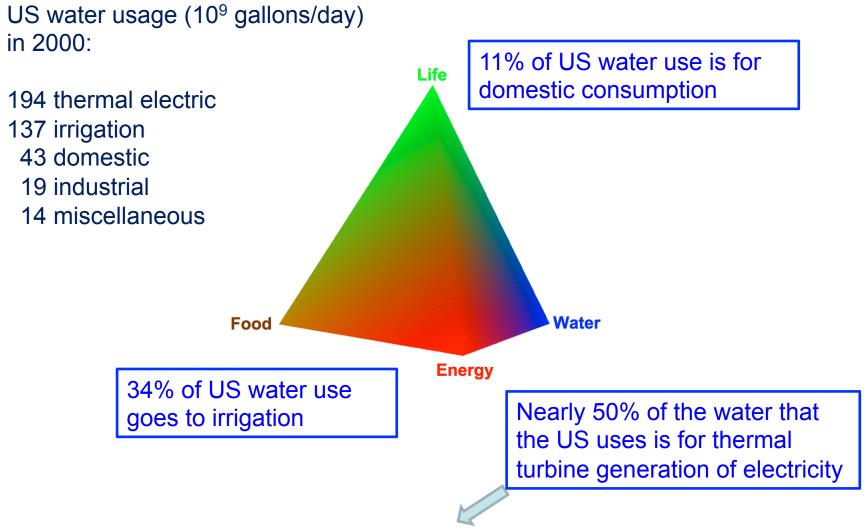
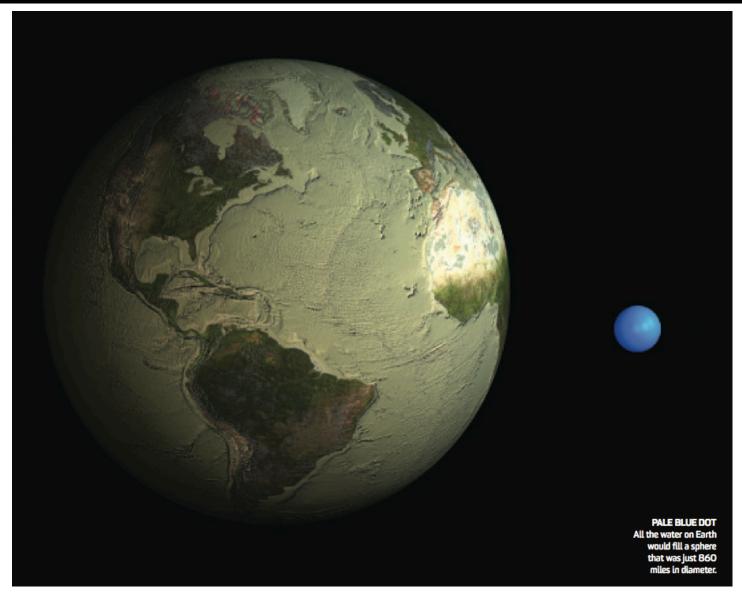
Water (properties)

Interconnectedness of Issues: Water



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 $\frac{1}{2}$ mile in diameter as a liquid $\frac{23}{3}$

Molecular Structure of Water

Chapter 2

 H_2O

:O: +2 H· → H:O:H





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





Steric # = 4, think "tetrahedron"

shape = bent



Chapter 5 Electron pairs not equally shared

Electronegativity tells us who "wins" in a shared pair

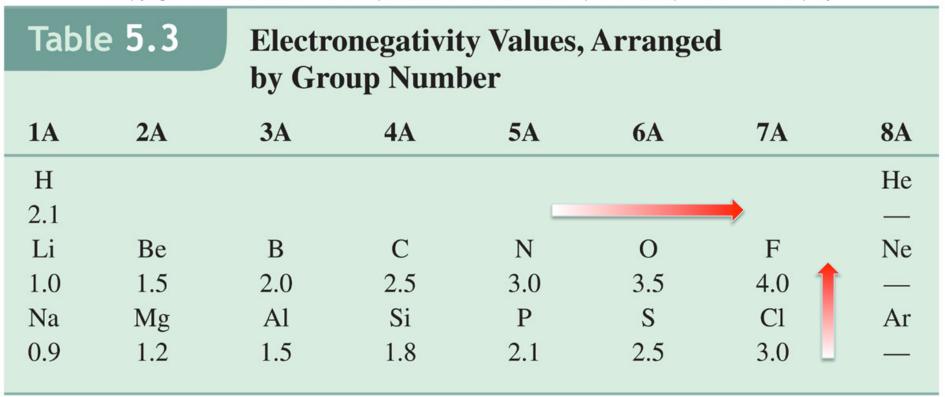
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Tabl	Table 5.3 Electronegativity Values, Arranged by Group Number								
1A	2A	3A	4A	5A	6A	7A	8A		
Н							Не		
2.1							_		
Li	Be	В	C	N	O	F	Ne		
1.0	1.5	2.0	2.5	3.0	3.5	4.0	_		
Na	Mg	Al	Si	P	S	Cl	Ar		
0.9	1.2	1.5	1.8	2.1	2.5	3.0	_		

Electron e value	egativity
3.5	2.1
δ ⁻ O ←	$-H^{\delta^+}$
EN differe	nce = 1.4

Electronegativity, periodic trends

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Numerical differences: O & Mg 3.5-1.2=2.3

Electronegativity, periodic trends

1A	N				1 2	25											8A
1 H 1.008	2 2A				24 Cr 52.00 -		Atomic n					13 3A	14 4A	15 5A	16 6A	17 7A	2 He 4.003
3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31	3 3B	4 4B	5 5B	6 6B	7 7B	8	- 8B -	10	11 1B	12 2B	13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 C1 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.61	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Te (98)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 1 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	57 La 138.9	72 Hf 178.5	73 Ta 180.9	74 W 183.9	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 TI 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (210)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (261)	105 Db (262)	106 Sg (266)	107 Bh (264)	108 Hs (269)	109 Mt (268)	110 Ds (271)	111	112	113	114	115	(116)	(117)	(118)
	Metals Metalloids		58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0	
Nonmetals			90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)	

Bond Energies

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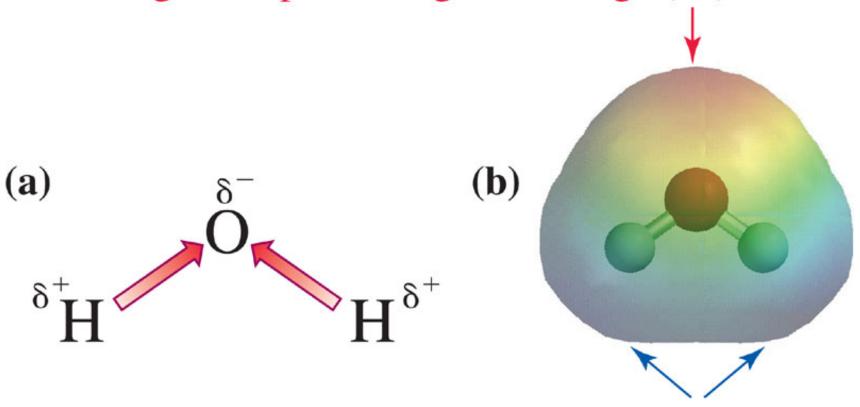
Table	4.2	Bo	Bond Energies (in kJ/mol)								
	H	C	N	O	S	F	Cl	Br	I		
Single E	Bonds										
Н	436										
C	416	356									
N	391	285	160								
O	467	336	201	146							
S	347	272	_	_	226						
F	566	485	272	190	326	158					
Cl	431	327	193	205	255	255	242				
Br	366	285	_	234	213	_	217	193			
I	299	213	_	201	_	_	209	180	151		
Multiple	Bonds										
C = C	598			C=N	616		C=O	803 ii	1 CO ₂		
C≡C	813			$C \equiv N$	866		C≡O	1073			
N=N	418			0=0	498						
$N \equiv N$	946										

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

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.

Water is a Polar Molecule

Region of partial negative charge (δ^-)

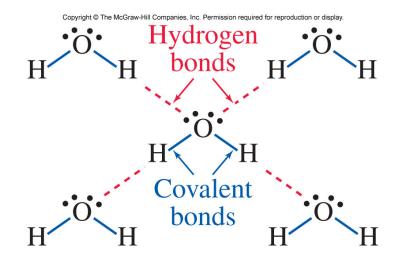


Regions of partial positive charge (δ^+)

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

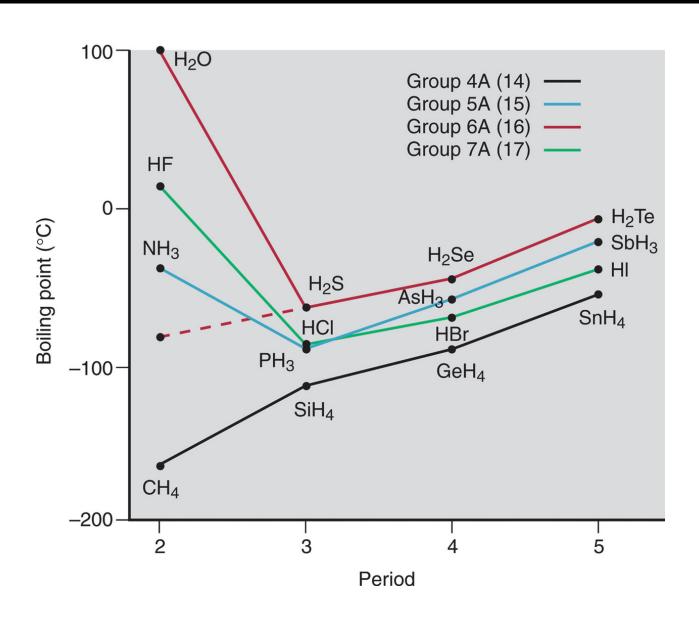


Energy required to break the hydrogen bonds in water: this gives the compound a high **specific heat** relative to most other things—it's why we use water to heat and cool things... (takes more heat to raise the temperature)

In 2000 US water usage (10⁹ 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



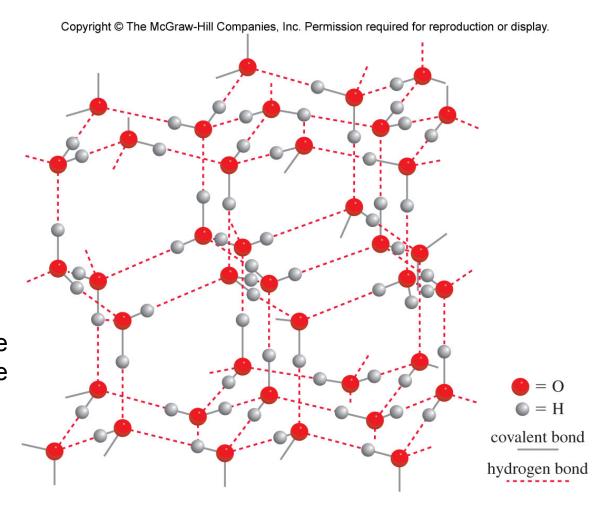
Hydrogen Bonding in Ice

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

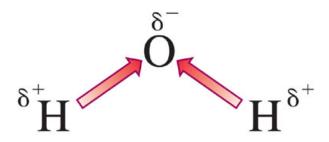
Aqueous solutions: solutions in which water is the solvent

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

sucrose (table sugar)