



Lesson Objectives

By the end of this lesson, you should be able to:

- Describe how the structure of water accounts for its polarity.
- Explain why water has unique properties including high surface tension and a high boiling point.
- Describe the unique role of water in chemical and biological systems.

Science Practice: Explain how the chemistry of water is important to biological systems.



Words to Know

Write the letter of the definition next to the matching word as you work through the lesson. You may use the glossary to help you.

- | | |
|-------------------------------|--|
| <u> D </u> surface tension | A. the angle formed between three or more atoms bonded together |
| <u> E </u> cohesion | B. the movement of water up a narrow tube due to attractions with the surface of the tube |
| <u> B </u> capillary action | C. the attraction between molecules of two different substances that are in physical contact at a surface |
| <u> A </u> bond angle | D. the property of the surface of a liquid that allows it to resist an external force |
| <u> C </u> adhesion | E. the attraction between molecules within a substance; the tendency of the molecules of a substance to “stick together” or group together |

Instruction

Properties of Water

Slide

1

Lesson
Question

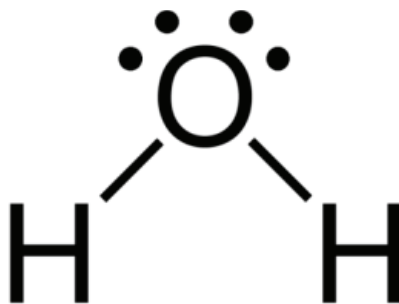
What are the properties of water that make it unique?

2

Molecular Structure of Water

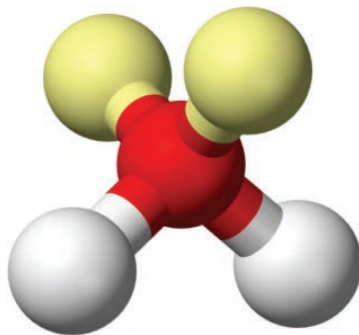
Features include the following:

- Single bonds between **oxygen** and hydrogen
- Two **lone** pairs on oxygen atom



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- Two lone pairs on oxygen atom
- Electron-domain geometry: **tetrahedral**



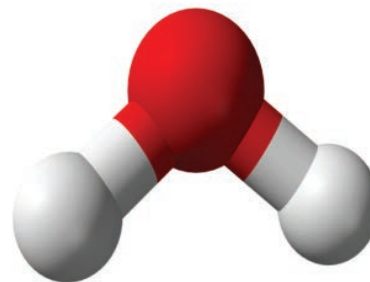
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Molecular Structure of Water

Features include the following:

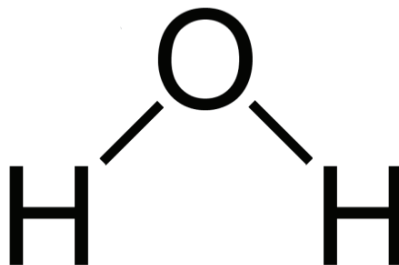
- Single bonds between oxygen and hydrogen
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- Molecular geometry: **bent**



- Lone pairs deflect **hydrogen** atoms

Features include the following:

- Single bonds between oxygen and hydrogen
- Two lone pairs on oxygen atom
- Electron-domain geometry: tetrahedral
- Molecular geometry: bent
 - Lone pairs deflect hydrogen atoms
 - **Bond angle** (the angle formed between three or more atoms bonded together) $\sim 104.5^\circ$



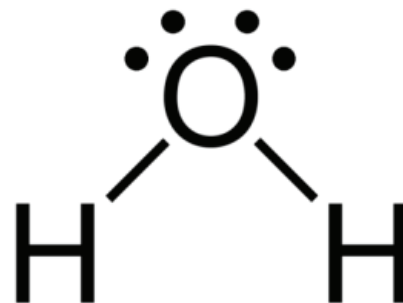
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Polarity of Water

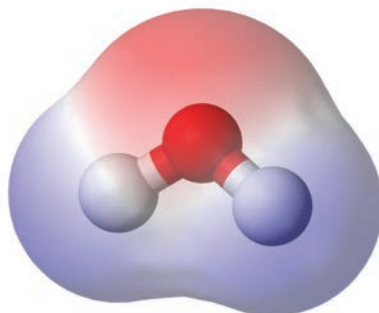
The **molecular** structure of water affects its molecular properties.

- **Electronegativity** difference between oxygen and hydrogen is large.
 - Bonds are highly polar.



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- Water molecule is polar.
 - **Oxygen** atom has partial negative charge.
 - Hydrogen atoms have partial positive charge.



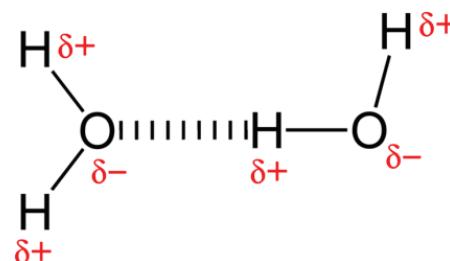
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Polarity of Water

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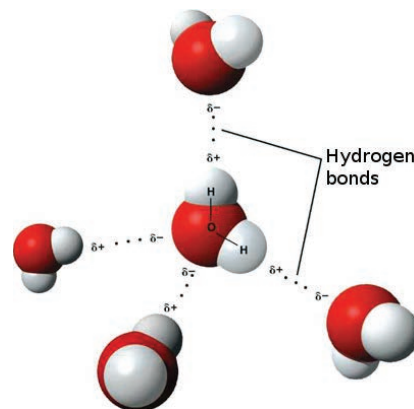
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- Large electronegativity difference allows for bonding interactions.



hydrogen

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- Electronegativity difference between oxygen and hydrogen is large.
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 - Hydrogen atoms have partial positive charge.
- Large electronegativity difference allows for hydrogen bonding interactions.



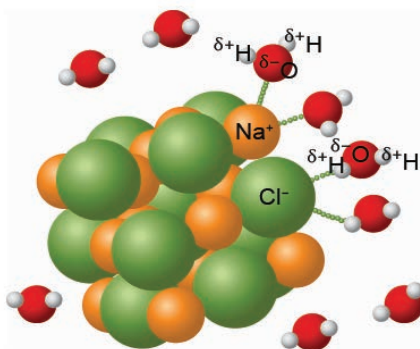
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Water as a Solvent

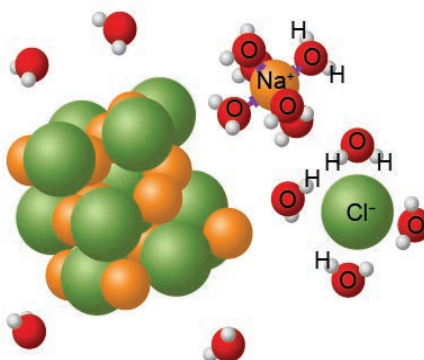
Water, the “universal” solvent:

- dissolves ionic compounds.
 - **Ion-dipole** interactions cause dissociation.
 - Hydration keeps ions in solution.



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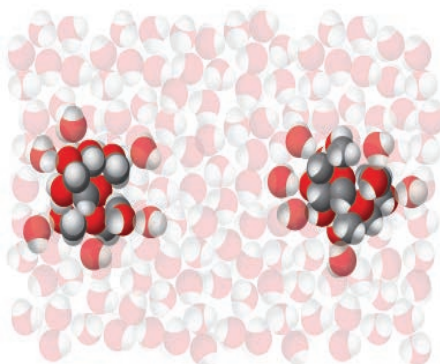
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Water as a Solvent

Water, the “universal” solvent:

- dissolves ionic compounds.
 - Ion-dipole interactions cause dissociation.
 - Hydration keeps ions in solution.
- dissolves polar covalent compounds.
 - **Dipole-dipole** interactions cause dissolution.
 - Hydration keeps molecules in solution.



Like Dissolves Like

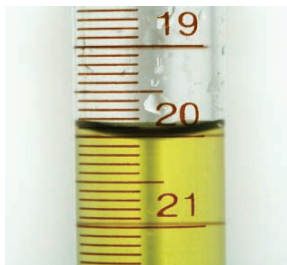
Not everything dissolves in **water**.

- Most nonpolar **covalent** compounds are not soluble in water.

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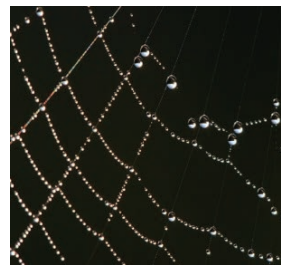
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Adhesion and Cohesion



Adhesion: The attraction between **molecules** of two different substances that are in physical contact at a surface.

- **Meniscus** in glass tubes



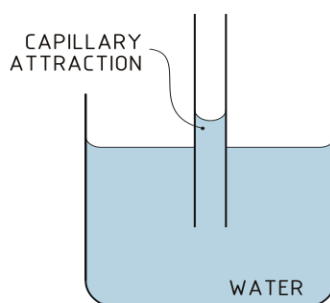
Cohesion: The attraction between molecules within a substance.

- Formation of **droplets**

Capillary Action

Adhesion + **Cohesion**

Capillary action: movement of water up a narrow tube due to attractions with the surface of the tube



Instruction | Properties of Water

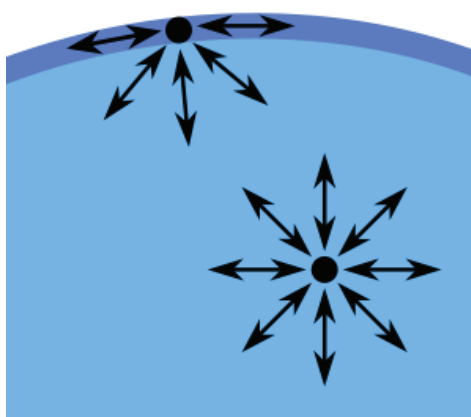
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Surface Tension

Surface tension is the property of the surface of a **liquid** that allows it to resist an external **force**.

- It results from **intermolecular** forces.
- Stronger intermolecular forces produce higher surface tension.



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Melting and Boiling Points

Consider this graph of boiling points for compounds of the Group 16 and Group 17

elements with hydrogen. The

hydrogen bonding causes the boiling

and melting points of water to be much higher than would otherwise be expected.

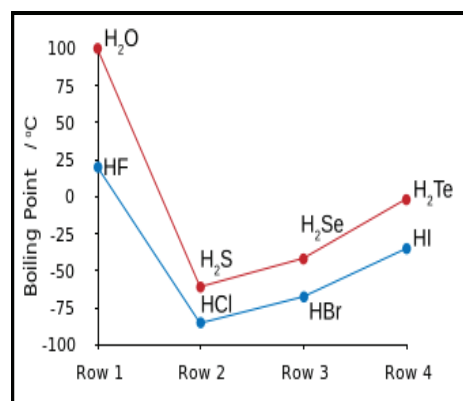


Image by Jon

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Melting and Boiling Points

During melting:

- **kinetic** energy of particles partially overcomes intermolecular forces.
- **particles** can slide past one another.

During boiling:

- kinetic energy of particles completely overcomes **intermolecular** forces.
- particles separate.

Naturally Occurring States of Water

The specific **melting** and boiling points of water allow it to naturally exist as:

- a solid.
- a liquid.
- **gas**.



Instruction

Properties of Water

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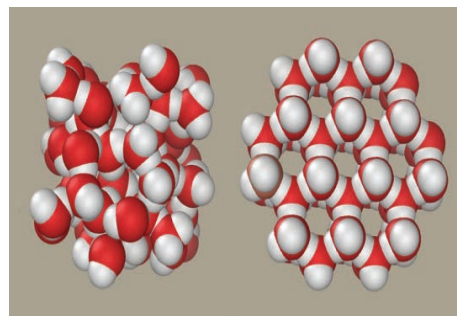
Density of Ice

Hydrogen bonds increase **distance** between water molecules in ice.

- The equation for density is

$$D = \frac{m}{V}$$

- As the **volume** increases, the density of water decreases.



The maximum density of water is ~4°C.

The ability of ice to float on liquid water has important consequences for

aquatic life.

Specific Heat

Specific heat is the measure of a substance's **resistance** to temperature change.

- Higher specific heat means more heat lost or gained for

temperature to increase.

- Hydrogen bonds increase the amount of energy required for **KE** (temperature) to change.

The high specific heat of water allows water bodies to moderate climate and store significant amounts of **thermal** energy.

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Water and Biological Systems

Functions of water in living things include the following:

- Support (turgor pressure, hydrostatic skeleton)
- Temperature regulation
- **Transport** (body fluids)
- Reaction environment (solution)

Additional importance of water to organisms include the following:

- **Climate** regulation
- Living **environment**

Summary

Properties of Water

**Lesson Question**

What are the properties of water that make it unique?

**Answer**

(Sample answer) Water is a polar solvent. Because of this, it can act as a universal solvent. Water can exist in three different states, solid, liquid, and gas. Water has strong adhesion, cohesion, and high surface tension.

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2

The Structure of Water

- The bonds in water are highly polar (electrons are unevenly distributed) because oxygen is highly electronegative and hydrogen is small.
- Water is a polar molecule: The **oxygen** atom has a partial negative charge, and the hydrogen atoms have a partial positive charge.
- Water has a **bent** molecular geometry due to the repulsion by the unbonded electron pairs of oxygen.
- Because of the highly polar bonds in water, water molecules can form hydrogen bonds with one another, producing unique properties.

Summary | Properties of Water

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2

The Properties of Water

- Water's ability to form hydrogen bonds affects many of its properties.
- Water exhibits strong **adhesion**, cohesion, and high surface tension.
- Water's melting and boiling points are higher than expected because of its hydrogen bonds.
- Hydrogen bonds increase the volume of ice, causing it to be less dense than liquid water.
- Because water has hydrogen bonds, its **specific** heat is relatively high.

As a result, it can store large amounts of thermal energy. This allows it to moderate climate.

- Water plays many important roles in biological systems, including support, temperature regulation, and transport.

Use this space to write any questions or thoughts about this lesson.