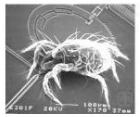
THE SCALE OF THINGS

Things Natural

Cat
~ 0.3 m

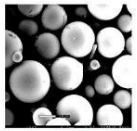
Monarch butterfly
~ 0.1 m



Dust mite
300 μm

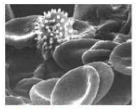
Bee
~ 15 mm

Human hair
~ 50 μm wide

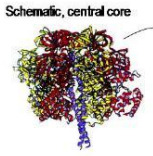


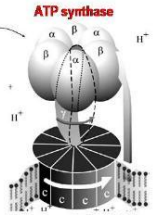
Fly ash
~ 10-20 μm

Magnetic domains
garnet film
11 μm wide stripes



Red blood cells
with white cell
~ 2-5 μm

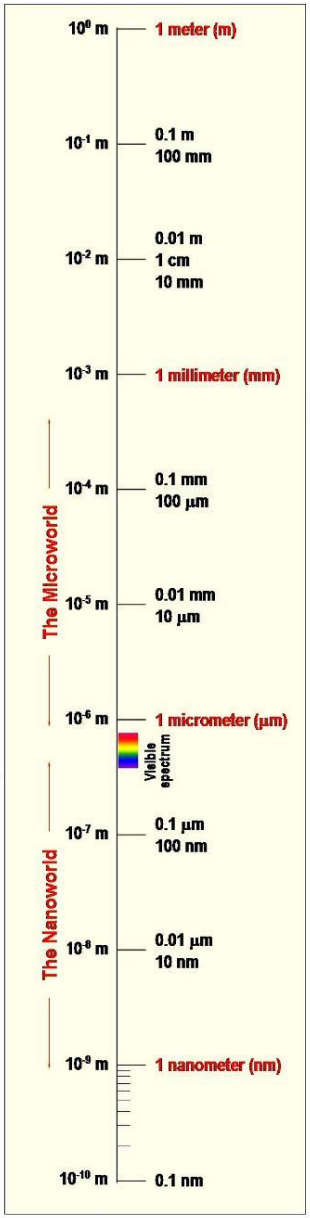




DNA
~2 nm wide

Image of silicon atoms in a crystal
spacing ~tenths of nm

Progress in atomic-level understanding

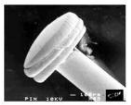


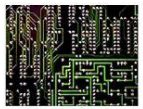
Things Manmade

Progress in miniaturization

Objects fashioned from
metals, ceramics, glasses, polymers ...

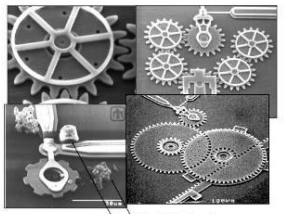
Head of a pin
1-2 mm



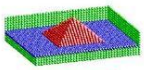


Microelectronics

MEMS (MicroElectroMechanical Systems) Devices
10 -100 μm wide

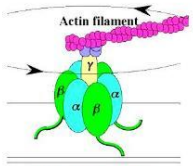


Red blood cells
Pollen

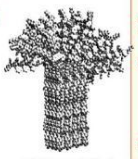


Indium arsenide
quantum dot

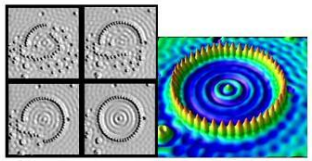
Quantum dot array --
germanium dots on silicon



Biomotor using ATP



Self-assembled
"mushroom"



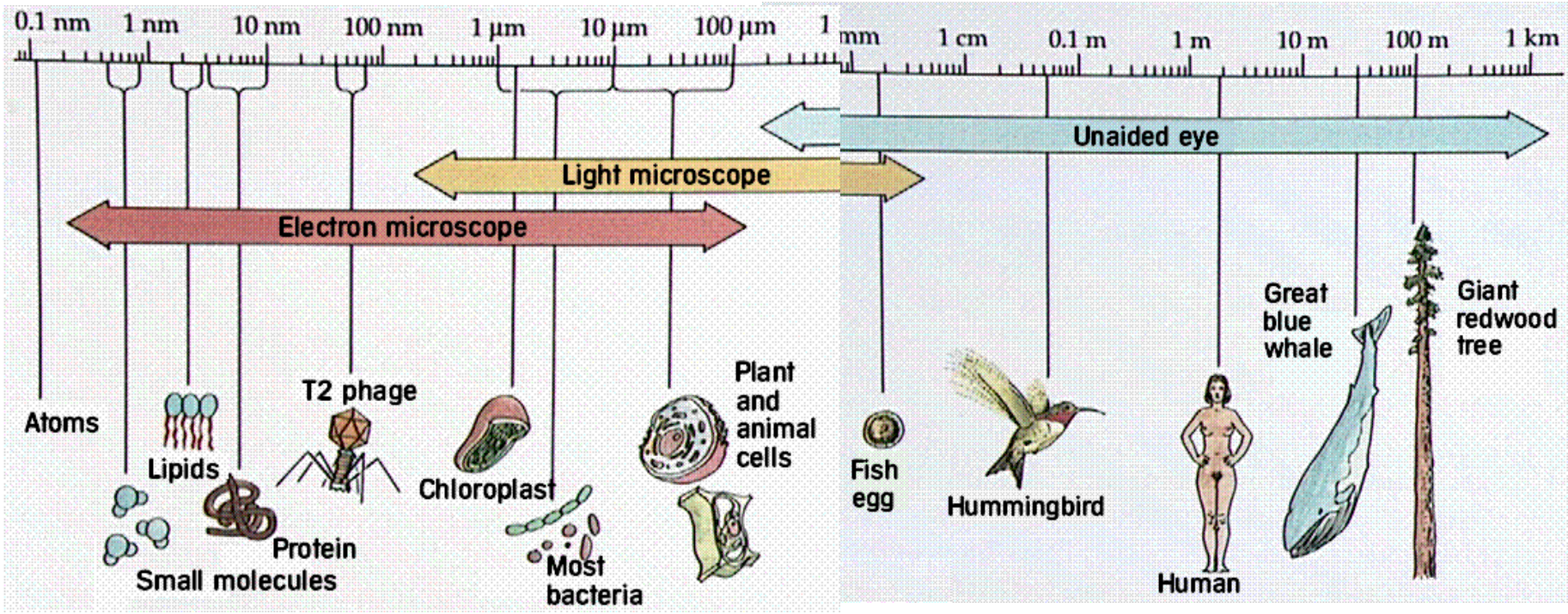
Quantum corral of 48 iron atoms on copper surface
positioned one at a time with an STM tip
Corral diameter 14 nm

The 21st century challenge -- Fashion materials at the nanoscale with desired properties and functionality

meter	m	10^{0}	1 m
centimeter	cm	10^{-2}	0.01 m
millimeter	mm	10^{-3}	0.001 m
micrometer	μm	10^{-6}	0.000001 m
nanometer	nm	10^{-9}	0.000000001 m

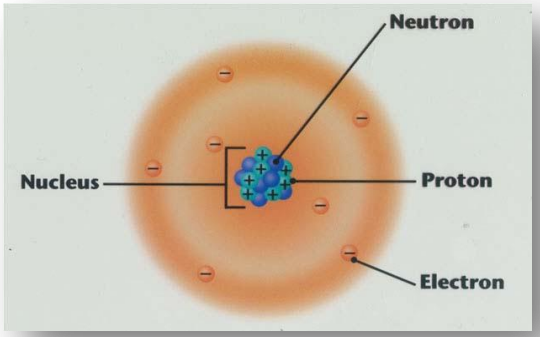
5/20/00

www.asu.edu/clas/csss/NUE/index.html


0.1 nm
1 nm
10 nm
100 nm
1 µm
10 µm
100 µm
1 mm
1 cm
0.1 m
1 m
10 m
100 m
1 km
Unaided eye
Light microscope
Electron microscope
Atoms
Lipids
Small molecules
Protein
T2 phage
Chloroplast
Most bacteria
Plant and animal cells
Fish egg
Hummingbird
Human
Great blue whale
Giant redwood tree

Atoms, subatomic particles, ions, isotopes I.

Name	Charge	Location	Mass	Atomic mass
Proton	+1	atomic nucleus	1.6726×10^{-27} kg	1
Neutron	0	atomic nucleus	1.6750×10^{-27} kg	1
Elcetron	-1	electron orbital	9.1095×10^{-31} kg	negligible



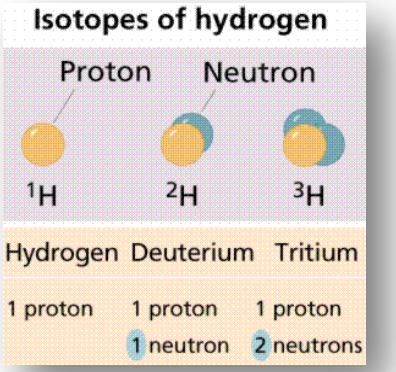
Atoms, subatomic particles, ions, isotopes II.

1. A substance composed of atoms with the same atomic number; it cannot be broken down in ordinary chemical reactions.

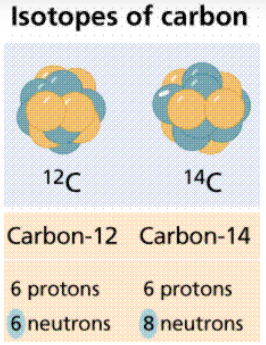
2. The smallest indivisible particle of matter that can have an independent existence.

3. Two or more atoms which are chemically combined to form a single species.

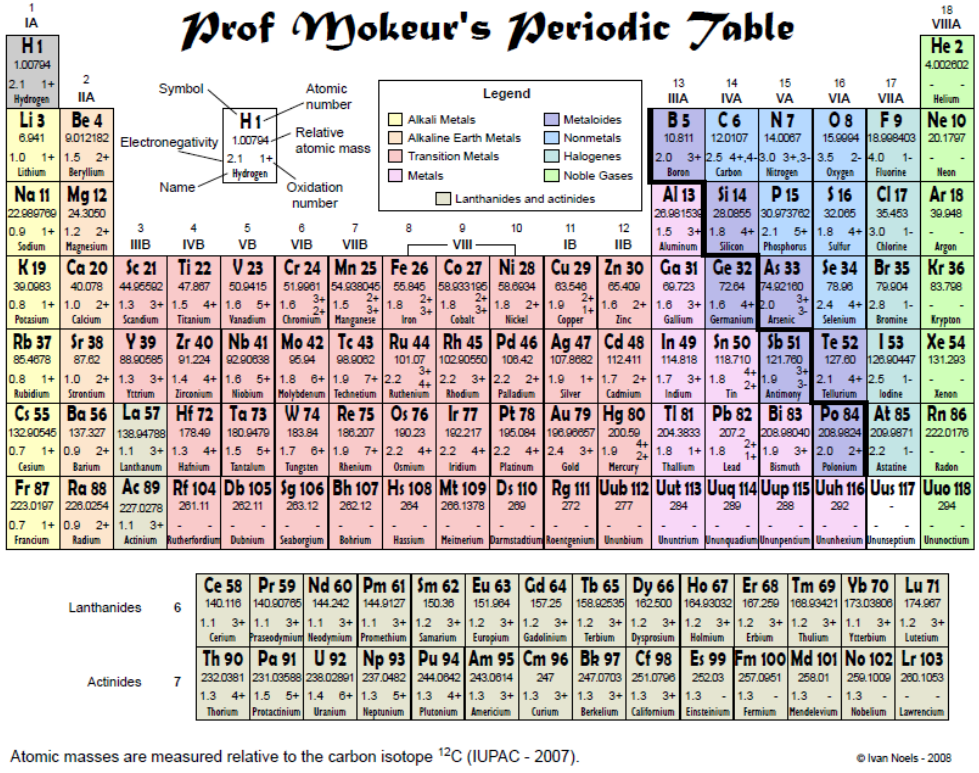
4. An atom that has lost or gained electrons from its outer shell and therefore has a positive or negative charge, respectively; symbolized by a superscript plus or minus sign and sometimes a number, e.g., H^+, Na^+, O^{2-} Cl^-.

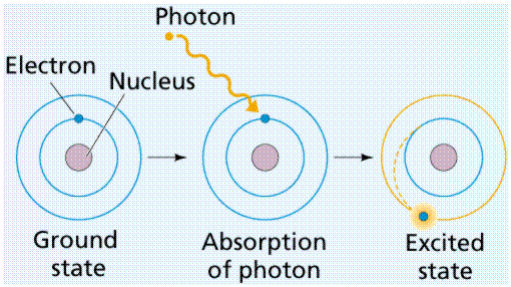


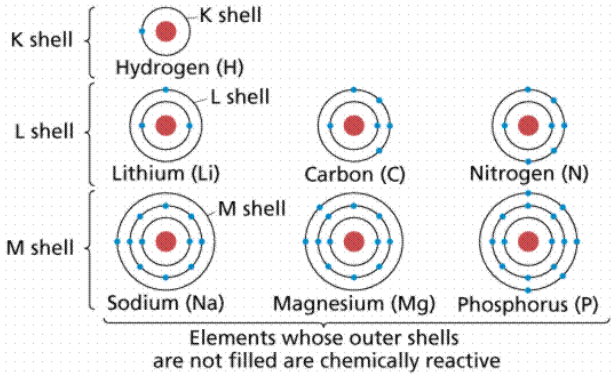
5. Atoms with the same atomic number but different numbers of neutrons; indicated by adding the mass number to the element's name, e.g., carbon 12 or ^{12}C.

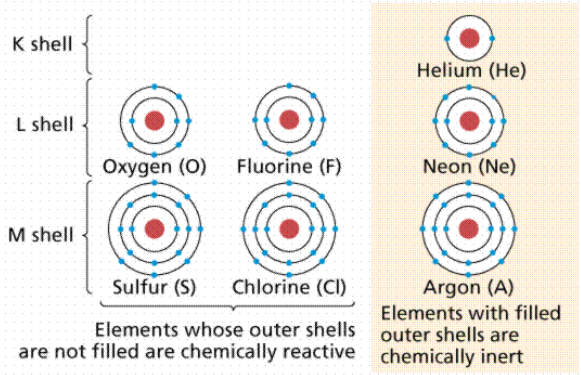


Atoms, subatomic particles, ions, isotopes III.

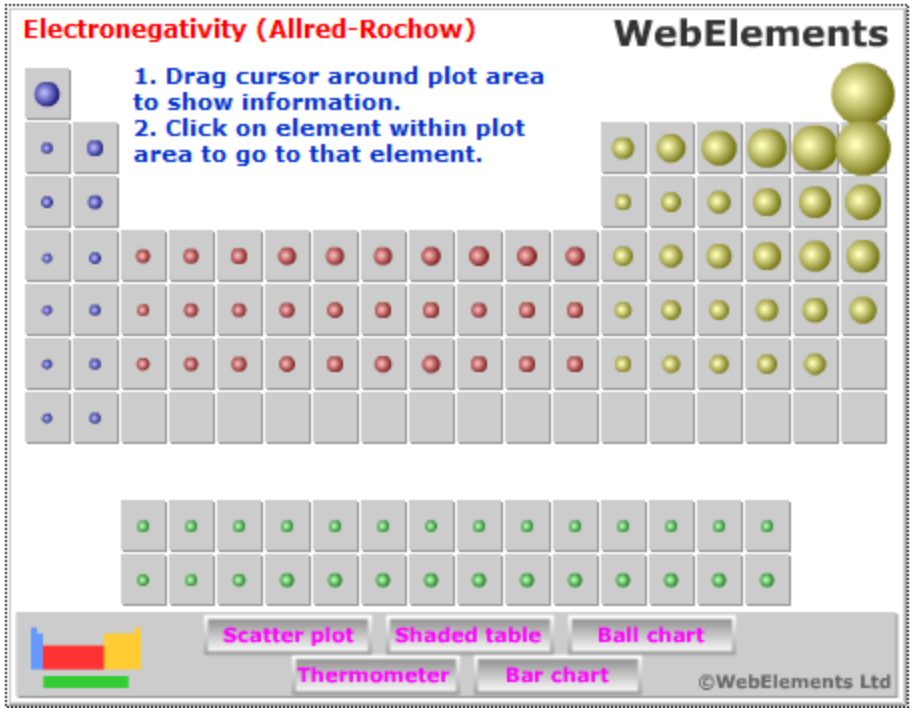








Electronegativity



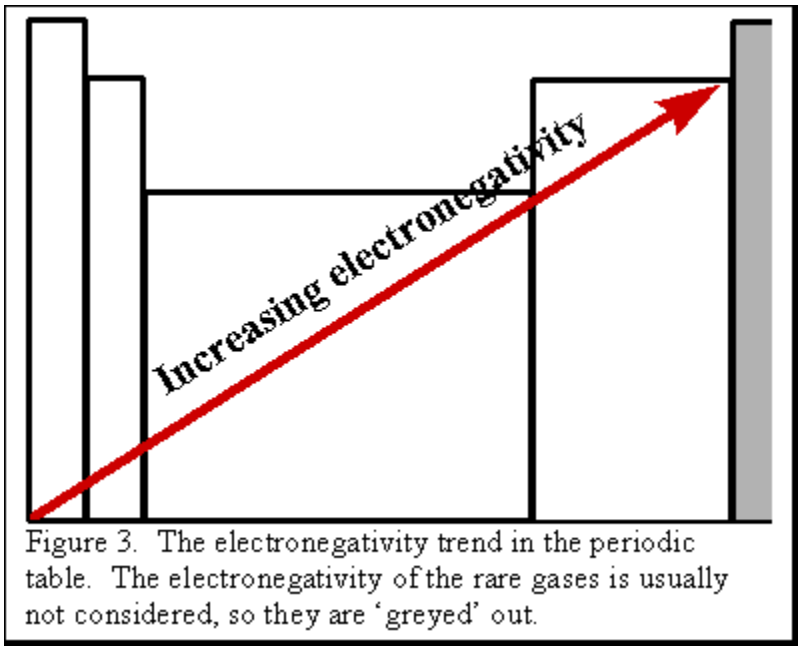


Figure 3. The electronegativity trend in the periodic table. The electronegativity of the rare gases is usually not considered, so they are 'greyed' out.

1. A chemical property which describes ing
   - the tendency of an atom or a functional group to attract electrons (or electron density) towards itself .
   - the tendency to form negative ions.
2. An atom's electronegativity is affected by:
   - atomic number and the
   - distance that its valence electrons reside from the charged nucleus.

- The higher the associated electronegativity number, the more an element or compound attracts electrons towards it.

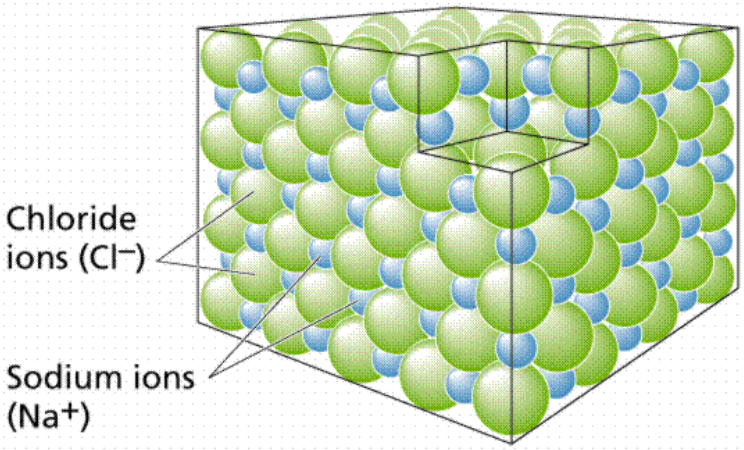
Chemical bonds I.

PRIMARY (strong)
- covalent
- metal
- ionic

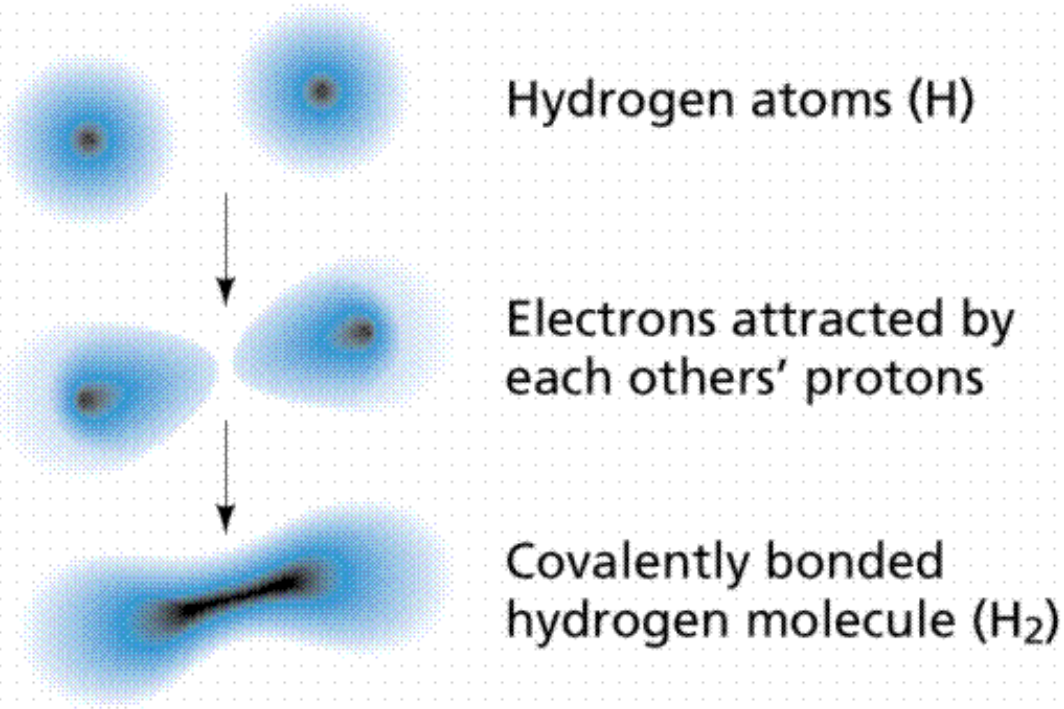
SECONDARY (weak)
- dipole-dipole
- hydrogen-bond
- London (van der Waals) dispersion force

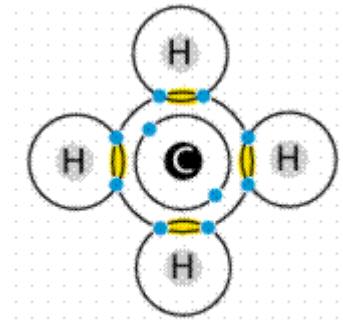
Bond type	Dissociation energy (kcal)
Covalent	400
Hydrogen bonds	12-16
Dipole-dipole	0.5 - 2
London (van der Waals) Forces	<1

Chemical bonds II.

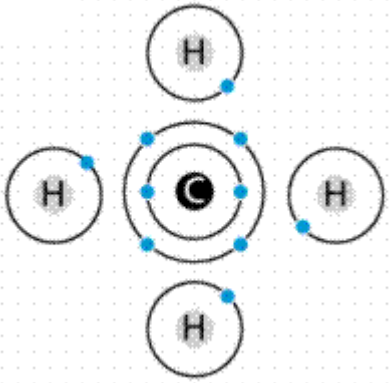


Chemical bonds III.

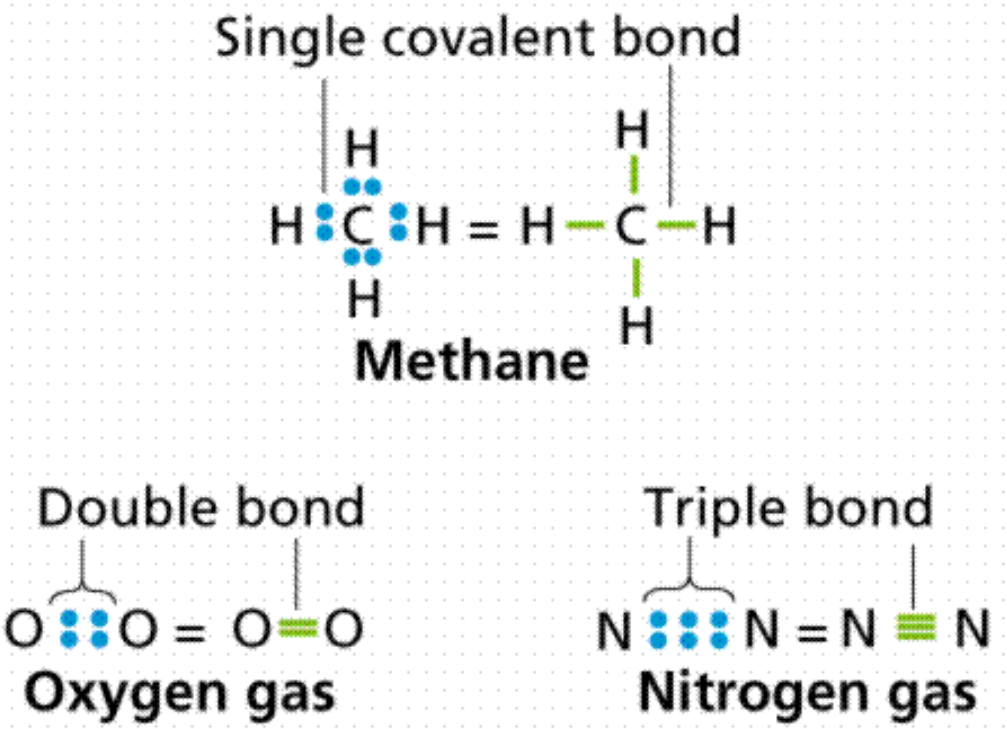


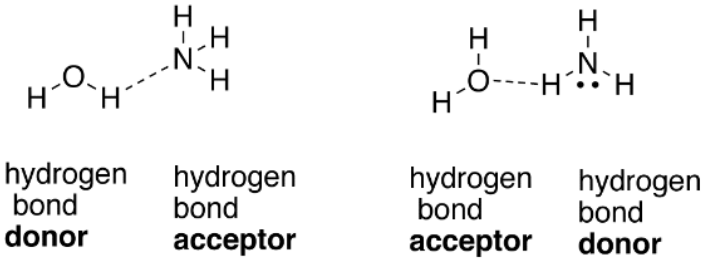


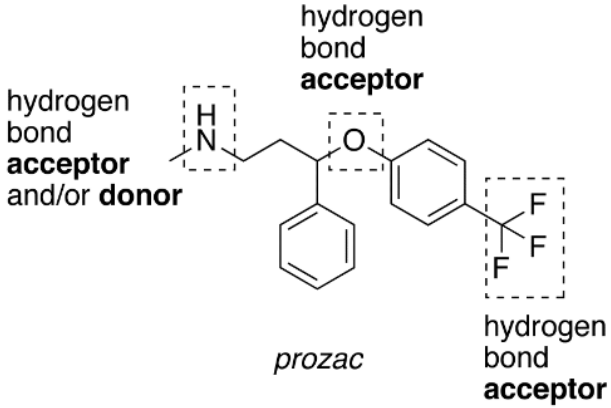
Methane



Chemical bonds IV.







Elements of the human body

1. **Oxygen (65%)**
2. **Carbon (18%)**
3. **Hydrogen (10%)**
4. **Nitrogen (3%)**
5. Calcium (1.5%)
6. Phosphorus (1.0%)
7. Potassium (0.35%)
8. Sulfur (0.25%)
9. Sodium (0.15%)
10. Magnesium (0.05%)
11. Copper, Zinc, Selenium, Molybdenum, Fluorine, Chlorine, Iodine, Manganese, Cobalt, Iron, Lithium, Strontium, Aluminum, Silicon, Lead, Vanadium, Arsenic, Bromine (trace amounts)

The most common chemical groups in living cells

Functional group	Class of compounds	Structural formula	Example	Ball-and-stick model
Hydroxyl –OH	Alcohols	R—OH	Ethanol	
Carbonyl –CHO	Aldehydes	R—C(=O)—H	Acetaldehyde	
Carbonyl >CO	Ketones	R—C(=O)—R	Acetone	
Carboxyl –COOH	Carboxylic acids	R—C(=O)—OH	Acetic acid	
Amino –NH_2	Amines	R—N(H)—H	Methylamine	
Phosphate –OPO_3^{2-}	Organic phosphates	R–O–P(=O)(–O⁻)–O⁻	3-Phospho-glyceric acid	
Sulfhydryl –SH	Thiols	R—SH	Mercapto-ethanol	

Water I.
Chemistry

1) H-O-H (**„V" shape**)

2) **Polar** (slightly negative and positive sites because of different affinities for elecrons)

3) **H-bond formation** (1water/4 neighbouring water or with other molecules)

4) **Solvent** of ions and polar substances (hydrohilic substances) eg. Glucose, NaCl, alcohols,… (hydrophilic functional groups)

5) Tendency to dissociate into H^+ and OH^- in liquid state

6) Existance in all three states of matter (gas, liquid, solid)

Expansion upon freezing leading to lower density

Water II.
Role in biology

1) enviroment for life
   a. cohesive behavior (H-bonds!)
   b. stabilisation of temperature
   c. expansion upon freezing
   d. dissolving capability
   e. weak viscosity (medium for transport, reactions)
   f. transparency

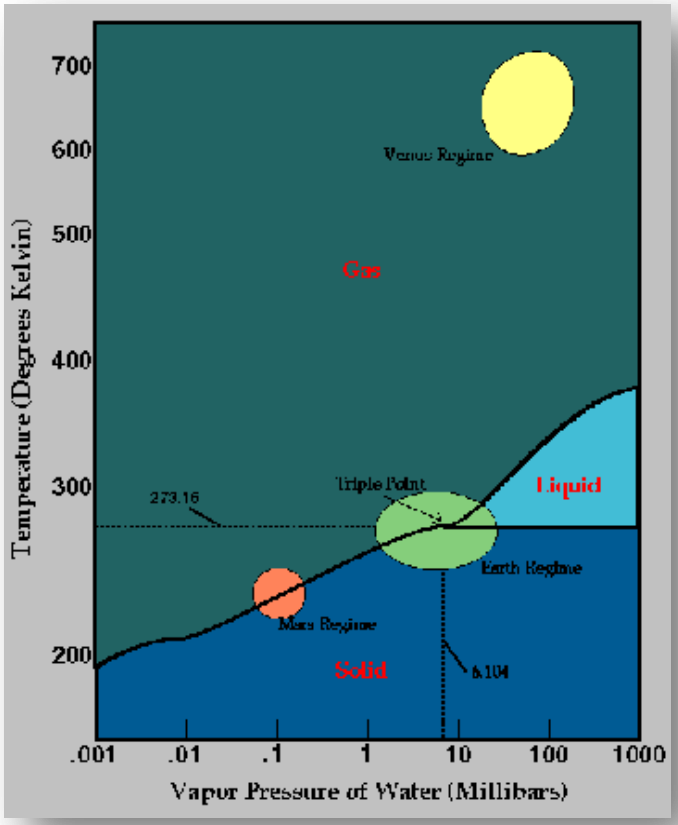
2) partner in biochemical reactions as either substrate or endproduct
   a) condensation (dehydration)
   b) hydrolysis (hydration)

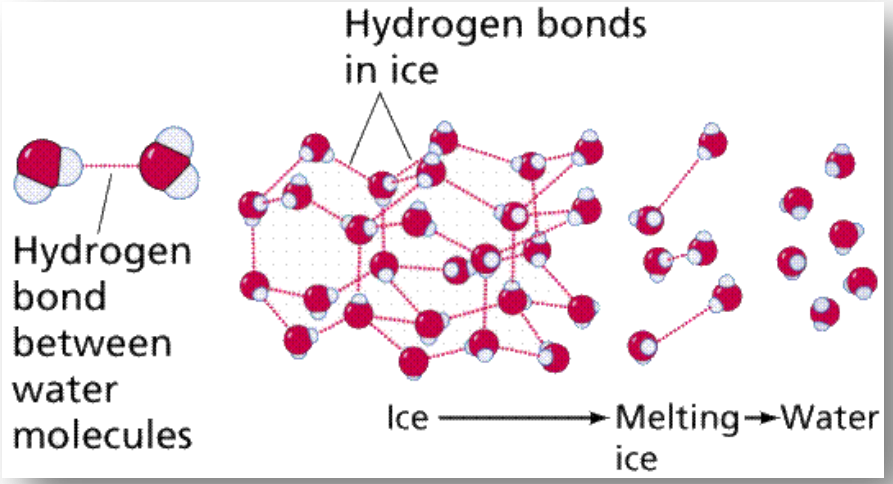
3) role in photosynthesis (photolysis of water)

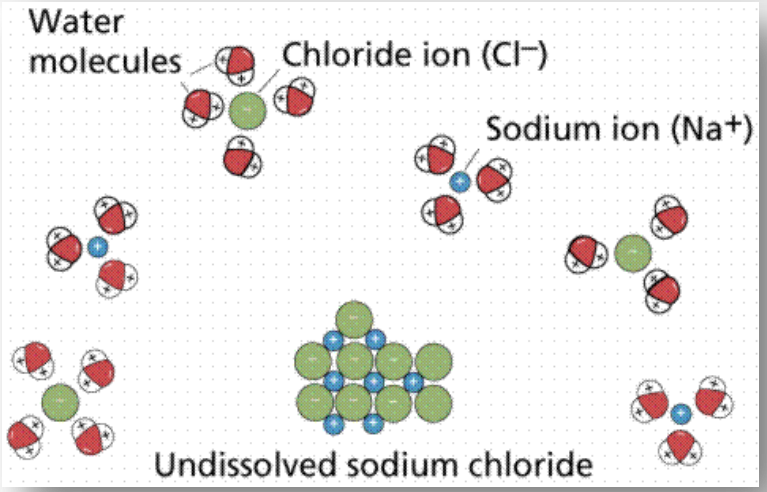
4) free movement through biological membranes without energy requirement (osmosis)

5) pH (negative logarithm (to the base 10) of H^+ concentration in a solution): 0-14

Water III.

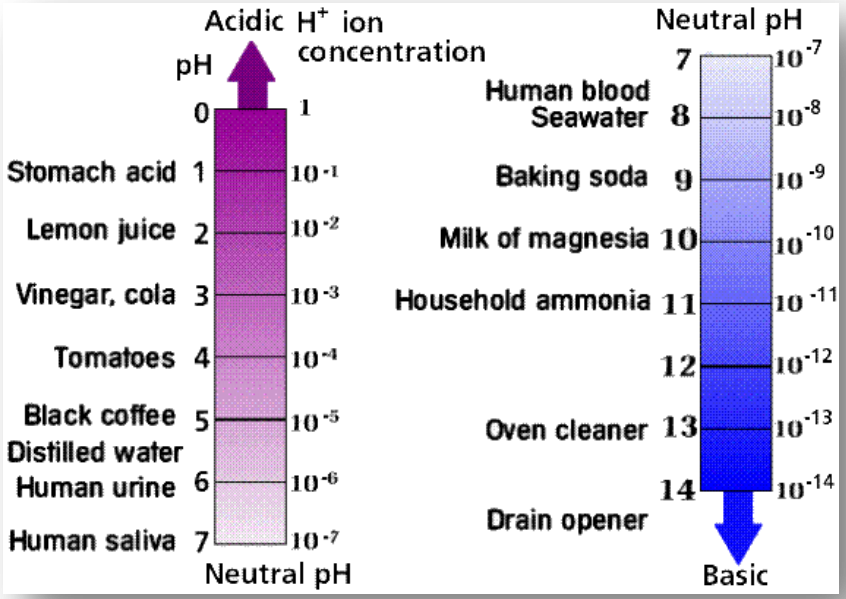

Temperature (Degrees Kelvin)
700
600
500
400
300
200
Venus Regime
Gas
Liquid
273.16
Triple Point
Earth Regime
Mars Regime
Solid
6.104
.001
.01
.1
1
10
100
1000
Vapor Pressure of Water (Millibars)


Hydrogen bonds in ice
Hydrogen bond between water molecules
Ice
Melting ice
Water


Water molecules
Chloride ion (Cl⁻)
Sodium ion (Na⁺)
Undissolved sodium chloride

Water IV.

pH



$$\mathrm{pH} = -\log_{10}[\mathrm{H_3O^+}] = -\lg[\mathrm{H_3O^+}]$$

$$\mathrm{pH} = -\log_{10}[\mathrm{H^+}] = -\lg[\mathrm{H^+}]$$