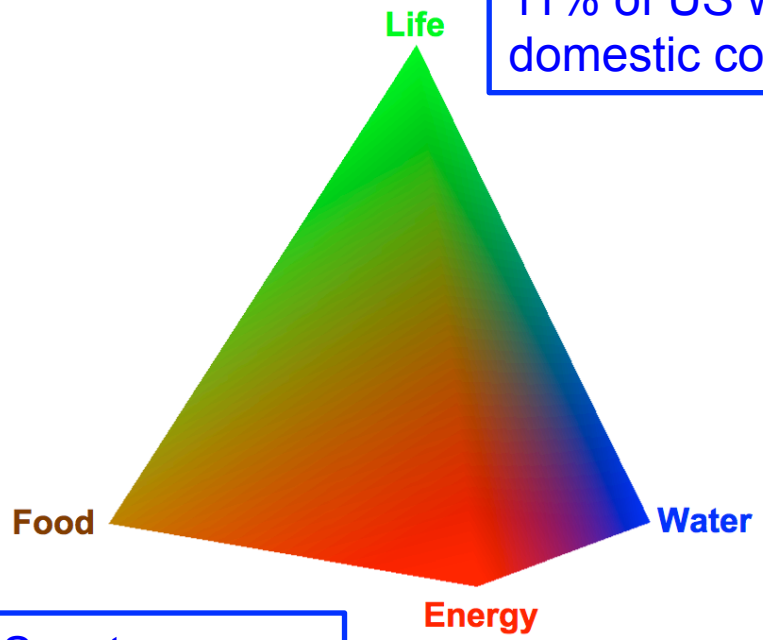
Water (properties)

Interconnectedness of Issues: Water

US water usage (10^9 gallons/day) in 2000:

194 thermal electric
137 irrigation
43 domestic
19 industrial
14 miscellaneous



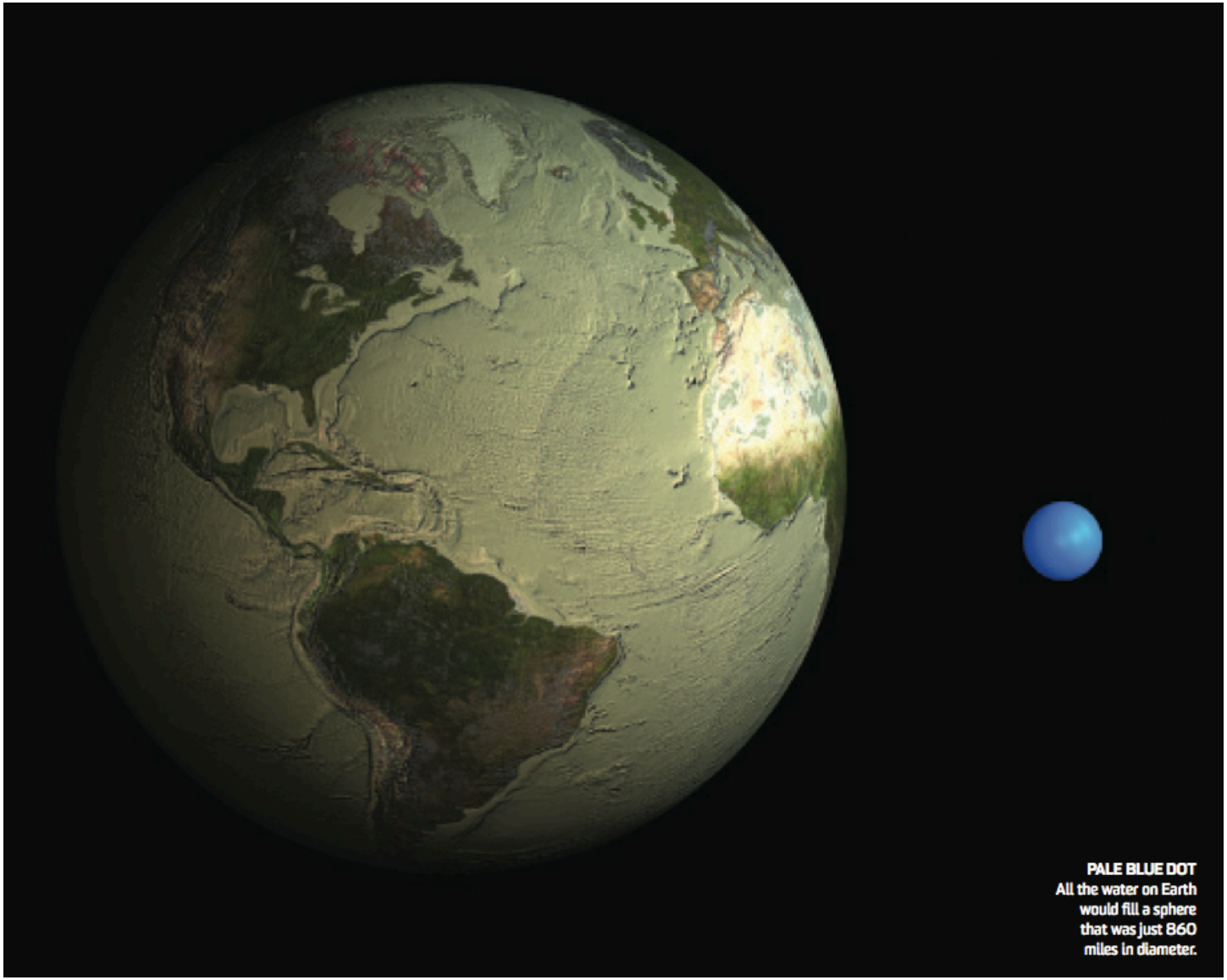
11% of US water use is for domestic consumption

34% of US water use goes to irrigation

Nearly 50% of the water that the US uses is for thermal turbine generation of electricity

positive: can use the water again; (big) negative: thermal pollution

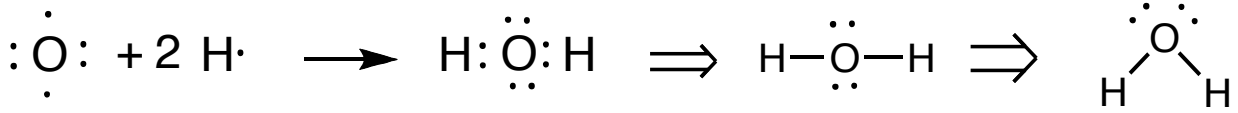
World's Water



Elizabeth Royte
POPULAR SCIENCE
July 2012, p52-53

The 750Gt Carbon in the atmosphere would fill a sphere ½ mile in diameter as a liquid

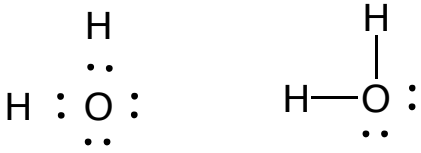
Molecular Structure of Water

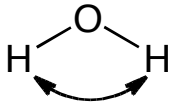
Chapter 2 H_2O 

Chapter 3 H looks like He and O looks like Ne

Basic procedure:

1. Determine # valence electrons for each atom
2. Arrange outer/valence electrons so each atom has noble gas configuration
3. Electron pairs repel (but are attracted to protons) so want to be as far apart as possible





104.5°

Steric # = 4,
think "tetrahedron"
shape = bent

Chapter 5 **Electron pairs not equally shared**

Electronegativity tells us who "wins" in a shared pair

Table 5.3 **Electronegativity Values, Arranged by Group Number**

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

Electronegativity value (EN)

3.5 2.1

δ^- O ⟵ H δ^+

EN *difference* = 1.4

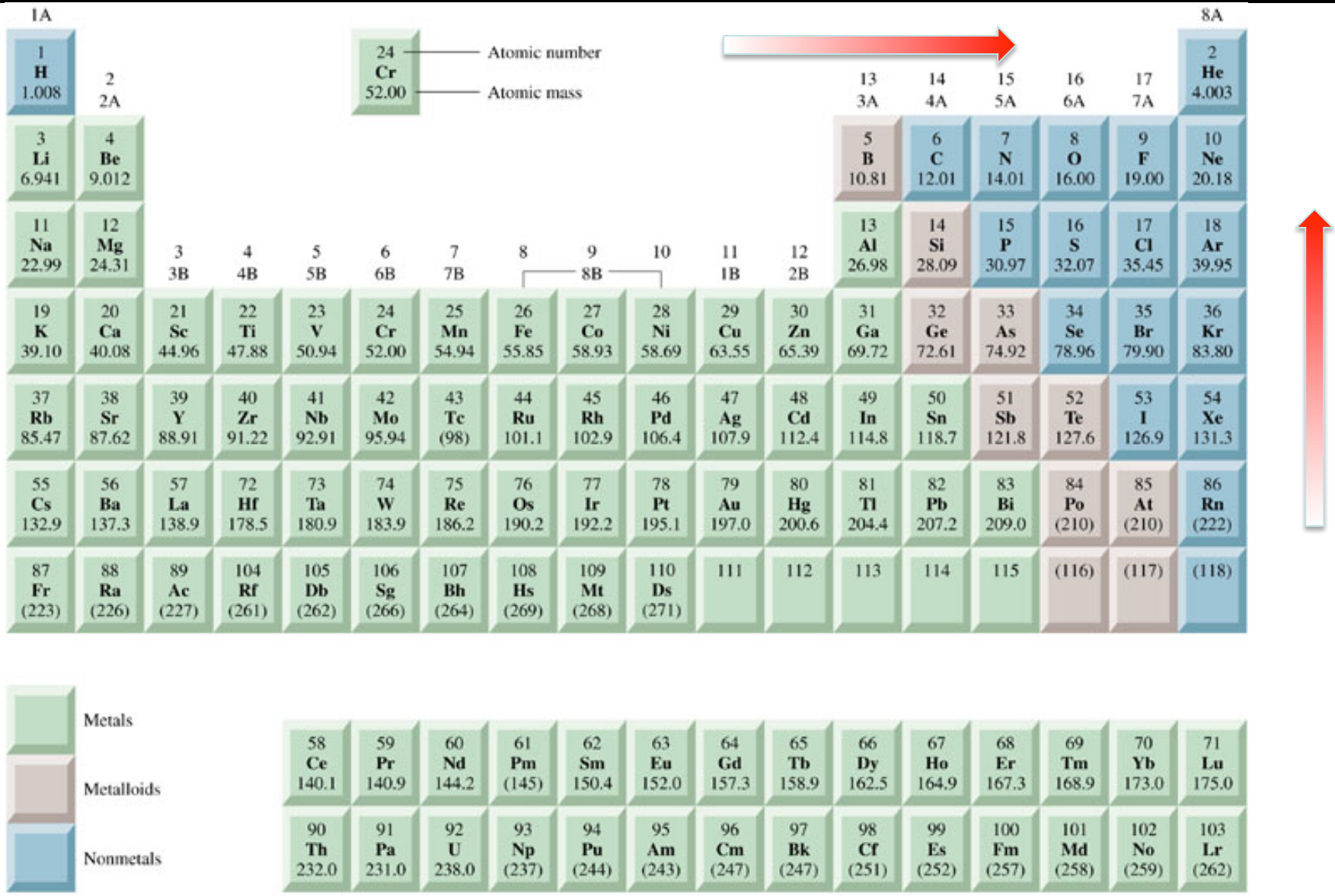
Electronegativity, periodic trends

Table 5.3 Electronegativity Values, Arranged by Group Number

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

Numerical differences: O & Mg 3.5-1.2=2.3

Electronegativity, periodic trends



Bond Energies

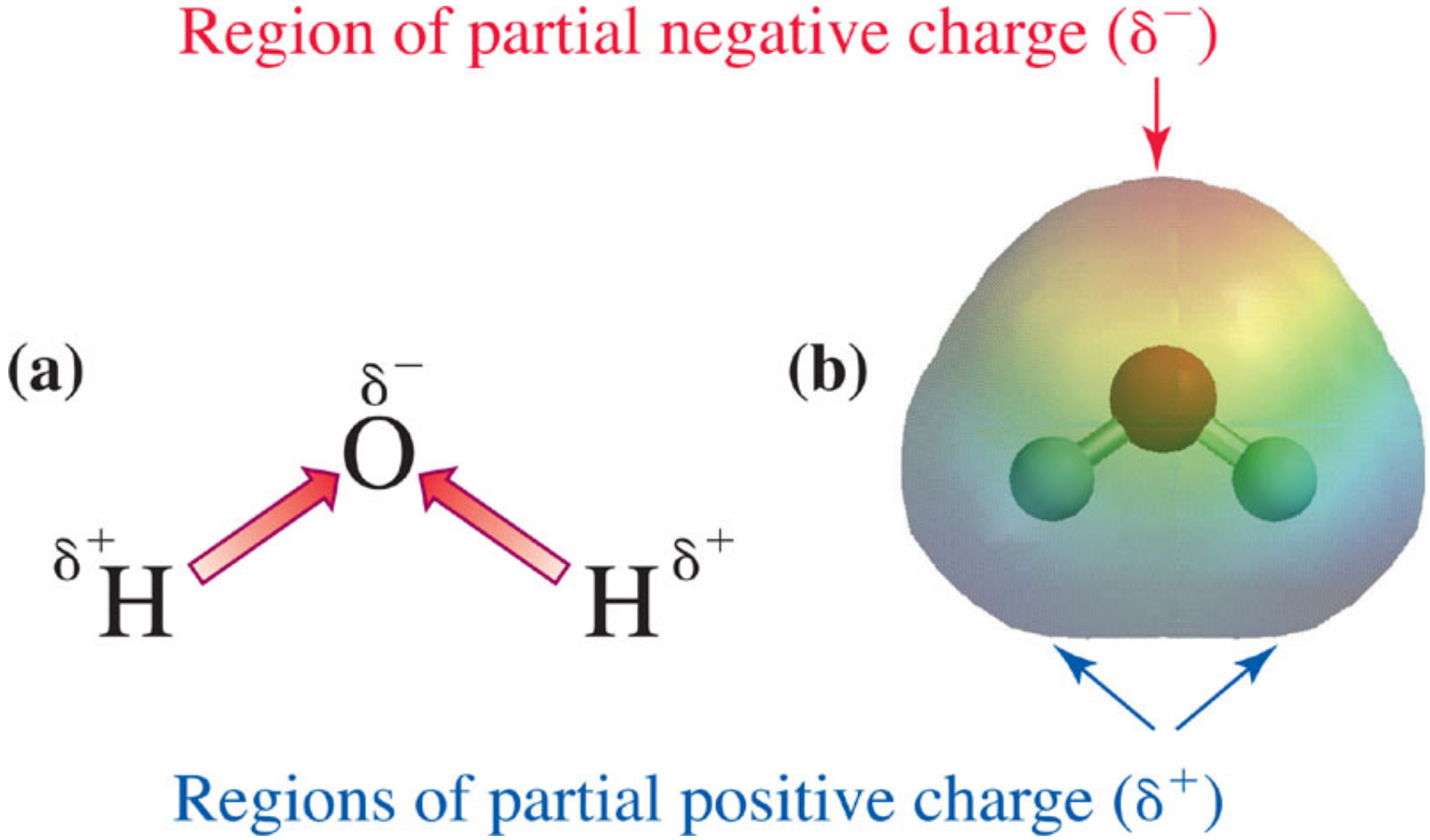
Table 4.2 Bond Energies (in kJ/mol)

	H	C	N	O	S	F	Cl	Br	I
Single Bonds									
H	436								
C	416	356							
N	391	285	160						
O	467	336	201	146					
S	347	272	—	—	226				
F	566	485	272	190	326	158			
Cl	431	327	193	205	255	255	242		
Br	366	285	—	234	213	—	217	193	
I	299	213	—	201	—	—	209	180	151
Multiple Bonds									
C=C	598			C=N	616		C=O	803 in CO_2	
C≡C	813			C≡N	866		C≡O	1073	
N=N	418			O=O	498				
N≡N	946								

Source: Data from Darrell D. Ebbing, *General Chemistry,* Fourth Edition, 1993 Houghton Mifflin Co. Data originally from *Inorganic Chemistry: Principles of Structure and Reactivity,* Third Edition, by James E. Huheey, 1983, Addison Wesley Longman.

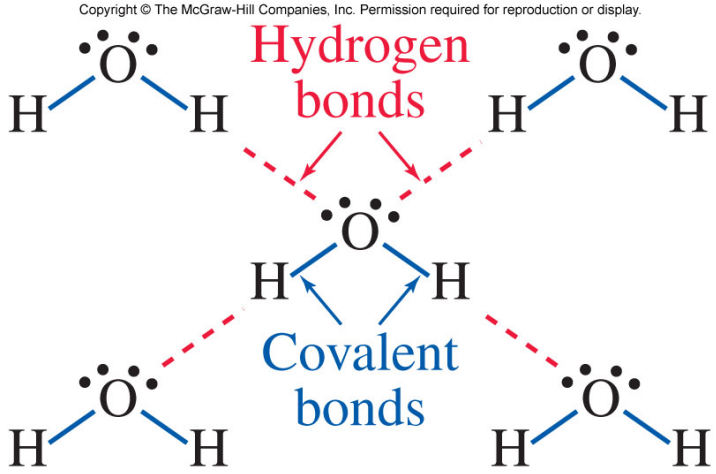
Bond energies track electronegativity trends
HF>HO>HN
566>467>391
4> 3.5> 3.0

Water is a Polar Molecule



Hydrogen Bonding in Liquid Water

Hydrogen bonds are **intermolecular** electrostatic interaction involving partial positive charges on H atoms



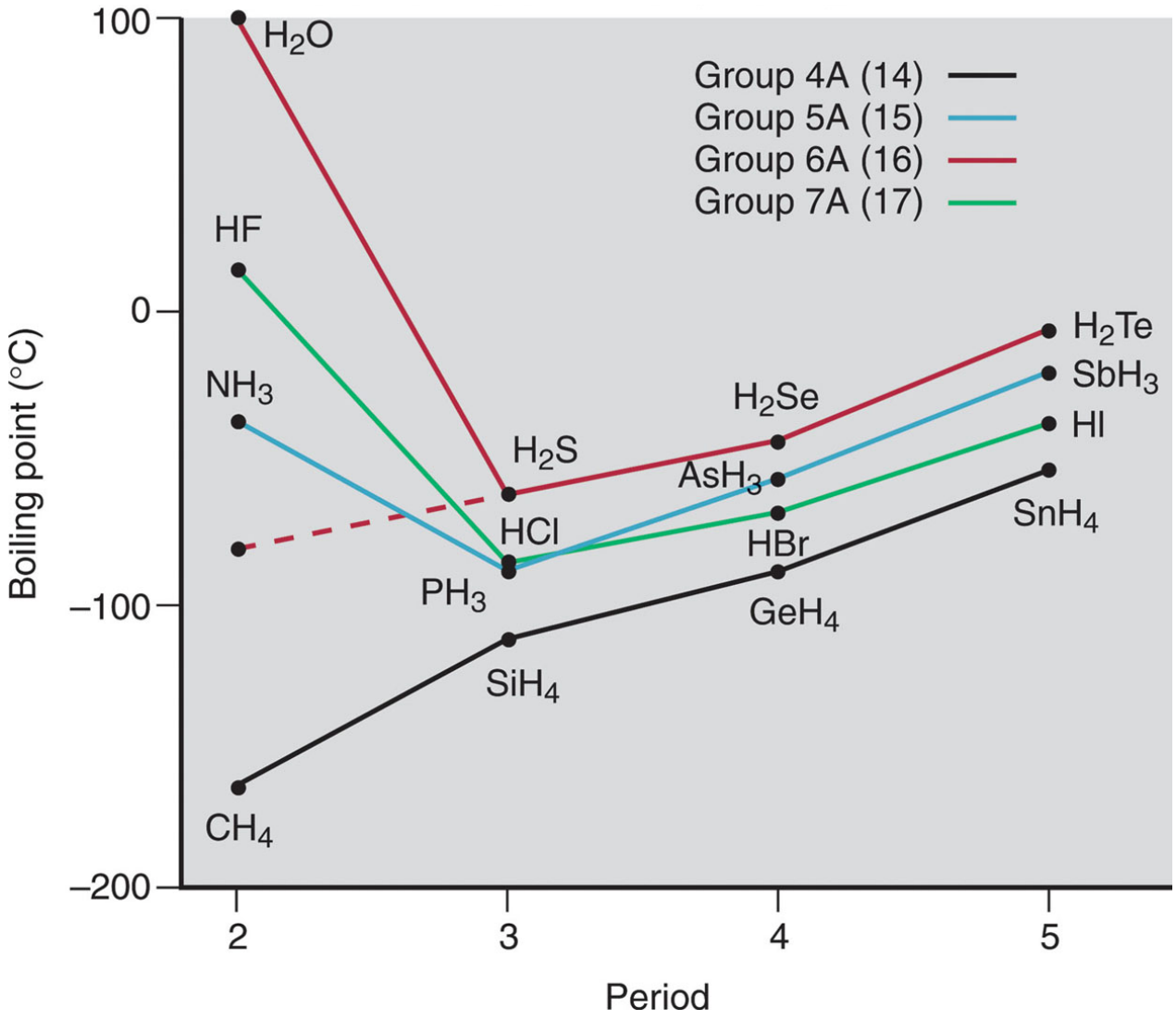
Hydrogen bonds in water worth ~22 kJ/mol
Remember: O-H bond strength = 467 kJ/mol

Energy required to break the hydrogen bonds in water: this gives the compound a high **specific heat** relative to most other things—it's why we use water to heat and cool things… (takes more heat to raise the temperature)

In 2000 US water usage (10^9 gallons/day):
194 thermal electric power; 137 irrigation; 43 domestic; 19 industrial;14 misc

Hydrogen bonding is not restricted to water: H···O, H···N, H···F all known (and some evidence for others in the chemical literature)

Hydrogen Bonding and Boiling Points



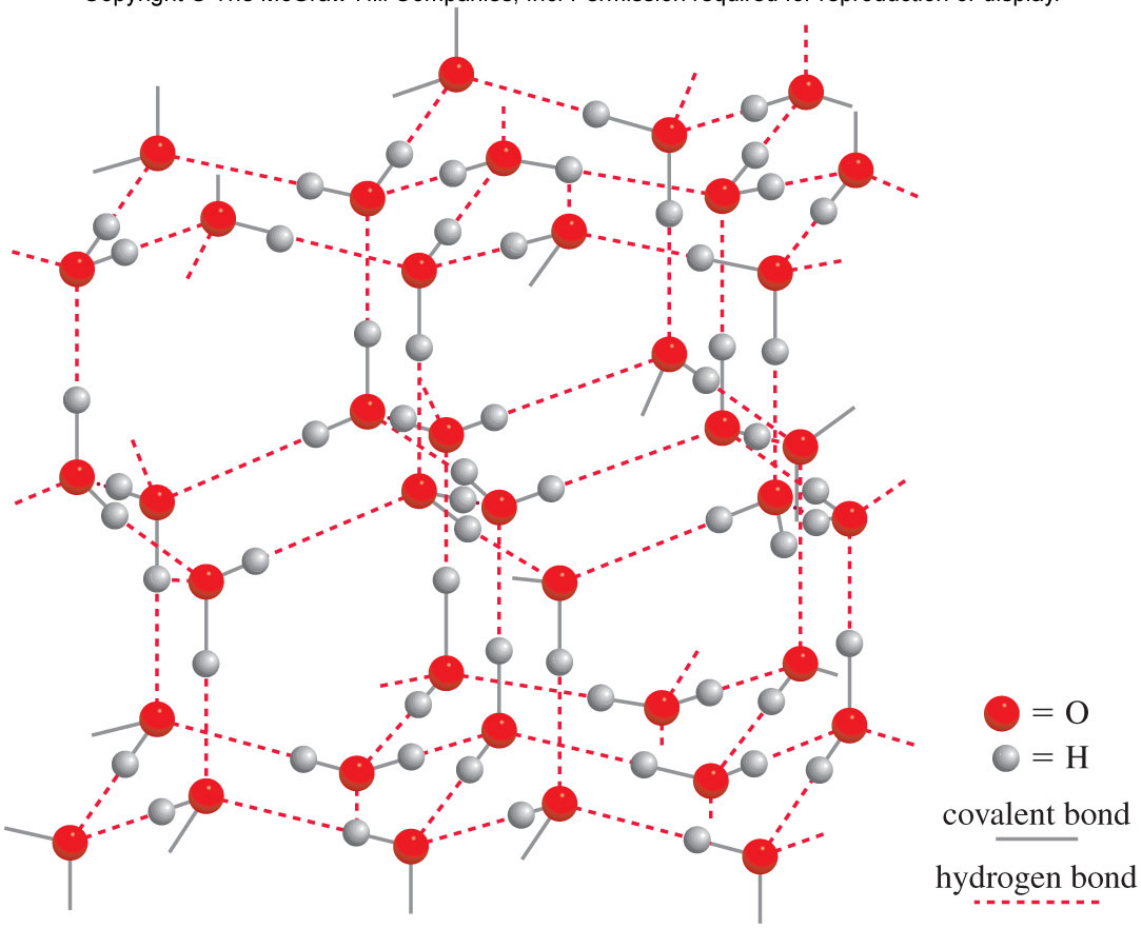
Hydrogen Bonding in Ice

Hydrogen bonds in water also help explain why ice floats on water…

Density = mass per unit volume

Structure of ice (one of many) shown at right…

H-bonds create a more open network than might be expected (usually solids are more dense than their corresponding liquids), so the density of ice is less than that of liquid water.



Water as a Solvent

(only rarely do we have/drink/use pure water)

Solvents: substances capable of dissolving other substances

Solutes: substances that dissolve in a solvent

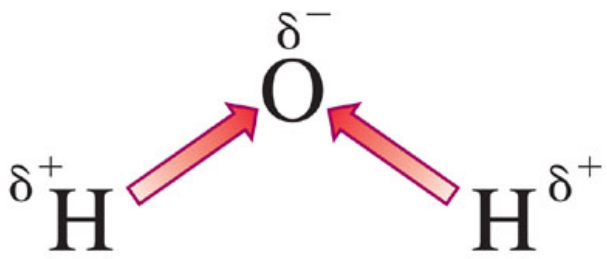
Solution: a homogenous mixture of uniform composition

Aqueous solutions: solutions in which water is the solvent

Like dissolves like:
Hydrogen bonding solutes dissolve in hydrogen bonding solvents

Polar solutes dissolve in polar solvents

Non-polar solutes dissolve in non-polar solvents

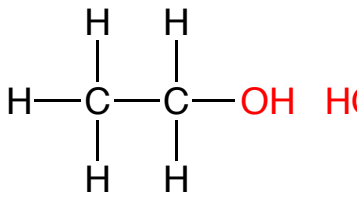


Covalent Compounds and Their Aqueous Solutions

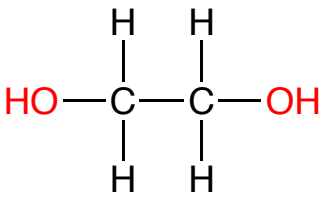
Review from beginning of the course:

C-H bonds are pretty non-polar (electronegativity for C = 2.5, electronegativity for H = 2.1)

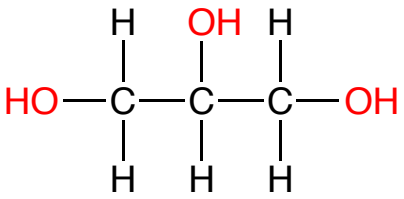
Water is polar *and* capable of hydrogen bonding



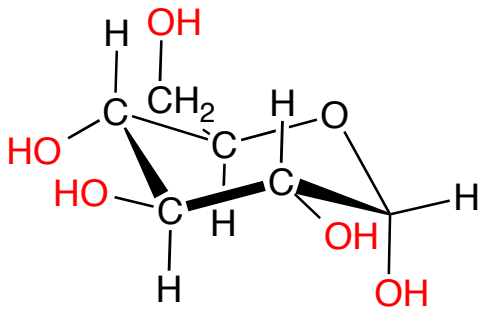
ethanol



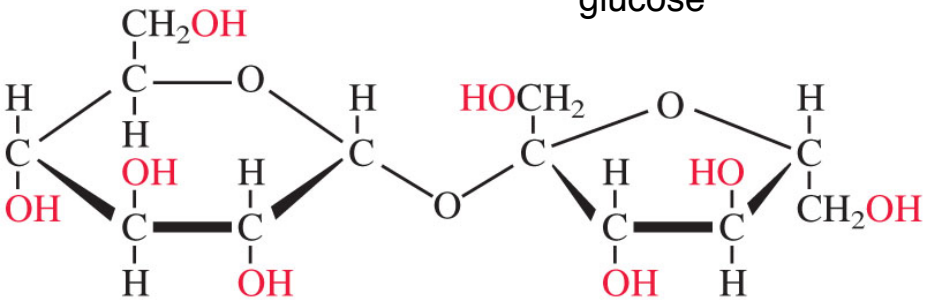
ethylene glycol



glycerin



glucose



sucrose (table sugar)