

Chemical and physical properties of water

[Environment](#), [Water](#)



Water is an essential ingredient for the existence of life as we know it.

Biochemical processes occur in aqueous environments, many of which use water. Water also plays a significant role in the process of photosynthesis ($6 \text{CO}_2 + 6\text{H}_2\text{O} + 672\text{kcal} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$). Photosynthesis is the most basic and significant chemical reaction on earth, providing the primary nutrients, directly or indirectly, for all living organisms and is the primary source of atmospheric oxygen. Without water and its unique and unusual properties, life as we know it on earth would not exist.

Water is the only substance naturally present on the earth that exists in three distinct states -solid, liquid, and gas. Many of the unique properties in the take for granted include the three physical phases, transparency, universal solvents, density behavior and temperature, high specific heat, high heat of vaporization, viscosity, surface tension and low compressibility. To understand why these properties exist in water and why they are essential to life on earth it is important to look at the shape and bonding patterns of the molecule because the uniqueness of water is a direct result of its shape and bonding patterns.

The shape of the water molecule In the water molecule the oxygen atom is the central atom. It has four pairs of valence electrons surrounding it. Two of these pairs are shared which form the shared pairs form covalent bonds with the hydrogen atoms. The remaining two pairs are unshared and have a greater repulsive effect than the shared pairs. The combined repulsive effect of the two unshared electron pairs produces an H-O-H bond angle that is smaller than the H-C-H bond angle (109. 47 degrees) in methane or the H-N-H bond angle (107 degrees) in ammonia. Actual measurement of the bond

<https://assignbuster.com/chemical-and-physical-properties-of-water/>

angle in water is 104.5 degrees. If the two hydrogen nuclei were as far apart as possible the angle would be 180 degrees. The unique bond angle in water is only 104.5 degrees. The resulting shape of the molecule is referred to as "bent" or "angular". Traditionally the VSEPR model theory is used to predict molecular shape. See appendix A. Chemical bonding To understand the unusual properties of water as well as what causes them we need to have a basic understanding of the chemical bonding and the structure of the water molecule. The shape of the water molecule is determined in part by the chemical bonding that occurs.

For a brief review of chemical bonding see appendix B. The water molecule consists of the elements hydrogen and oxygen. The chemical bonds in the water molecule are covalent bonds since the hydrogen atoms combine with the oxygen atoms in shared electron pairs. The oxygen atoms exerts a relatively strong pull on the shared electron pairs which causes the hydrogen atom to become electropositive regions and the oxygen atoms to become an electronegative region. The water molecule is considered a polar molecule because the positive and negative regions are not evenly distributed around a center point.

The water molecule due to its polar nature is electrostatically attracted to other water molecules as well as other ions in solution. The attraction of the electropositive hydrogen atom to the electronegative oxygen atom of an adjacent water molecule is the bridging phenomenon known as hydrogen bonding and is only about 10 percent the strengths of a covalent bond. This special bond is responsible for most of the unusual properties of water: high

freezing and boiling points, high heat capacity, high heat's of fusion and evaporation, solvency, and high surface tension.

Let us look more closely at the bonding patterns of water. Polar Covalent Bond When oxygen and hydrogen atoms are brought together the difference in their electronegativities is not sufficient to yield ions. Instead they must share a pair of electrons between them forming a covalent bond. Some sharing is more equal than others and oxygen's greater electronegativity draws the electron pairs closer to its nucleus and further away from the hydrogen's nuclei. This results in a concentration of negative charges nearer the oxygen atom and thus further from the positively charged protons that make the nuclei of the hydrogen atoms.

The bond formed is intermediate between a fully ionic bond and a purely covalent bond. There is a separation of charges but not complete as in the formation of ions. The partial charge that is produced is symbolized by δ . In Water, one side of the molecule, where the hydrogen atoms are, will be partially positively charged. The other side with the unshared pairs of electrons will be negatively charged. As a whole the molecule is polar. So it can be said that the water molecule has a polar covalent bond. The polarity of the water molecule makes mutual attraction between water molecules possible. The Hydrogen Bond

Each molecule has a δ^- and δ^+ region. The attraction occurs between the δ^- and δ^+ regions (remember unlike charges attract). This means that each water molecule attracts four other water molecules to it. The hydrogen atom is attracted to the oxygen atom of the adjacent water molecule. Each oxygen

atom can associate with two hydrogen atoms of other nearby water molecule through its unshared pair of electrons. The force of attraction between these polar molecules is not as strong as a covalent or ionic bond but strong enough to be significant. It is important enough to be called the HYDROGEN BOND.

It is the hydrogen bonding that occurs between water molecules that accounts for many of the remarkable and vital properties of water that make the presence of water synonymous with life itself. Firstly, the ability of water to remain liquid over a large portion of the range of temperatures found on earth is one such vital property. Other molecules, as small as water (eg CO₂), change from liquid to gas at temperatures far below that of water. It is also the Hydrogen bond which is responsible for the large amount of heat energy needed to convert water from liquid to gas.

Water is therefore a great stabilizer of temperature which is essential to the survival of life on this planet. It accounts for more moderate temperatures near large bodies of water. This property is also exploited by many living organisms. Sweat, and its evaporation is a vital cooling process for biological mammals and depend greatly on the large amount of heat energy required to break the hydrogen bonds between water molecules. Hydrogen bonding maintains the integrity of the water molecule during chemical reactions. Other compounds undergo chemical changes (ionization), where as water will maintain its chemical integrity.

As a result water is a poor conductor of electrical current. Hydrogen bonding is the reason for the lower density of ice relative to water. In conclusion,

<https://assignbuster.com/chemical-and-physical-properties-of-water/>

three main unique features which are the consequences of hydrogen bonding in water are: melting point, surface tension, density. These and other unique properties of water are responsible for the important role that water plays in life. **Water's Important Role** Water is the single most abundant molecule in living things. It provides the medium in which most biochemical interactions occur.

Some biochemical reactions water is involved in are: cellular respiration, digestion, and photosynthesis. Water is the home for many animals, plants and micro-organisms. Water is involved in the cycling of all other material by living things both on a local and global scale. Water has a number of unique and unusual properties that are responsible for its important roles it plays in the biosphere. **BOILING AND MELTING POINTS.** Water has unusually high boiling and freezing points compared to other compounds with similar molecular structure. A comparison of boiling and freezing points can be seen in the following chart.

Notice only water has a boiling and melting point that exists within the range of life. The boiling point of water is a unique 100°C results in and the freezing point is a remarkable 0°C due to the fact of the polar nature of the water molecule and hydrogen bonding. Two important, but not unique, properties of water for life are that water is liquid at normal temperatures over much of the earth and that water is transparent. If water were not liquid, nutrients could not flow from soil to the roots of plants, blood could not circulate, and bodies of organisms would be so rigid that they could not move.

If water were not transparent, light could not penetrate through cellular protoplasm into chloroplasts to drive photosynthesis in plants, you would be blind because light could not penetrate through the vitreous humor to the retina of your eyes, and light could not penetrate into lakes to allow growth of phytoplankton. Clearly life cannot exist without the amazing properties of water. **SOLVENT CAPABILITY.** A solvent is a substance capable of dissolving another substance (solute) to form a homogeneous mixture (solution) at a molecular level.

The polar nature of water makes it an excellent solvent especially with other polar compounds such as salts, alcohols, carboxylic compounds and many more. As a solvent water is unsurpassed in its ability to dissolve a wide range of inorganic and organic substances. More substances dissolve in water than any other known substance. The versatility of water as a solvent allows it to serve as the medium of transport for so many materials. This is true both for individual organism and for the biosphere as a whole. The essential transport systems including blood, lymph, and urine are all water based.

Without water's solvent capabilities to make three systems work, life could not exist. **A LESS DENSE SOLID FORM.** Water exists in liquid form over a wide range of temperatures outside of which life processes are slowed down or halted completely. Between 4° c and the freezing point at 0° c, an amazing thing happens that occurs with very few substances, Water gradually expands becoming less dense. Water is the only substance where the liquid state is heavier than the solid state. All other substances the solid form is

denser than the liquid form. Since the density of ice is less than that of liquid water, ice floats on water.

It is very significant that ice expands and floats on water because if lakes and streams froze from the bottom to the top, aquatic life would not even exist, and climate and weather patterns would be altered drastically. This is an important quality of water because as ice forms it floats on top of the water. It acts to provide a thermal blanket for the rest of the water beneath and all its many life forms. This is important because if water behaved like all other substances, water bodies would freeze from the bottom up and in most cases would never thaw completely during summer.

This would have a dramatic cooling effect globally and would impact all life on earth. LARGE HEAT CAPACITY. The remarkable property of water is its extremely high capacity to absorb heat without a significant increase in temperature. We see examples of this all the time. For example, under the summer sun at the beach, sand will increase in temperature to the point where it is too hot to walk on, whereas the water temperature is still cool, even though both are heated by the same amount of solar heat energy. Water has the largest heat capacity of any common substance.

This means that water takes more heat energy to raise the temperature of water a given number of degrees than for any other material. In cooling water gives up more heat than any other material. This property is important globally and individually. Individually, the high heat capacity buffers organisms from sudden extreme shifts in temperature which would be harmful to it. Globally, the oceans moderate seasonal temperature

fluctuations. That is why coastal areas are cooler than inland areas at the same latitude. These differences influence the weather globally.

And without weather changes life would be very unbearable. The absorption of huge amounts of solar heat energy by water during the day and the slow release of heat energy during the night is responsible for the moderate climate in the coastal areas. A wider range of temperatures typically exist inland away from bodies of water. If not for the vast oceans on earth tempering the climate life would not exist. This property combines with the H₂O property to create the water cycle which supports life on earth. HIGH HEAT OF VAPORIZATION.

Water has an extraordinarily high heat of vaporization. On average it takes 580 calories to convert one gram of water into water vapour. A value that is higher than any other common substance. This property is of important significance to animals in regulating body temperature because of the large amount of body heat that is required to evaporate water (sweat). Without this property of water, organisms would overheat and die and the climate would be thrown into chaos. SURFACE TENSION. Water has the highest surface tension of any other liquid except Mercury.

Surface tension is the attractive force exerted by the molecules below the surface on those at the liquid-air interface. The liquid is restrained from flowing by this inward force. The exceptionally high surface tension of water is due to the hydrogen bonding of water. This is demonstrated when you see an insect being able to support itself on the surface layer of water. The surface tension also leads to a higher viscosity as it doesn't flow as easily.

<https://assignbuster.com/chemical-and-physical-properties-of-water/>

This is known as the clumping effect like the high melting point and boiling point the clumping effect occurs in liquid, that have hydrogen bonding.

Conclusion All of these unusual properties stem from the unusual structure and bonding patterns of the water molecule. The molecule is strongly polar because of its uneven distribution of electrons. This allows water to interact easily with other polar substances which accounts for the great solvent power of water. The electronegativity difference between the oxygen and hydrogen atoms in water molecules is responsible for the establishing of hydrogen bonds between molecules.

It is the mutual attraction of water molecules that accounts for the ability of water to remain liquid over a broad range of temperature (0oC-100oC) and also for its high heat of vaporization and high heat capacity. Water could not have all these special characteristics/properties without its unique shape and bonding patterns, life could not exist if not for these special properties of water, espacally the hydrogen bond. You can order a custom essay, term paper, research paper, thesis or dissertation on water from our professional custom writing service which provides high-quality custom written papers on any topic.