

Structure and Properties of Water

Learning objective 1.1.A Explain how the properties of water that result from its polarity and hydrogen bonding affect its biological function.

Name: _____

Date: _____

Period: _____

Use the tool **Two Facts About a Bent Molecule**. Part 1 uses **One molecule**, Parts 2 and 3 use **Turn up the heat**, and Parts 4 and 5 use **What follows from it**. Almost everything on the AP exam about water comes back to two facts about one molecule: oxygen pulls harder on shared electrons than hydrogen does, and the molecule is **bent** rather than straight. Keep those two facts in front of you and check at every step that you can trace the property back to them.

Part 1 • The two facts

Use the three buttons on the first tab. Record the values from the readout, then answer in your own words.

Quantity	Value	What it tells you
Electronegativity of oxygen		
Electronegativity of hydrogen		
Difference		
Bond angle		

1. Explain why a water molecule is polar. Your answer needs both facts from the table, not one.

2. Carbon dioxide has more polar bonds than water and no net dipole at all. Explain how that is possible, and what it shows about the difference between “has polar bonds” and “is a polar molecule”.

3. Describe what a hydrogen bond is, and explain how it differs from the bonds holding one water molecule together.

Part 2 · What heating actually does

Go to **Turn up the heat**. A water molecule can hydrogen bond to **4** neighbors — two hydrogens to donate, two lone pairs to accept. Record the count at each temperature, and the prediction it is being checked against.

Temperature	Thermal energy RT	Bonds per molecule	Predicted	Fraction intact
0 °C				
25 °C				
37 °C				
50 °C				
75 °C				
99 °C				

4. Describe what happens to hydrogen bonds as water is heated from 0 °C to 99 °C.

5. Water arrives at its boiling point with most of its hydrogen bonds still intact. Explain what boiling actually is, given that.

6. The last two columns come from two separate methods that were never shown each other's results. Explain why their agreement matters.

Part 3 · Specific heat and evaporative cooling

Open the panels headed **Specific heat, worked through** and **Evaporative cooling, worked through**. Both start from the same idea: energy put into water goes into breaking hydrogen bonds before it goes anywhere else.

Substance	Specific heat (J/g/°C)	Rise on 41,800 J into 1 kg
Water, H ₂ O		
Methane, CH ₄		
Ammonia, NH ₃		
Hydrogen sulfide, H ₂ S		

7. Explain why water has a high specific heat, and give one biological consequence.

8. Explain why sweating cools an animal so effectively. Use a figure from the evaporation panel.

Part 4 · Ice, and why it is strange

Open **Why ice floats, and why that is surprising**. Almost every other substance contracts when it freezes. Record the two densities and the two bond counts before you explain the difference.

State at 0 °C	Density (g/cm ³)	Hydrogen bonds per molecule	Molecules packed closer or further apart?
Liquid water			
Ice			

9. Explain why ice is less dense than liquid water. Your answer must account for ice having more hydrogen bonds, not fewer.

10. Explain why it matters biologically that ice floats.

Part 5 · Everything else follows

Go to **What follows from it** and step through the seven properties. For each, write the cause in your own words — and notice that you are writing the same sentence seven times.

Property	Why hydrogen bonding causes it	One biological consequence
Cohesion		
Adhesion		
Surface tension		
High specific heat		
High heat of vaporization		
Ice floats		
Solvent for polar substances		

11. Explain how cohesion and adhesion together let a tree move water from its roots to its leaves.

12. Hydrogen sulfide has nearly twice the molecular mass of water and boils at -60 °C. Explain what this comparison shows.

13. Explain why water dissolves salt but not oil.

What the model simplifies

A water molecule is treated as having exactly four possible hydrogen bonds, each independently intact or broken at any instant. Real liquid water has a continuous distribution of geometries, and whether a given pair counts as bonded depends on where the line is drawn — which is why published bond counts differ between studies.

The thermal model's two parameters — the enthalpy and entropy of breaking one bond inside the liquid — are calibrated to measured bond counts near 0 °C and 100 °C rather than derived from first principles. The familiar figure of about 20 kJ/mol is the energy of an isolated hydrogen bond between two molecules in the gas phase; inside the liquid a molecule that loses a bond reorients and partly bonds elsewhere, so the effective cost is several times smaller. Building the tool with the gas-phase number produced a model in which every bond stayed intact at every temperature.

Boiling itself is not modeled, and the bond count is shown only up to 99 °C. Beyond that the liquid is no longer the thing being described — and a model that switches everything off at exactly 100 °C teaches the wrong lesson about what boiling is.

The specific-heat panel splits added energy between breaking bonds and increasing molecular motion in a fixed proportion, which is illustrative rather than measured. The direction is right and the exact split is not.

Boiling points, specific heats, densities, electronegativities and the heat of vaporization are measured constants from standard references, not outputs of the model; every calculation built on them is shown in full so it can be checked.