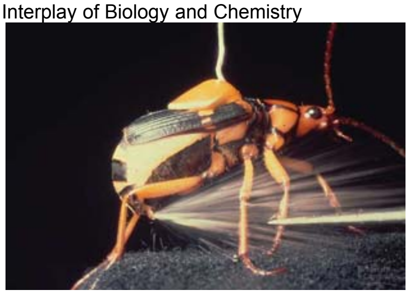
Interplay of Biology and Chemistry



Here is a link to the video…these beetles are fairly common locally – an amazing adaptation, and a good example of chemistry and physics in biology.

Also look for creationist-evolutionist arguments about these on the internet. Bombardier beetle

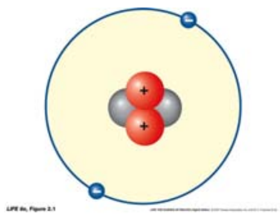
Definition of Matter

- Matter has mass and occupies space.
- Mass is a property of matter that causes inertia and weight.
- Matter is composed of several kinds of subatomic particles that combine to make atoms.

Subatomic particles

- Proton has mass of 1 and an electrical charge of +1
- Neutron has mass of 1 and no charge
- Electron has mass near zero and electrical charge of -1
- Opposite charges attract, so protons attract electrons

Atoms



- Protons and neutrons in small, dense nucleus
- Protons (+) attract electrons (-) which surround the nucleus
- Rutherford model- see p. 22 Brooker

Neutral vs Ionized

- Atoms with equal numbers of protons & electrons are electrically neutral
- Ions are atoms with a net electrical charge
- Cations are positively charged (more protons than electrons)
- Anions are negatively charged (more electrons than protons)

Charge & electrostatic force

- Opposite charges attract each other and balance each other at close range. Like charges repel each other
- When opposite charges are separated, or similar charges are together, they have energy (electrostatic force)

static cling or static "fling" ?

+/-

Charge separation and electrostatic forces lead to…

- Molecular shape
- Cell membrane potential & coupled transport processes
- Nerve & muscle action potentials

Elements

- Kinds of atoms, each with unique number of protons (= atomic number)
- Atomic number is indicated by a left subscript. For example: $_6C$ (carbon)
- Periodic table lists the elements and their properties.

Isotopes

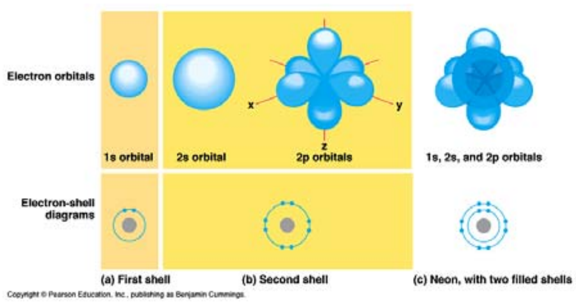
- Forms of an element that differ in the number of neutrons in the nucleus
- Atomic mass is indicated by a left superscript, e.g. ^{14}C (carbon-14) or ^{12}C
- Isotopes of an element have different mass but same atomic number and similar chemical properties.

Electrons

- move around the nucleus in patterns called shells, subshells, and orbitals
- follow rules called "quantum mechanics"
- First shell holds up to 2 electrons. The second and third shells hold up to 8 electrons each…..

Electron orbitals

These patterns have complex shapes (upper row) but are often diagrammed as circles (lower row, below)



Electron configurations of the first 18 elements

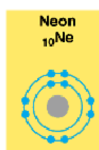
What atoms "want"

1. Full outermost shell (valence shell)
2. No net electrical charge (i.e. equal numbers of protons and electrons)

- "noble gases" have the right atomic numbers do both.
- Other atoms share electrons to fill the valence shell: chemical bonds result

Noble elements- examples

- Helium ($_2$He) has 2 protons, so 2 electrons fill first shell
- Neon ($_{10}$Ne) has 10 protons, so 10 electrons fill first 2 shells
- Both are chemically unreactive (don't make bonds with other atoms)



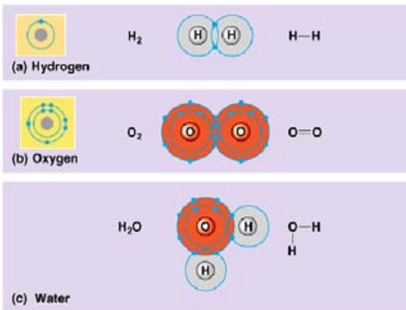
Covalent bonds

- Two or more atoms share electrons in a combined valence (covalent) shell
- Single or double bonds: one or two pairs of electrons may be shared
- Shared electrons bind the atoms together

Note: The blue area represents the shared electrons

Examples of molecules with covalent bonds

note the 3 different types of diagrams are shown below- all illustrate the same 3 molecules.



Polar covalent bonds

- nonpolar = equal sharing of electrons
- polar = electrons spend more time near one nucleus than the other
- Therefore the charge distribution is "polar" (meaning that there are positive and negative ends)

Note: The blue area represents the shared electrons, which carry the negative charge

Which covalent bonds are polar?

- Bonds between atoms that differ in electronegativity (affinity for electrons)
  H 2.1 N 3.0 C 2.5 O 3.4
- A bond between atoms that differ by 0.5 - 2.0 is a polar bond. Examples:

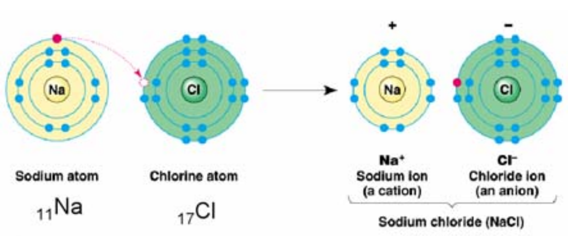
$O^{(-)}$—$H^{(+)}$ $N^{(-)}$—$H^{(+)}$ $C^{(+)}$=$O^{(-)}$

Polar & ionic bonds

- Electronegativity difference
  0 - 0.5……………..0.5 - 2………..>2
- Bond type
  non-polar cv....polar covalent……ionic
- Sharing of electrons:
  Equal………..unequal………very unequal

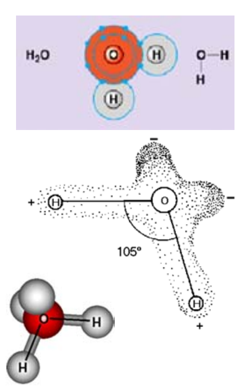
Ionic bond

Oppositely charged ions are attracted to each other electrostatically

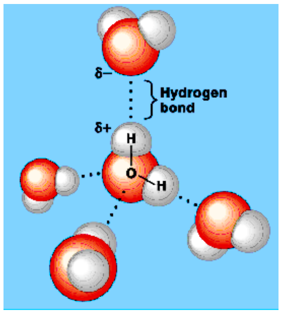


Water

- O-H bonds are polar
- Bond angles place the H atoms on one side of the molecule
- Therefore, the water molecule is polar



Hydrogen bonds among water molecules



Hydrogen bonds

- hydrogen in polar covalent bonds is attracted to nearby electronegative atoms (O or N)
- weak electrostatic bonds – easily broken
- Very important in biology. Examples:
  - properties of water
  - protein folding
  - DNA and RNA folding

TABLE 2.1

Chemical Bonds and Interactions

NAME	BASIS OF INTERACTION	STRUCTURE	BOND ENERGY* (KCAL/MOL)
Covalent bond	Sharing of electron pairs		50–110
Ionic bond	Attraction of opposite changes		3–7
Hydrogen bond	Sharing of H atom		3–7
Hydrophobic interaction	Interaction of nonpolar substances in the presence of polar substances (especially water)		1–2
van der Waals interaction	Interaction of electrons of nonpolar substances		1

*Bond energy is the amount of energy needed to separate two bonded or interacting atoms under physiological conditions.

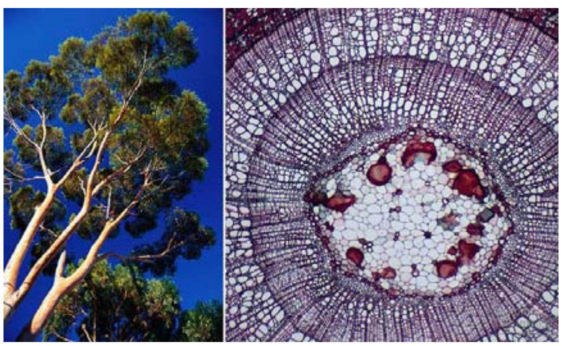
Regarding this table, note how strong covalent bonds are compared to other forces holding molecules together.

LIFE 8e, Table 2.1

Properties of water

- Cohesion
- Surface tension
- Adhesion to hydrophilic substances
  e.g. cellulose
- Not to hydrophobic substances
  e.g. waxes

Figure 3.2 Water transport in plants



Surface tension shapes water on a hydrophobic surface

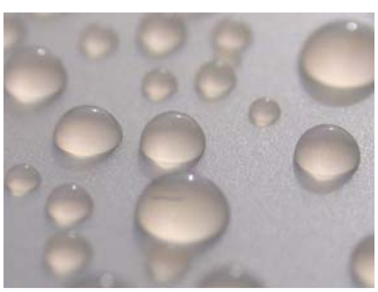
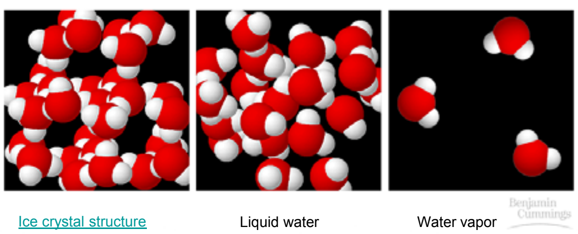


Figure 3.3 Walking on water

Water physical phases



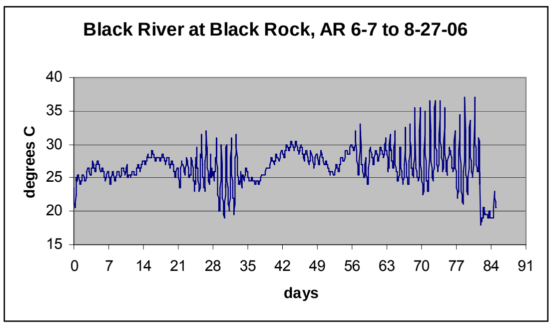
Ice crystal structure Liquid water Water vapor

Heat

- random movements of atoms and molecules
- add heat: faster movement, higher temperature (heat energy per molecule)
- no heat = "absolute zero" (-273^o Celsius, 0^o Kelvin)
- units of heat: calorie, kcal = Calorie, calorie=4.184 Joules

Water stabilizes temperature

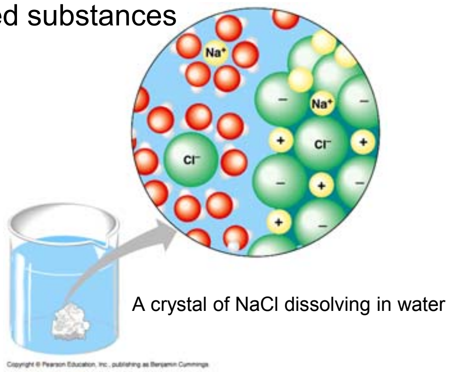
- Specific heat: 1 cal/g ºC
- Heat of fusion: ~80 cal/g released by freezing, absorbed by melting
- Heat of vaporization: ~539 cal/g absorbed by evaporation, released by condensation.
- Water expands as it freezes: ice less dense and floats



One of my temperature recorders, placed in (very) shallow water in the Black River - can you explain the fluctuations?

Floating ice and the fitness of the environment

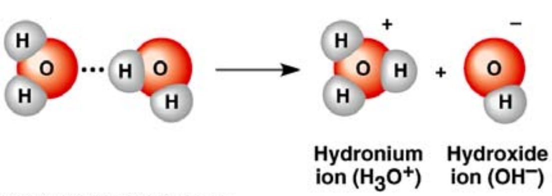
Water is good solvent for polar or ionized substances



Electrolytes

- Compounds held together by ionic bonds that dissolve in polar solvents
- example: sodium chloride (NaCl) becomes Na^+ and Cl^-
- electrolytes are the most abundant solutes in body fluids- common ions include Na^+ Cl^- K^+ HCO_3^-

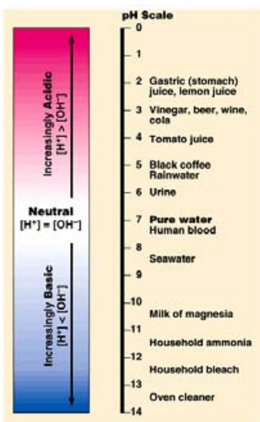
Water is a weak electrolyte



H_3O^+ or just H^+

Acid-base relations

- In pure water at 20 °C:
  - $[H_2O] = 55.4$ M
  - one molecule in 554 million is dissociated
  - $[H^+] = 10^{-7}$ M
  - pH = -log $[H^+]$ = 7
- pH is the negative logarithm (base 10) of the hydrogen ion concentration



pH of aqueous solutions

"acidic"
higher $[H^+]$, lower pH

"basic"
lower $[H^+]$, higher pH

neutral

buffer
stabilizes pH