"Water has never lost its mystery. After at least two and a half millennia of philosophical and scientific inquiry, the most vital of the world's substances remains surrounded by deep uncertainties. Without too much poetic license, we can reduce these questions to a single bare essential: What exactly is water?"

Philip Ball, in *Life's Matrix: A Biography of Water*,
University of California Press,
Berkeley, CA, 2001, p. 115

Chapter 5: Water for Life

Do you know where your drinking water comes from?

Do you know if your drinking water is safe to drink?

How would you know?

Water

Cycles nutrients on the planet.
Drives weather and climate.
Excellent solvent.
Essential medium for biochemical reactions (life) in cells.
Solid state less denser than liquid state.
High heat capacity – water bodies, heat reservoirs.
Oceans and lakes moderates extreme temperature swings.
An excellent indicator of 'life on planets'.

Issues of current interest

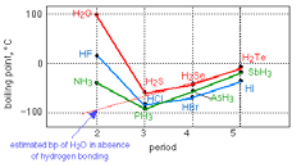
Using water ends up in contaminating water.
Cleaning water occurs naturally, compared to the rate of use, its is a slow cleaning rate.
Fresh water is not in unlimited supply.
Fresh water from renewal of used water: rate's incompatible.

Uneven distribution of water on the planet.
Accessibility of water – not equitable.
Strategic resource, leads to conflict between communities.

Properties of water

Properties of water are unique due to the molecular features of the water molecule.

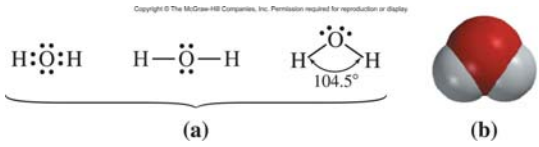
Liquid at ambient temperature (25ºC).
Boiling point is unusually high.
Freezing point unusually high.
Expands upon solidifying → lower density than water.



Water and it's properties from the molecular standpoint.

Different Representations of Water

Lewis structures | Space-filling



5.1

Covalent bond –
ideally equal sharing
by participating atoms.

When the bonding atoms are heteronuclear (different) the supposed equal sharing would not occur.

Electronegativity is a measure of an atom's attraction for the electrons it shares in a covalent bond.

Table 5.1 Electronegativity Values for Selected Elements

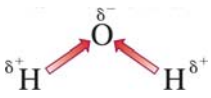
1A	2A	3A	4A	5A	6A	7A	8A
H 2.1							He *
Li 1.0	Be 1.5	B 2.0	C 2.5	N 3.0	O 3.5	F 4.0	Ne *
Na 0.9	Mg 1.2	Al 1.5	Si 1.8	P 2.1	S 2.5	Cl 3.0	Ar *

On periodic table, EN increases

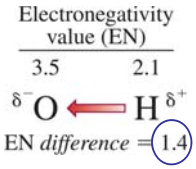
EN Values assigned by *Linus Pauling*, winner of TWO Nobel Prizes.

5.1

A difference in the electro-negativities of the atoms in a bond creates a **polar bond**.

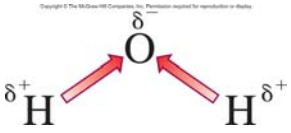


Partial charges result from bond polarization.

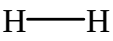


A ***polar covalent bond*** is a covalent bond in which the electrons are not equally shared, but rather displaced toward the more electronegative atom. An intramolecular force!!

5.1



A water molecule is polar – due to polar covalent bonds and the ***shape of the molecule***.



H_2 has a nonpolar covalent bond.

NaCl

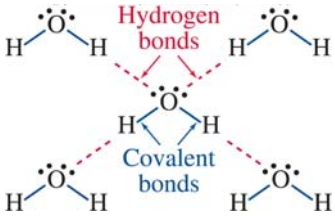
NaCl has an ionic bond – note: *EN difference*.

Na = 1.0

Cl = 2.9

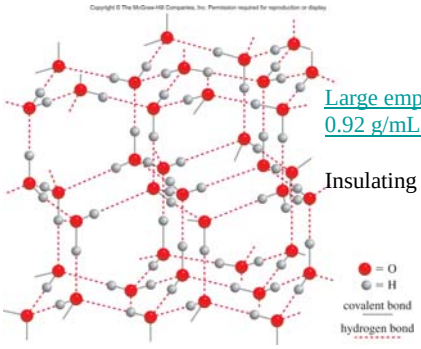
ΔEN = 1.9

5.1



Polarized bonds and the electron distribution in the water molecule allow **hydrogen bonding** to occur.

5.2



Large empty space in ice! 0.92 g/mL.

Insulating properties of ice.

A **hydrogen bond** is an electrostatic attraction between an atom bearing a partial positive charge in one molecule and an atom bearing a partial negative charge ***in a neighboring molecule***. The H atom must be bonded to an O, N, or F atom.

Hydrogen bonds typically are only about one-fifteenth as strong as the covalent bonds that connect atoms together *within* molecules.

H–bonds are *intermolecular bonds.* Covalent bonds are intramolecular bonds.

Heat capacity of water is very high.

As such water can absorb large quantities of heat: excellent coolant. Vaporizing water can pick up excess heat from hot engines and living animals bodies.

Large water bodies influence climate, water droplets in clouds mediate global temperatures.

Humid atmospheres retain heat for a longer time than earth.

Water

Potable water: drinking and cooking.
~100 gallons/person/day US
10% domestic use.

Non potable water – other uses.

20% industrial, 70% agriculture
Economic base/shifts

Availability of water – variable .

Water footprint: estimate (individual/nation) of amount of water required to sustain the consumption of goods and services.

Water Footprint

Water is necessary to produce food:

Table 5.2 Fresh Water Needed to Produce Food

Food (1 kg)	Water (L)	Food (1 kg)	Water (L)
beef	15,500	rice	3,400
pork	4,800	soybeans	1,800
chicken	3,900	wheat	1,300
sheep	6,100	corn	900

Source: Water Footprint Network. www.waterfootprint.org.

Water footprint calculations account for all water usage in producing the product.

Water Footprint

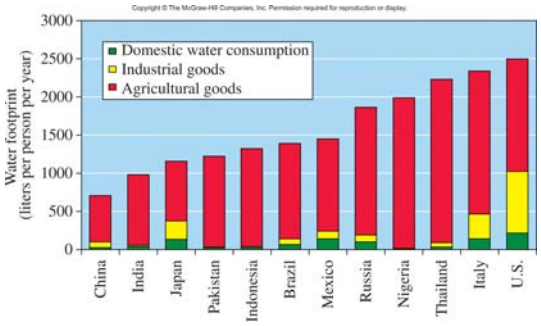
Water is necessary for products:

Table 5.3 Product Water Footprints

Product	Water Footprint (L)
1 cup of coffee (125 mL)	140
1 apple (100 g)	70
1 orange (100 g)	50
1 glass of orange juice (200 mL)	170
1 egg (60 g)	200
1 hamburger (150 g)	2400
1 cotton T-shirt (250 g)	2700
1 computer chip (2 g)	32

Source: Adapted from A. Y. Hoekstra and A. K. Chapagain, Water footprints of nations, *Water Resource Management* (2007) 21: 35–48.

International Water Footprint (per capita)



5.3

Total Global water footprint = 7×10^{15} L/yr

Total Global water footprint = 1×10^{6} L/yr/person

US water footprint = 2×10^{6} L/yr/person

India water footprint = 8.0×10^{5} L/yr/person