Water's Unique Properties

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Dihydrogen monoxide, H_2O, and the liquid of life all are names for the same thing: water. Water is an interesting molecule because it has unique characteristics because of hydrogen bonding: in particular, the cohesive/adhesive property of the water molecule, the insulation of liquid water by ice, and its high specific heat. Most other properties of water can be traced back to these three properties.

Water molecules are polarized, with a slightly negative side and a slightly positive side. A water molecule is composed of two hydrogen atoms (atomic number of one) and one oxygen atom (atomic number of eight). Because the single oxygen atom out-masses the hydrogen atoms by four amu, it attracts electrons more readily than hydrogen. This encourages hydrogen bonding, leading to cohesion with other water molecules or adhesion with other materials. Cohesion is important in biological systems because it gives water the tendency to coalesce, whether it is a raindrop, a pond, or an ocean, allowing for easy access by organisms. It also allows for easier transportation of water through a biological system. For instance, a plant would need to take in liquid water through its roots, while an animal generally drinks water, which flows through its digestive system. Other organisms, such as some microorganisms and fish, live inside the aquatic environment, which would not be available if water could disperse easily. Another type of hydrogen bonding, adhesion, allows water to cling to different substances. For example, water will climb up a tree through its pores by adhering to the cell walls, much like it would do in a sponge or paper towel. This allows plants such as trees to carry water up to tall heights without much trouble, and therefore keeping them from dehydrating.

A second property caused by the hydrogen bonding is that when water freezes into ice, it expands, becoming less dense. This is highly unusual; most substances become more dense as a solid. Because water molecules are polarized, they bond into ring-shaped structures. The arrangement of molecules in ice is similar to those in a crystal, which has open spaces within its ring-like pattern. Therefore, frozen water will end up being less dense than in liquid form. Because it is less dense, the ice floats on top of bodies of liquid water, providing a layer of insulation. One hypothesis states that one of Jupiter's moons, Europa, has an entire ocean of liquid water under the icy crust. Here on Earth, life thrives in liquid water, and when the water beneath the ice is kept relatively warm, it allows the marine life to maintain homeostasis and survive in a normally extremely cold environment. The fish, crab, and squid become food for arctic mammals, such as seals and polar bears. If ice did not become less dense and float, it would sink, allowing the top of the water to also freeze and sink, eventually leading to totally frozen lakes, ponds, and seas.

Although its freezing property is significant, so is its specific heat, giving water the ability to remain liquid for an extremely wide range of temperatures. This range lies between 0°C and 100°C. Just as life can survive in the arctic, life is also found around the equator or even near undersea hydrothermal vents. Examples of marine life near the vents include tube worms, eels, and octopi. By having such a wide range of temperatures in which water is a liquid, it increases the chances of finding a place where life can survive. A function of water's large temperature range is its specific heat. Specific heat refers to the amount of energy, as heat (measured in calories), that a substance requires to raise one gram of that substance one degree Celsius. For water, this energy is equal to one calorie per gram per degree Celsius, which is abbreviated as 1 cal/g/°C. For many other substances, such as ethyl alcohol, the energy required is less than one (0.6 cal/g/°C for ethyl alcohol). By being such a good absorber and releaser of heat, water can maintain stability of the environment across a large range of temperatures. For instance, heat is stored in water during the daytime or during summer in the vast oceans, which is later released at night or during winter to help moderate the Earth's temperatures. Evaporative cooling is one method of releasing heat through vaporization of the surface molecules of the water, which cools down the molecules of water beneath the surface. Water vapor, or water in a gaseous form, will rise until it is cooled down high in the atmosphere and condenses into water droplets in the form of clouds and precipitation. The constant evaporation, condensation, and precipitation of water are together known as the water cycle. The water cycle allows the distribution of water throughout the planet. On one hand, evaporation allows for moderation of temperature. On the other hand, it helps the distribution of water. Water's high specific heat capacity allows it to both exist at a wide range of temperatures as a liquid and moderate the temperature of the environment by absorbing and releasing heat.

From the cohesive/adhesive property of the molecules to its high specific heat capacity, water is one of the most precious substances in the universe. All terrestrial life is based on water, and water's unique properties are what allow life as we know it. Because the water molecule is polarized, it can form ring structures as a solid, allowing ice to be less dense than liquid water. The ice insulates bodies of liquid water below, allowing life to live in those areas. The polarization also allows water to be cohesive and therefore be collected and transported in a biological system. Water also exhibits adhesive properties, allowing it to cling to objects, such as the sides of pores in a tree to transport water to the highest branches on the tree itself. Because water has a very high specific heat, one calorie per gram per degree Celsius, it can absorb and emit heat efficiently. Its specific heat capacity also allows it to remain liquid between 0°C and 100°C. Water's chemical and physical properties are what make it truly the liquid of life.