Handout 1.4 What is so unique about water?

Primary sources: USGS Water Science School - https://www.usgs.gov/special-topics/water-science-school/science/water-basics-information-topic

In a course about water, it is a good idea to understand the unique qualities of this substance that makes all life on this planet possible. About 60% of the human body is water. Lake all life on earth we need water to live and most of us live around waters. To me water is what makes the Virginia Peninsula unique. Have you ever thought about how unique this critical substance might be? In this handout we will explore the uniqueness of water. Water is essential for life on earth and covers about 71 percent of the Earth's surface, and the **oceans** hold about 96.5 percent of all Earth's water. Water also exists in the air as **water vapor**, in **rivers** and **lakes**, in icecaps and **glaciers**, in the ground as soil moisture and in **aquifers**, and even in us (varies between 45 to 75 %)

Why is water unique:

1. It is the only substance on earth that exists as a solid, liquid and gas under natural conditions and the only substance that can expand when you cool it.
   - Hydrogen bonds are stable below degrees centigrade and break and reform between 0 and 100 degrees centigrade
   - Water actually expands when cooled below 37 degrees Fahrenheit.
2. Water exhibits the property of cohesion, that is it has a very high surface tension. This is because the hydrogen bonds hold the water molecules together in liquid form
   - It forms a meniscus in a tube
   - It transports in plants
   - It can be “walked on” by certain insects
3. Water has a high specific heat capacity (the amount of energy required to raise temperature of 1 gram of liquid by 1 degree centigrade}.
   - Large bodies of water stabilize air temperature
   - Removes heat from living tissue by absorbing heat
4. Polarity: Water is an excellent solvent to ionic salts and other polar molecules. A sphere of water molecules, called a hydration shell, surrounds each solute ion.
   - Water removes ions from substances that contain them such as rock
   - Water transports ions easily keeping them in solution
5. Water has both acid and basic qualities. Liquid water has both hydronium (H+) and hydroxide (OH-).
   - Pure water is neutral with a pH of 7 (The two ions are balanced)
   - Acidic water has a greater number of hydronium ions caused by the strong disassociation of the acid salt. Such as hydrogen chloride
   - Basic water has a greater number of hydroxide molecules caused by the strong disassociation of basic salt such sodium hydroxide
6. Water is essential for life on earth and covers about 71 percent of the Earth's surface, and the **oceans** hold about 96.5 percent of all Earth's water. Water also exists in the air as **water vapor**, in **rivers** and **lakes**, in icecaps and **glaciers**, in the ground as soil moisture and in **aquifers**, and even in us (varies between 45 to 75 %)

Water facts (USGS Water Science School - Facts About Water | U.S. Geological Survey (usgs.gov)

Water numbers

Some of water's physical properties:

- Weight: 62.416 pounds/cubic foot at 32°F; 1,000 kilograms/cubic meter
- Weight: 61.998 pounds/cubic foot at 100°F; 993 kilograms/cubic meter
- Weight: 8.33 pounds/gallon; 1 kilogram/liter
- Density: 1 gram/cubic centimeter (cc) at 39.2°F, 0.95865 gram/cc at 212°F

Flow rates:

- 1 cubic foot/second (cfs) = 449 gallons/minute = 0.646 million gallons/day = 1.98 acre-feet/day

Water facts

Sources/Usage: Public Domain. Water is unique primarily because of its polar nature. Hydrogen bonds are attractions of electrostatic force caused by the difference in charge between slightly positive hydrogen ions and other, slightly negative ions. In the case of water, hydrogen bonds form between neighboring hydrogen and oxygen atoms of adjacent water molecules. The attraction between individual water molecules creates a bond known as a hydrogen bond. Water and Hydrogen Bonds by Science Sauce. - https://youtu.be/mbAC6HpTu34

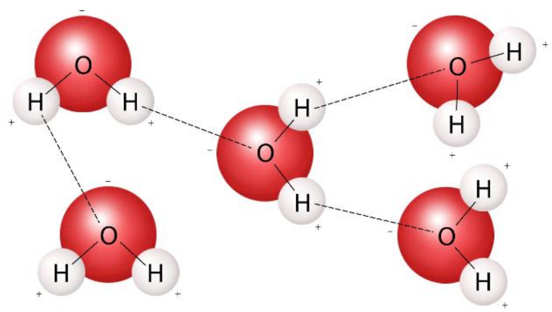


Figure 1 The water molecule is a polar molecule and forms loose covalent bonds.

“Water is called the "**universal solvent**" because it dissolves more substances than any other liquid. This means that wherever water goes, either through the ground or through our bodies, it takes along valuable chemicals, minerals, and nutrients.

Pure water has a neutral **pH** of 7, which is neither acidic (less than 7) nor basic (greater than 7).

The water molecule is highly **cohesive** — it is very sticky, meaning water molecules stick to each other. Water is the most cohesive among the non-metallic liquids. Water is highly cohesive because of its polar nature.

Pure water, which you won't ever find in the natural environment, does not **conduct electricity**. Water becomes a conductor once it starts dissolving substances around it.

Water has a high **heat index**—it absorbs a lot of heat before it begins to get hot. This is why water is valuable to industries and in your car's radiator as a coolant. The high heat index of water also helps regulate the rate at which air changes temperature, which is why the temperature change between seasons is gradual rather than sudden, especially near the oceans.

Water has a very high **surface tension**. In other words, water is sticky and elastic, and tends to clump together in drops rather than spread out in a thin film, like rubbing alcohol. Surface tension is responsible for **capillary action**, which allows water (and its dissolved substances) to move through the roots of plants and through the tiny blood vessels in our bodies.

Air pressure affects the boiling point of water, which is why it takes longer to boil an egg at Denver, Colorado than at the beach. The higher the altitude, the lower the air pressure, the lower the boiling point of water, and thus, the longer time to hard-boil an egg. At sea level water boils at 212°F (100°C), while at 5,000 feet, water boils at 202.9°F (94.9 °C).

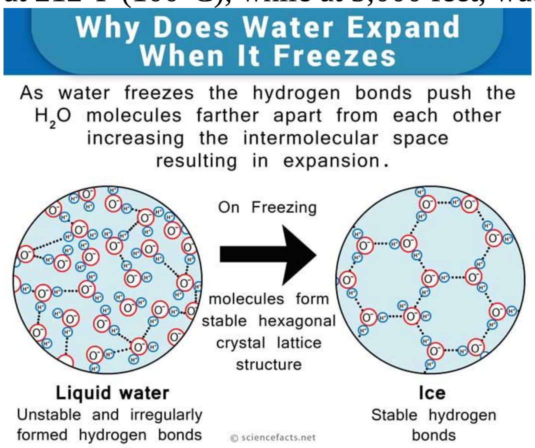
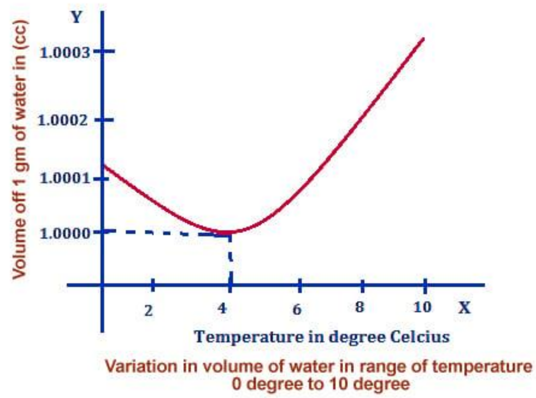


Figure 2 http://www.sciencefacts.net/why-does-water-expand-when-it-freezes.html



When water freezes, its molecules get arranged in a crystalline structure, thereby attaining a defined shape. This crystalline structure is less dense, and since there are gaps between individual molecules in the structure, the overall volume increases, and water 'expands'.

The ocean as a (huge) storehouse of water

The oceans contain the vast majority of all water on Earth.

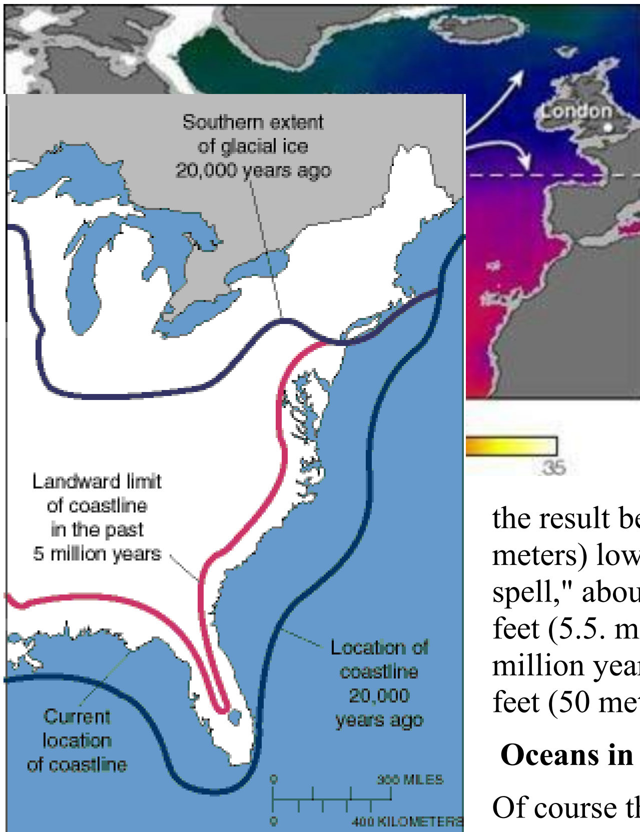
The water cycle sounds like it is describing how water moves above, on, and through the Earth... and it does. But, in fact, much more water is "in storage" for long periods of time than is actually moving through the cycle. The storehouses for the vast majority of all water on Earth are the oceans. It is estimated that of the 332,500,000 cubic miles (mi^3) (1,386,000,000 cubic kilometers (km^3)) of the world's water supply, about 321,000,000 mi^3 (1,338,000,000 km^3) is stored in oceans. That is about 96.5 percent of **all Earth's water**. It is also estimated that the oceans supply about 90 percent of the evaporated water that goes into the water cycle.

The water in the oceans is **saline** (saltwater), but, what do we mean by "saline water?" Saline water contains significant amounts (referred to as "concentrations") of dissolved salts. In this case, the concentration is the amount (by weight) of salt in water, as expressed in "parts per million" (ppm). Water is saline if it has a concentration of more than 1,000 ppm of dissolved salts; ocean water contains about 35,000 ppm of salt.

The volume of the oceans does change ... slowly

Sources/Usage: Public Domain.

Of course, nothing involving the water cycle is really permanent, even the amount of water in the oceans. Over the "short term" of hundreds of years the oceans' volumes don't change much. But



the amount of water in the oceans does change over the long term. During the last Ice Age, sea levels were lower, which allowed humans to cross over to North America from Asia at the (now underwater) Bering Strait.

During colder climatic periods more **ice caps and glaciers** form, and enough of the global water supply accumulates as ice to lessen the amounts in other parts of the water cycle. The reverse is true during warm periods. During the last ice age **glaciers** covered almost one-third of Earth's land mass, with the result being that the oceans were about 400 feet (122 meters) lower than today. During the last global "warm spell," about 125,000 years ago, the seas were about 18 feet (5.5. meters) higher than they are now. About three million years ago the oceans could have been up to 165 feet (50 meters) higher.

Oceans in movement: Tides

Of course the oceans are always in movement. The moon influences daily tides, which make the beach a more interesting place to go. **Tides** vary greatly around the world, and in some places can be quite dramatic. The highest tides occur in confined estuaries, such as the Bay of Fundy, Nova Scotia, Canada, Ungava Bay, Quebec, and Bristol Channel in Britain. The Bay of Fundy has maximum tides of up to 53 feet (16 meters) during certain times of the year (Bay of Fundy Com).

Oceans in movement: "Rivers" in the oceans

If you have ever been seasick (we hope not), then you know how the ocean is never still. You might think that the water in the oceans moves around because of waves, which are driven by winds. But, actually, there are currents and "rivers" in the oceans that move massive amounts of water around the world. These movements have a great deal of influence on the water cycle. The Kuroshio Current, off the shores of Japan, is the largest current. It can travel between 25 and 75 miles (40 and 121 kilometers) a day, 1-3 miles (1.4-4.8 kilometers) per hour, and extends some 3,300 feet (1,000 meters) deep.

Credit: NOAA, Public domain

The Gulf Stream carries warm, salty water northward along the Northeast Shelf (Gulf of Maine to Cape Hatteras, NC), bringing heat from the tropics to higher latitudes. The northward and landward extent of warm Gulf Stream waters affects ecological processes in the ocean, including the distribution of commercially important fish species. It also affects weather in the region. The Gulf Stream returns a considerable amount of heat to the atmosphere.

Credit: NASA. Map by Robert Simmon

The Gulf Stream is a well known stream of warm water in the Atlantic Ocean, moving water from the Gulf of Mexico across the Atlantic Ocean towards Great Britain. At a speed of 60 miles (97 kilometers) per day, the Gulf stream moves 100 times as much water as all the rivers on Earth. Coming from warm climates, the Gulf Stream moves warmer water to the North Atlantic. Cornwall, at the southwest corner of Great Britain, is sometimes referred to as the "Cornish Riviera" because of the milder climate attributable to the Gulf Stream—palm trees (true, a hardy variety) can even grow there....all because of the Gulf Stream.

This map shows sea-surface temperatures of the North Atlantic Ocean. Data are from NASA satellite observations. Cold waters are shown in darker colors, whereas orange and yellow indicate the warmest temperatures. The Gulf Stream is visible as a warm water current traveling northward along the coast of North America and eastward into the central Atlantic Ocean. As it continues its journey heat from the ocean is lost to the atmosphere, warming the air above it. Cornwall and its palm trees are located southwest of London, and if you draw a line westward, you'll end up near Newfoundland, Canada. Cornwall and Newfoundland might be at similar latitudes, but you would be hard-pressed to find any palm trees growing in eastern Canada!

Where is Earth's water?

For an estimated explanation of where Earth's water exists, look at this bar chart. You may know that the water cycle describes the movement of Earth's water, so realize that the chart and table below represent the presence of Earth's water at a single point in time. If you check back in a thousand or million years, no doubt these numbers will be different!

Notice how of the world's total water supply of about 332.5 million cubic miles of water, over 96 percent is saline. And, of the total freshwater, over 68 percent is locked up in ice and glaciers. Another 30 percent of freshwater is in the ground. **Fresh surface-water** sources, such as rivers and lakes, only constitute about 22,300 cubic miles (93,100 cubic kilometers), which is about 1/150th of one percent of total water. Yet, rivers and lakes are the sources of most of the water people use everyday.

Source: Gleick, P. H., 1996: Water resources. In Encyclopedia of Climate and Weather, ed. by S. H. Schneider, Oxford University Press, New York, vol. 2, pp. 817-823.