh water, water with low concentrations of salts (See diagram below). Most fresh water is ice, in polar ice caps and glaciers. Storage locations for water are known as reservoirs. Earth's reservoirs are oceans, glaciers, ground water, lakes, rivers and the atmosphere. A water molecule may pass through a reservoir very quickly or may remain for much longer. How is the 3% of fresh water divided into different reservoirs? How much of that water is useful for living creatures? How much is available for people?

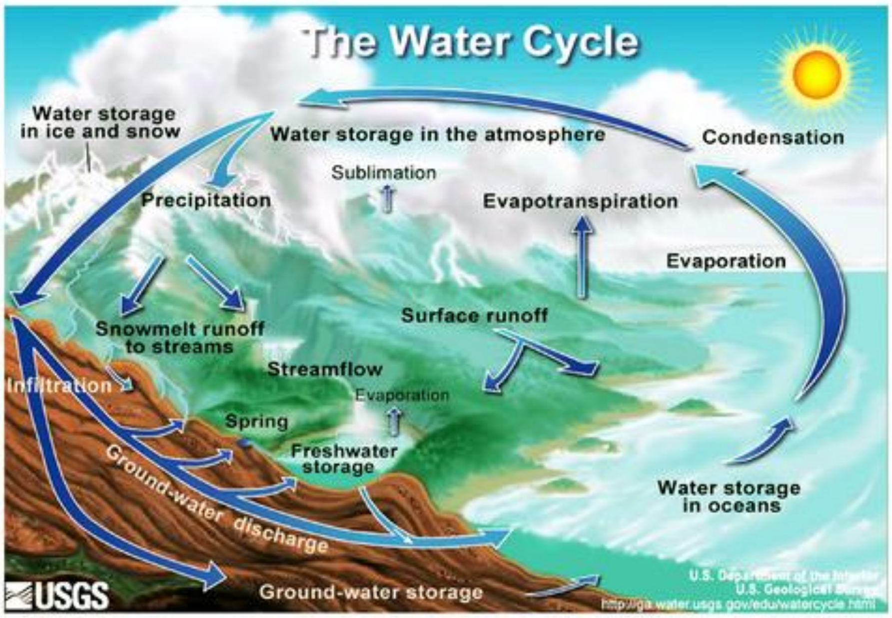


The Hydrologic (Water) Cycle - (the cycle of processes by which water circulates between Earth's reservoirs)

Because of the unique properties of water, water molecules can cycle through almost anywhere on Earth. The water molecule found in your glass of water today could have erupted from a volcano early in Earth history. In the intervening billions of years, the molecule probably spent time in a glacier or far below the ground. The molecule surely was high up in the atmosphere and maybe deep in the belly of a dinosaur. Where will that water molecule go next?

Because Earth's water is present in all three states, it can get into a variety of environments around the planet. The movement of water around Earth's surface is the hydrologic (water) cycle (Figure above).

Because it is a cycle, the **hydrologic (or water) cycle** has no beginning and no end. It has been an ongoing process since well before the dinosaurs.



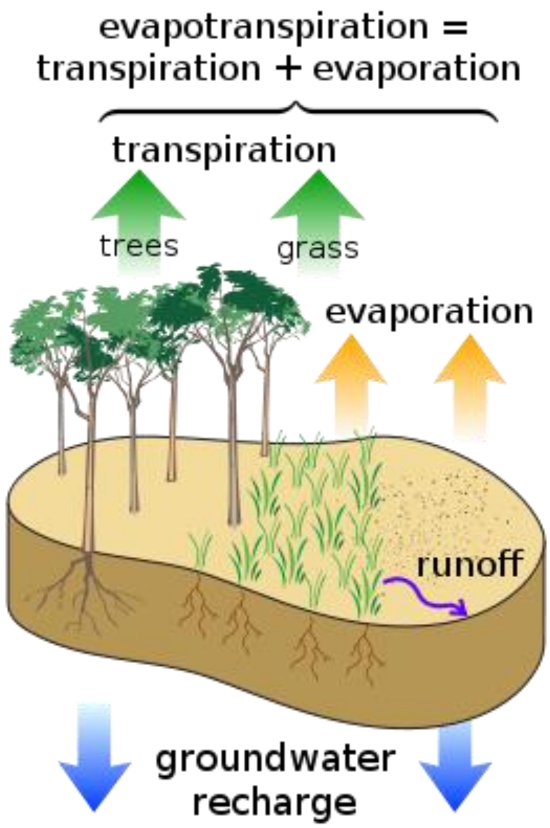
The Sun, which is 149, 600,000 kilometers away, provides the energy that drives the water cycle. Our nearest star directly impacts the water cycle by supplying the energy needed for **evaporation -** (the process of going from a liquid to a gas)**.**

Most of Earth’s water is stored in the oceans where it can remain for hundreds or thousands of years. The oceans are discussed in detail in the chapter Earth's Oceans.

Water changes from a liquid to a gas by **evaporation** to become **water vapor (**water in a gas state that is diffused in the atmosphere). The Sun’s energy can evaporate water from the ocean surface or from lakes, streams, or puddles on land. Only the water molecules evaporate; the salts remain in the ocean or a fresh water reservoir.

The water vapor remains in the atmosphere until it undergoes **condensation** (the process of changing phase from a gas to a liquid) to become tiny droplets of liquid. The droplets gather in clouds, which are blown about the globe by wind. As the water droplets in the clouds collide and grow, they fall from the sky as **precipitation** (water that falls to the ground as rain, hail, snow, etc)**.**

Plants and animals depend on water to live, and they also play a role in the water cycle. The interaction between plants and the atmosphere is a process known as **transpiration** (Plants take up water from the soil and release large amounts of water vapor into the air through their leaves).



Precipitation can be rain, sleet, hail, or snow. Sometimes precipitation falls into the ocean and sometimes it falls onto the land surface.

When water falls from the sky as rain it may enter streams and rivers that flow downward to oceans and lakes. Water that falls as snow may sit on a mountain for several months. Snow may become part of the ice in a glacier, where it may remain for hundreds or thousands of years. Snow and ice may go directly back into the air by sublimation, the process in which a solid changes directly into a gas without first becoming a liquid. Although you probably have not seen water vapor sublimating from a glacier, you may have seen dry ice sublimate in air.

Snow and ice slowly melt over time to become liquid water. This provides a steady flow of fresh water to streams, rivers, and lakes below. A water droplet falling as rain could also become part of a stream or a lake. At the surface, the water may eventually evaporate and reenter the atmosphere.

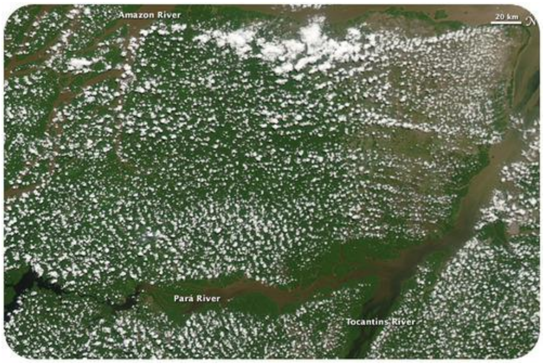
A significant amount of water is called groundwater (water that filters into the ground). Soil moisture is an important reservoir -(a place where water is stored for a certain period of time) for water. Water trapped in soil is important for plants to grow. Although this may seem surprising, water beneath the ground is commonplace. Usually groundwater travels slowly and silently beneath the surface, but in some locations it bubbles to the surface at springs and geysers.

Water becomes groundwater by seeping through dirt and rock below the soil through pores, infiltrating the ground. Groundwater storage is called an **aquifer** (porous rock and sediment with water trapped in between). Aquifers may store fresh water for centuries. The water may come to the surface through springs or find its way back to the oceans. All of these are **reservoirs** within the water cycle. Groundwater is the largest reservoir of liquid fresh water on Earth and is found in **aquifers** (porous rock and sediment with water in between)
Aquifers are found at different depths. Some are just below the surface and some are found much deeper below the land surface. A region may have more than one aquifer beneath it and even most deserts are above aquifers. The source region for an aquifer beneath a desert is likely to be far from where the aquifer is located; for example, it may be in a mountain area.

The amount of time water can be in an aquifer can be from minutes to thousands of years. Groundwater is often called “fossil water” because it has remained in the ground for so long, often since the end of the ice ages. When coastal aquifers are overused, salt water from the ocean may enter the aquifer, contaminating the aquifer and making it less useful for drinking and irrigation. Salt water incursion is a problem in developed coastal regions, such as on Hawaii.

Wells

A well is created by digging or drilling to reach groundwater. When the water table is close to the surface, wells are a convenient method for extracting water. When the water table is far below the surface, specialized equipment must be used to dig a well. Most wells use motorized pumps to bring water to the surface, but some still require people to use a bucket to draw water up.



Clouds form above the Amazon Rainforest even in the dry season because of moisture from plant transpiration.

People also depend on water as a natural resource. Not contented to get water directly from streams or ponds, humans create canals, aqueducts, dams, and wells to collect water and direct it to where they want it.

Water Use		
Use	United States	Global
Agriculture	34%	70%
Domestic (drinking, bathing)	12%	10%
Industry	5%	20%
Power plant cooling	49%	small

Table 1.1 above displays water use in the United States and globally (Estimated Use of Water in the United States in 2005, USGS).

It is important to note that water molecules cycle around. If climate cools and glaciers and ice caps grow, there is less water for the oceans and sea level will fall. The reverse can also happen.

Lesson Summary

- Although Earth's surface is mostly water covered, only 3% is fresh water.
- Water travels between phases and reservoirs as part of the hydrologic (water) cycle.
- The major processes of the water cycle include evaporation, transpiration, condensation, precipitation, and return to the oceans via runoff and groundwater supplies.
- Groundwater is the largest reservoir of fresh water.
- The water table is the top of an aquifer below which is water and above is rock or soil mixed with air.
- Aquifers are underground areas of sediment or rock that hold groundwater.
- An aquifer needs good porosity and permeability.
- People dig or drill wells to access groundwater.
- Natural processes of evaporation, infiltration and others naturally filter and purify water as it travels to the aquifer.
- Water treatment performed at sewage treatment plants mimics natural processes. Sewage plants also employ biological and chemical purification processes.

Think Like a Hydrologist

1. About what percent of the Earth's water is fresh water?

2. What powers the water cycle? How?

3. Define the words condensation and evaporation.

4. Sketch the water cycle.

5. What is transpiration? How is it like evaporation?

6. How is groundwater different from surface water? What is the water table?

7. What are aquifers and why are they so important?

8. What process does ground water go through that makes it useable by living things? Since groundwater is largely unseen from the surface, how might you monitor the amount of groundwater in an aquifer?

Points to Consider

9. Is water from a river or from a well more likely to be clean to drink?

10. Why is overuse of groundwater a big concern?

11. What policies might people put in place to conserve water levels in lakes and aquifers?

Going Further

This animation shows porosity and permeability. The water droplets are found in the pores between the sediment grains, which is porosity. When the water can travel between ores, that’s permeability.

http://www.nature.nps.gov/GEOLOGY/usgsnps/animate/POROS_3.MPG

How do we Use Water?

Terms to know

- drought
- irrigation

Lesson Objectives

- List ways that humans use water.
- State why some people don't have enough water.
- Explain why poor quality water is a problem.

Introduction

All forms of life need water to survive. Humans are no exception. We can survive for only a few days without it. We also need water for agriculture, industry, and many other uses. Clearly, water is one of Earth's most important natural resources. It's a good thing that water is recycled in the water cycle.

Many crops are grown where there isn't enough rainfall for plants to thrive. For example, crops are grown in deserts of the United States, such as Utah. How is this possible? The answer is irrigation. Irrigation is any way of providing adequate water for plants. Most of the water used in agriculture is used for irrigation. Livestock also use water, but they use much less.

Irrigation can waste a lot of water. The type of irrigation shown in the image below is the most wasteful. The water is simply sprayed into the air. Then it falls to the ground like rain. But much of the water never reaches the crops. Instead, it evaporates in the air or runs off the fields.

Irrigation water may dissolve agricultural chemicals such as fertilizer. The dissolved chemicals could soak into groundwater or run off into rivers or lakes. Salts in irrigation water can also collect in the soil. The soil may get too salty for plants to grow.

Overhead irrigation systems like this one are widely used to irrigate crops on big farms. What are some drawbacks of irrigation?

Water in Industry

Almost a quarter of the water used worldwide is used in industry. Industries use water for many purposes. For example, they may use water to cool machines. Or they may use it in chemical processes. These uses of water may pollute it. Water is also used to generate electricity. This use doesn't pollute the water, but it may dam up streams and rivers. This can bring harm to wildlife and limit our use of the land.

Household Uses of Water

Think about all the ways people use water at home. Besides drinking it, they use it for cooking, bathing, washing dishes, doing laundry, and flushing toilets. The water used inside homes goes down the drain. It usually ends up in a sewer system. This water can be treated and reused.

Households may also use water outdoors. If your family has a lawn or garden, you may water them with a hose or sprinkler. You may also use water to wash the car. Much of the water used outdoors evaporates or runs off. The runoff water may end up in storm sewers. They carry it to a body of water, such as the ocean.

Water for Fun

There are many ways to use water for fun, from white water rafting to snorkeling. These uses of water don't actually use water up. If you were to guess which recreational activity consumes the most water, what would you guess? Believe it or not, it's golf! Playing golf doesn't use water, but keeping golf courses green uses a lot of water. Many golf courses have sprinkler systems. They keep the greens well watered. Much of this water is wasted. It evaporates or runs off the ground.

Water Problems: Not Enough Water

Most Americans have plenty of fresh, clean water. But many people around the world do not. In fact, water shortage is the world's most serious resource problem. How can that be? Water is almost everywhere. More than 70 percent of Earth's surface is covered by water.

Section 1: Where Is All the Water?

One problem is that only a tiny fraction of Earth's water is fresh, liquid water that people can use. More than 97 percent of Earth's water is salt water in the oceans. Just 3 percent of all water on earth is freshwater. Most of the freshwater is frozen in ice sheets, icebergs, and glaciers (see Figure below).

This glacier in Patagonia, Argentina stores a lot of frozen freshwater

Rainfall and the Water Supply

Rainfall varies around the globe. About 40 percent of the land gets very little rain. About the same percentage of the world's people don't have enough water. Drier climates generally have less water for people to use. In some places, people may have less water for an entire year than many Americans use in a single day! How much water is there where you live?

Wealth and the Water Supply

Richer nations can drill deep wells or supply people with water in other ways. In these countries, just about everyone has access to clean running water in their homes. It's no surprise that people in these countries also use the most water. In poorer nations, there is little money to develop water supplies.

Water Shortages

Water shortages are common in much of the world. They frequently occur during droughts. A drought is a period of unusually low rainfall.

We already use six times as much water today as we did a hundred years ago. As the number of people rises, our need for water will grow. By the year 2025, only half the world's people will have enough. Water is such a vital resource that serious water shortages may cause other problems:

- Crops and livestock may die so people will have nothing to eat.
- Other uses of water, such as industry, may have to stop.
- People may fight over water resources.
- People may die from lack of water.

Water Problems: Poor Quality Water

The water Americans get from their faucets is generally safe. This water has been treated and purified. But at least 20 percent of the world's people do not have clean drinking water. Their only choice may be to drink water straight from a river. The river water may be polluted with wastes. It may contain bacteria and other organisms that cause disease. Almost 9 out of 10 cases of disease worldwide are caused by unsafe drinking water. It's the leading cause of death in young children.

This boy is getting drinking water from a hole that has been dug. It may be the only source of water where he lives.

Lesson Summary

- People use water for agriculture, industry, and municipal uses. Agriculture uses the most water. Almost all of it goes for irrigation.
- Too little water is a major problem. Places with the least water get little rainfall. They also lack money to develop water resources. Droughts make the problem even worse.
- Poor water quality is also a problem. Many people must drink water that contains wastes. This causes a lot of illness and death.

Think Like a Hydrologist

1. List and describe the three major ways that humans use water.
2. What is the single biggest use of water in agriculture and why?
3. Give an example of an industrial use of water.
4. What problems may result from serious water shortages?
5. More than 70 percent of Earth's surface is covered by water. Why is scarcity of water the world's most serious resource problem?

Points to Consider

6. In this lesson, you learned that many people don't have clean water to drink. They must drink polluted water instead. How does water become polluted? Can polluted water be treated so it is safe to drink?

How do humans and animals cause water pollution?

Lesson Objectives

- Define point and nonpoint source pollution.
- List sources of water pollution.
- Describe ocean water pollution.
- Identify causes and effects of thermal pollution.

Introduction

Water pollution is a worldwide problem. Almost anything can end up in Earth’s water.

Section 1: Point and Nonpoint Source Pollution

Pollution that enters water at just one point is called point source pollution. For example, chemicals from a factory might empty into a stream through a single pipe (see Figure below). Pollution that enters in many places is called nonpoint source pollution. It happens when runoff carries pollution into a body of water. Which type of pollution do you think is harder to control?

Sources of Water Pollution

There are three main sources of water pollution:

- Agriculture
- Industry
- Municipal, or community, sources.

Water Pollution from Agriculture

Huge amounts of chemicals such as fertilizer are applied to farm fields. The chemicals dissolve in rainwater. Runoff may carry some of the chemicals to nearby rivers or lakes. Dissolved fertilizer causes too much growth of water plants and algae. This can lead to dead zones in the water where nothing can live. Also, some of the chemicals may soak into the ground and pollute groundwater. They may end up in water wells. If people drink the polluted water, they may get sick. Waste (fecal matter) from livestock can also pollute water. The waste contains bacteria and other organisms that cause disease. In fact, more than 40 human diseases can be caused by water polluted with animal waste. Many farms in the U.S. have thousands of animals. They produce millions of gallons of waste. The waste is stored in huge lagoons. Many leaks have occurred. Two examples are described below.

- In North Carolina, 25 million gallons of hog manure spilled into a nearby river. It killed millions of fish.
- In Wisconsin, cow manure leaked into a city’s water supply. Almost half a million people got sick. More than 100 of them died.

Water Pollution from Industry

- Factories and power plants may pollute water with harmful substances.
- Many industries produce toxic chemicals. Some of the worst are arsenic, lead, and mercury.
- Nuclear power plants produce radioactive chemicals. They cause cancer and other serious health problems.
- Oil tanks and pipelines can leak. Leaks may not be noticed until a lot of oil has soaked into the ground. The oil may pollute groundwater so it is no longer fit to drink.

Municipal Water Pollution

"Municipal" refers to the community. Households and businesses in a community may also pollute the water supply. For example:

- People apply chemicals to their lawns. The chemicals dissolve in rainwater. They run off into storm sewers and end up in nearby rivers or lakes.
- Underground septic tanks can develop leaks. They let household sewage seep into groundwater.
- Municipal sewage treatment plants dump treated wastewater into rivers or lakes. The wastewater may not be treated enough. It may still contain bacteria or toxic chemicals.

Ocean Water Pollution

The oceans are vast. You might think they are too big to be harmed by pollution. But that’s not the case. Ocean water is becoming seriously polluted.

Coastal Pollution

The oceans are most polluted along coasts. That’s because pollution usually enters ocean water from land. Runoff and rivers carry the majority of pollution into the ocean. Many cities also dump their wastewater there. In some parts of the world, raw sewage and trash may be thrown into the water. Coastal water may become so polluted that people get sick if they swim in it or eat seafood from it. The polluted water may also kill fish and other ocean life.

Oil Spills

Oil spills are another source of ocean pollution. Many oil rigs float on the oceans. They pump oil from beneath the ocean floor. Huge ocean tankers also carry oil around the world. Millions of barrels of oil may end up in the water if anything goes wrong. The oil may coat and kill ocean animals. Much of the oil may wash ashore. It can destroy coastal wetlands and ruin beaches. The figure to the left shows oil on a Louisiana beach after an oil spill. The oil washed ashore after a deadly oil rig explosion in the Gulf of Mexico in 2010.

After an oil rig explosion, hundreds of miles of beaches looked like this one. Cleaning them up was a huge task.

Thermal Pollution

Thermal pollution is pollution that raises the temperature of water. It's commonly caused by power plants and factories. They use cold water to cool their machines. They may pump cold water from a lake through giant cooling towers, like those in the Figure below. The cold water absorbs heat as it flows through the towers. Then the warm water is returned to the lake. It can kill fish and other water life. One reason is that warm water can't hold as much oxygen as cool water. It may not have enough oxygen for living things.

Nuclear power plants need huge amounts of water for cooling, so they are built close to water. The water that's returned to the lake may be warm enough to kill fish.

Lesson Summary

- Point source pollution enters water at just one place. For example, it might enter a stream through a pipe. Nonpoint source pollution enters water everywhere. It is carried by runoff.
- Major sources of pollution are agriculture, industry, and communities. Pollution from agriculture includes chemicals and animal waste. Industry produces toxic chemicals. Communities produce sewage.
- Ocean water is most polluted along coasts. That’s because pollution usually enters the water from land. Oil spills also pollute ocean water.
- Thermal pollution raises the temperature of water. It is commonly caused by power plants and factories. The change in temperature can kill fish and other water organisms.

Think Like a Hydrologist

1. Describe two major ways that agriculture can pollute water.

2. List 3 harmful substances that industry may add to water.

3. What are three municipal sources of water pollution? Why are they harmful?

4. State why ocean water is most polluted near coasts.

5. Name 2 ways oil can end up in ocean water?

6. What is thermal pollution? Why is it harmful for fish and other water life?

7. A nuclear power plant is located near the ocean. The plant uses ocean water for cooling. Describe two types of water pollution this plant might produce.

Points to Consider

8. People can't live without water. They need it for life itself. More than almost any other resource, water must be protected. How can water pollution be prevented? How can we use less water?

What makes H_2O unique?

Standard 4, Objective 2. Analyze the characteristics and importance of freshwater found on Earth's surface and its effect on living systems.

Terms to know

- Adhesion
- Cohesion
- Biotic
- Abiotic
- Ecosystems
- pollution

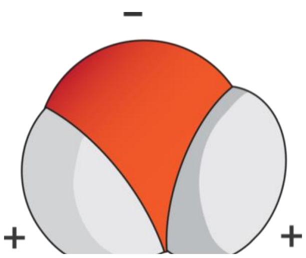
Introduction

Dihydrogen oxide or dihydrogen monoxide. Does this chemical sound dangerous?

Another name for this compound is…water. Water is necessary for life. The importance of water to life cannot be emphasized enough. All life needs water. Life started in water. Essentially, without this simple three atom molecule, life would not exist.

Section 1: Structure and Properties of Water

No doubt, you are already aware of some of the properties of water. For example, you probably know that water is tasteless and odorless. You also probably know that water is transparent, which means that light can pass through it. This is important for organisms that live in water, because most of them need sunlight to make food.

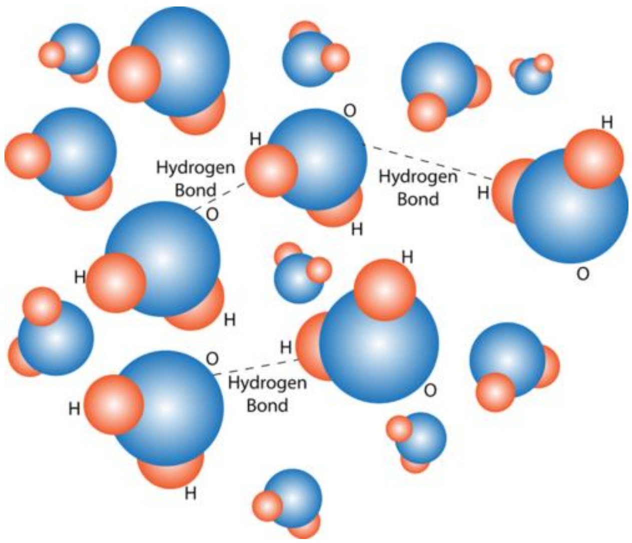


Water Molecule. This diagram shows the positive and negative parts of a water molecule.

Chemical Structure of Water

To understand some of water's properties, you need to know more about its chemical structure. As you have seen, each molecule of water consists of one atom of oxygen and two atoms of hydrogen. The oxygen atom in a water molecule attracts negatively-charged electrons more strongly than the hydrogen atoms do. As a result, the oxygen atom has a slightly negative charge, and the hydrogen atoms have a slightly positive charge. A difference in electrical charge between different parts of the same molecule is called polarity, making water a polar molecule. The diagram in Figure to the right shows water's polarity.

Opposites attract when it comes to charged molecules. In the case of water, the positive (hydrogen) end of one water molecule is attracted to the negative (oxygen) end of a nearby water molecule. Because of this attraction, weak bonds form between adjacent water molecules, as shown in the diagram to the left. In water the bonds are strong enough

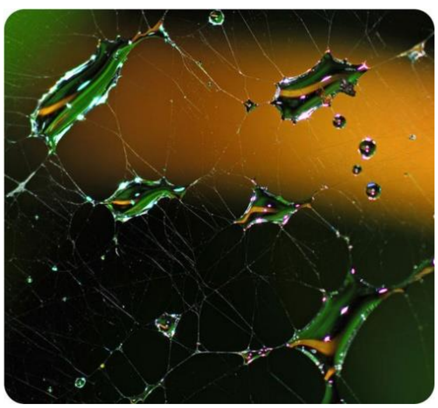


to hold together nearby molecules.

Properties of Water

Hydrogen Bonding in Water Molecules. Hydrogen bonds form between nearby water molecules. How do you think this might affect water's properties?

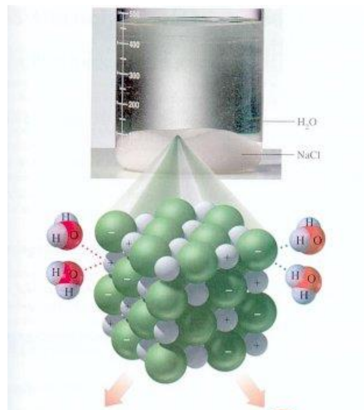
Hydrogen bonds (weak bonds between adjacent water molecules) between water molecules explain some of water's properties. For example, hydrogen bonds explain why water molecules tend to stick together or have cohesion (water molecules sticking to other water molecules). Hydrogen bonds are constantly breaking, with new bonds being formed with different molecules. Have you ever watched water drip from a leaky faucet or from a melting icicle? If you have, then you know that water always falls in drops rather than as separate molecules. The dew drops in the diagram below are another example of water molecules sticking together through cohesion. Water also has high adhesion properties (the ability of water molecules to be attracted to other substances) because of its polar nature. On extremely clean/smooth glass the water may form a thin film because the molecular forces between glass and water molecules (adhesive forces) are stronger than the cohesive forces.



Droplets of Dew. Drops of dew cling to a spider web in this picture. Can you think of other examples of water forming drops? (Hint: What happens when rain falls on a newly waxed car?

Hydrogen bonds cause water to have a relatively high boiling point of 100°C (212°F). Because of its high boiling point, most water on Earth is in a liquid state rather than in a gaseous state. Water in its liquid state is needed by all living things. Hydrogen bonds also cause water to form into a crystalline type structure thus expanding when it freezes. This, in turn, causes ice to have a lower density (mass/volume) than liquid water. The lower density of ice means that it floats on water. For example, in cold climates, ice floats on top of the water in lakes. This allows lake animals such as fish to survive the winter by staying in the liquid water under the ice.

Section 2: Water as the Universal Solvent



Due to hydrogen bonds, water dissolves more substances than any other common liquid. Most elements have high solubilities in water, which means that even in large concentrations, many things will dissolve into and be suspended in water.

Water is the only substance on Earth that is naturally present in all three states of

matter - as a solid, liquid or gas. (And Earth is the only planet where water is present in all three states.) Because of the ranges in temperature in specific locations around the planet, all three phases may be present in a single location or in a region. The three phases are solid (ice or snow), liquid (water), and gas (water vapor). See ice, water, and clouds (Figure below).

(a) Ice floating in the sea. Can you find all three phases of water in this image? (b) Liquid water. (c) Water vapor is invisible, but clouds that form when water vapor condenses are not.

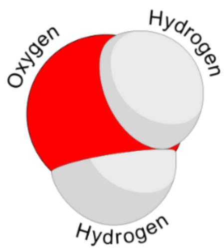
States of Water

H - two - O. Why is something so simple so important?

Water is the most important substance on Earth. Think about all the things you use water for? If your water access were restricted what would you miss about it?

The Water Molecule

Water is simply two atoms of hydrogen and one atom of oxygen bonded together. The hydrogen ions are on one side of the oxygen ion, making water a **polar molecule**. This means that one side, the side with the hydrogen ions, has a slightly positive electrical charge. The other side, the side without the hydrogen ions, has a slightly negative charge.



A water molecule. The hydrogen atoms have a slightly positive charge, and the oxygen atom has a slightly negative charge.

Despite its simplicity, water has remarkable properties. Water expands when it freezes, has high surface tension (because of the polar nature of the molecules, they tend to stick together), and others. Without water, life might not be able to exist on Earth and it certainly would not have the tremendous complexity and diversity that we see.

Lesson Summary

- Water is a polar molecule with a more positive charge on one side and a more negative charge on the other side.
- Water is the only substance on Earth that is stable in all three states.
- Earth is the only planet in the Solar System that has water in all three states. Some special properties of water are cohesion (the ability to stick to itself) and adhesion (the ability to stick to other substances).

Think like a hydrologist

1. List three unique properties that water has due to hydrogen bonding?

2. Water can exist in all three states of matter. Why is water typically in the liquid form?

3. Why is it essential for life that water is less dense when frozen than when liquid?

4. Water always beads up on a freshly waxed car. Is this due to adhesion or cohesion? Both? Explain.

5. Why is water considered a polar molecule?

6. Where in the solar system is water found in all three states?