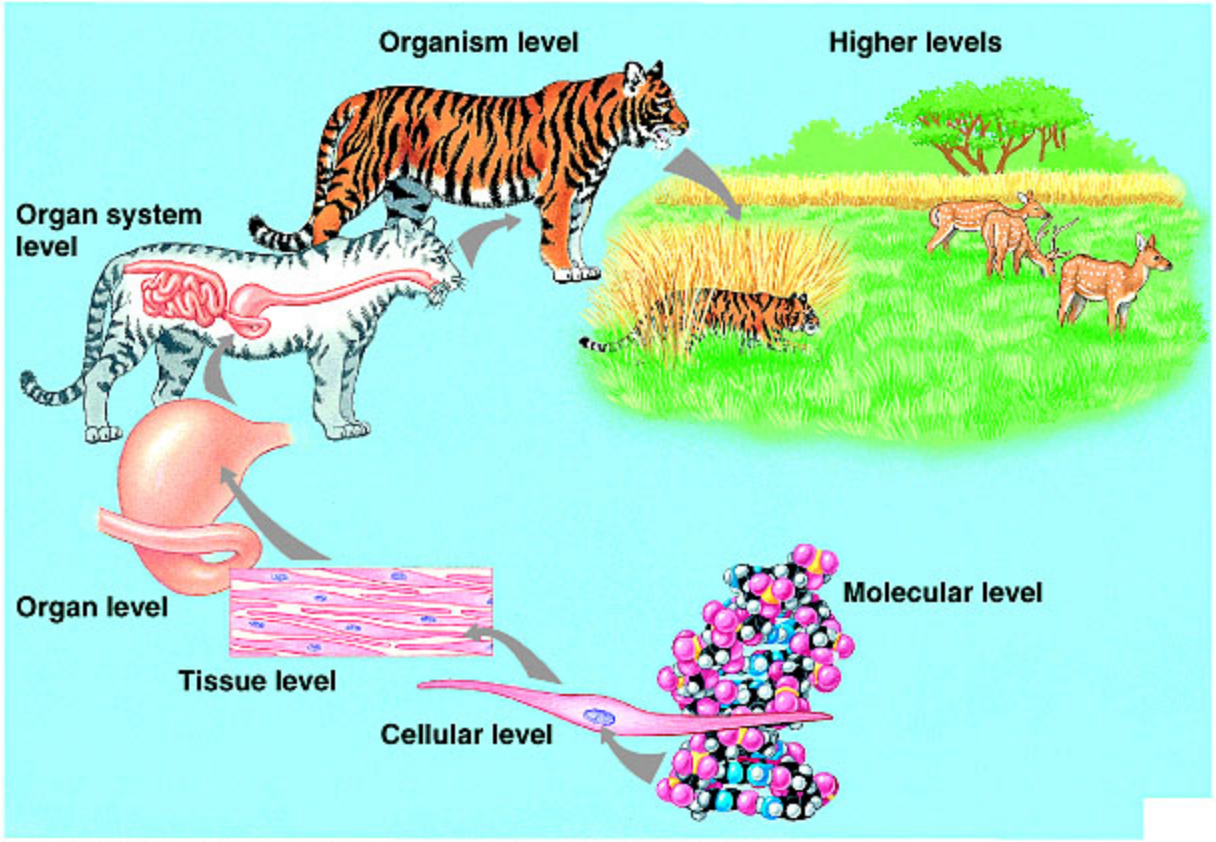
CHEMICAL BASIS OF LIFE

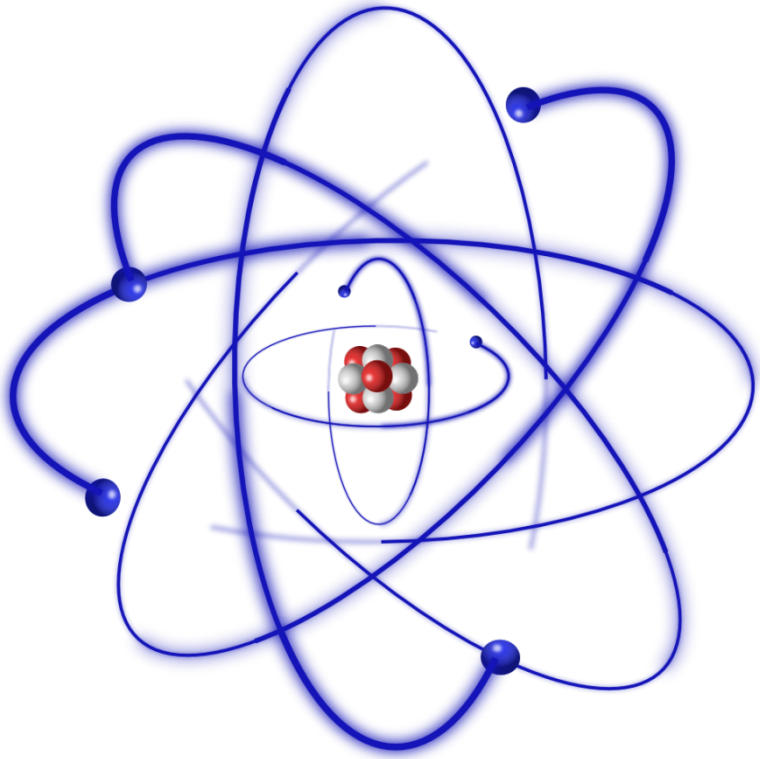
Life is hierarchically organized

Figure 2.1 The hierarchy of biological order



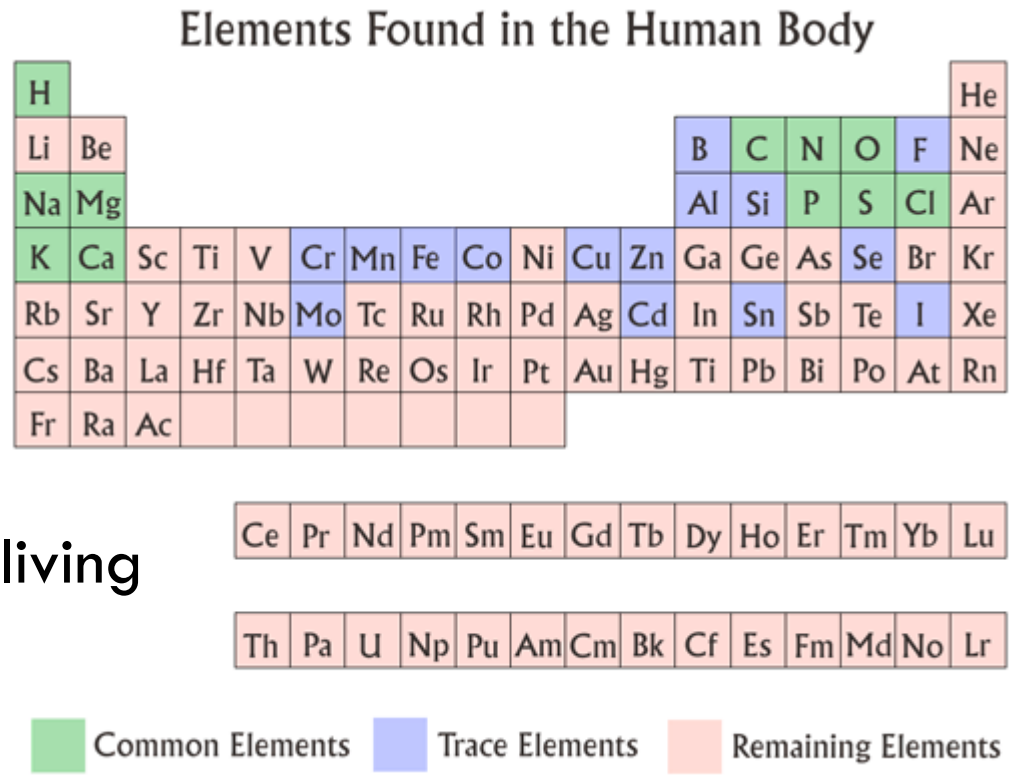
What's the matter?

- All "stuff" is matter
  - Matter has mass
- Fundamental unit = atom
- Elements = different atoms
- Compounds
  - =combinations of elements
  - i.e. NaCl



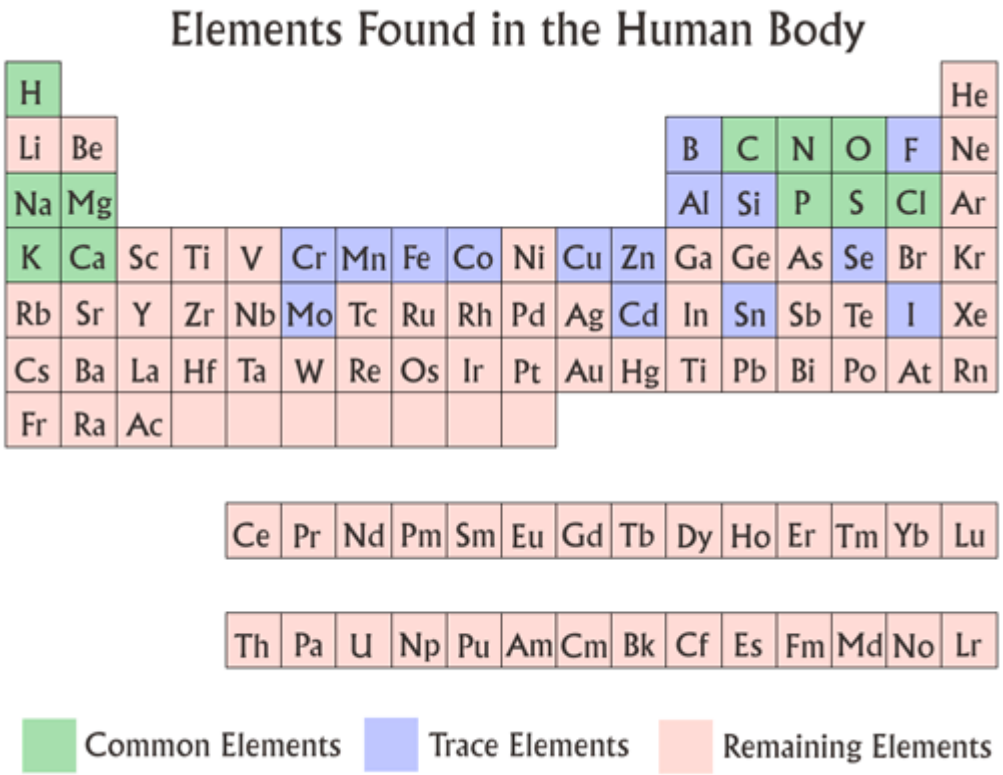
Elements essential to life

- All life forms require 25 elements
- The Big 4
  - CHON
    - Carbon
    - Hydrogen
    - Oxygen
    - Nitrogen
  - Makes up 96% of living matter



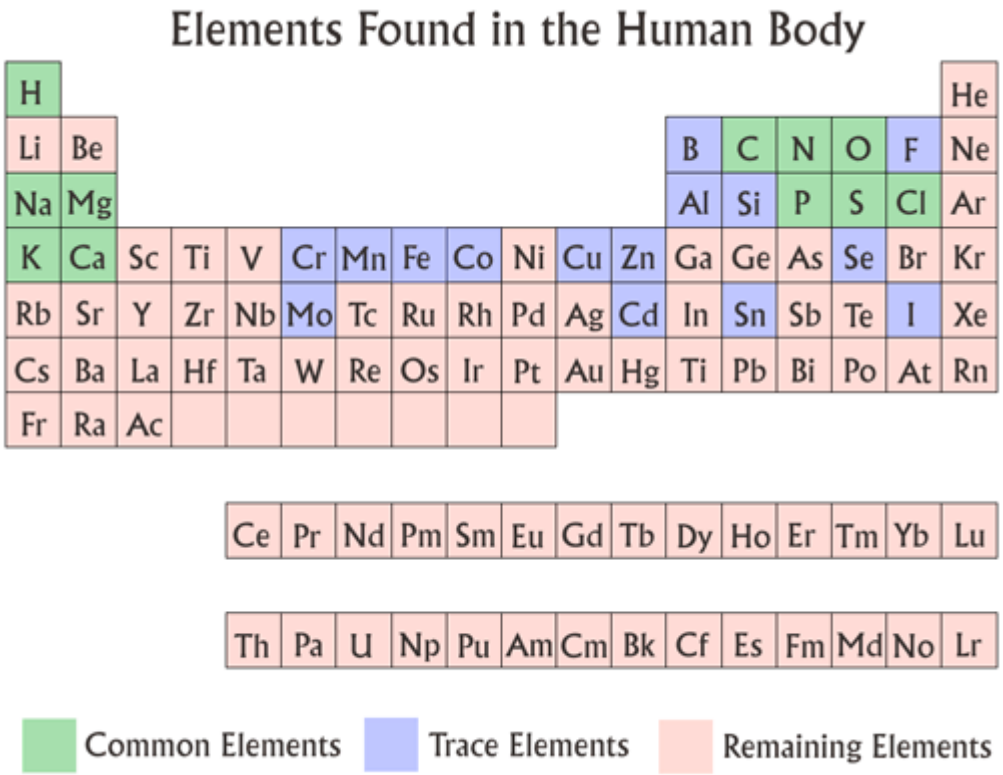
Elements essential to life

- All life forms require 25 elements
- The Little 4
  - P-CaSK
  - Phosphorous
  - Calcium
  - Sulfur
  - Potassium (K)
- Makes up >3%

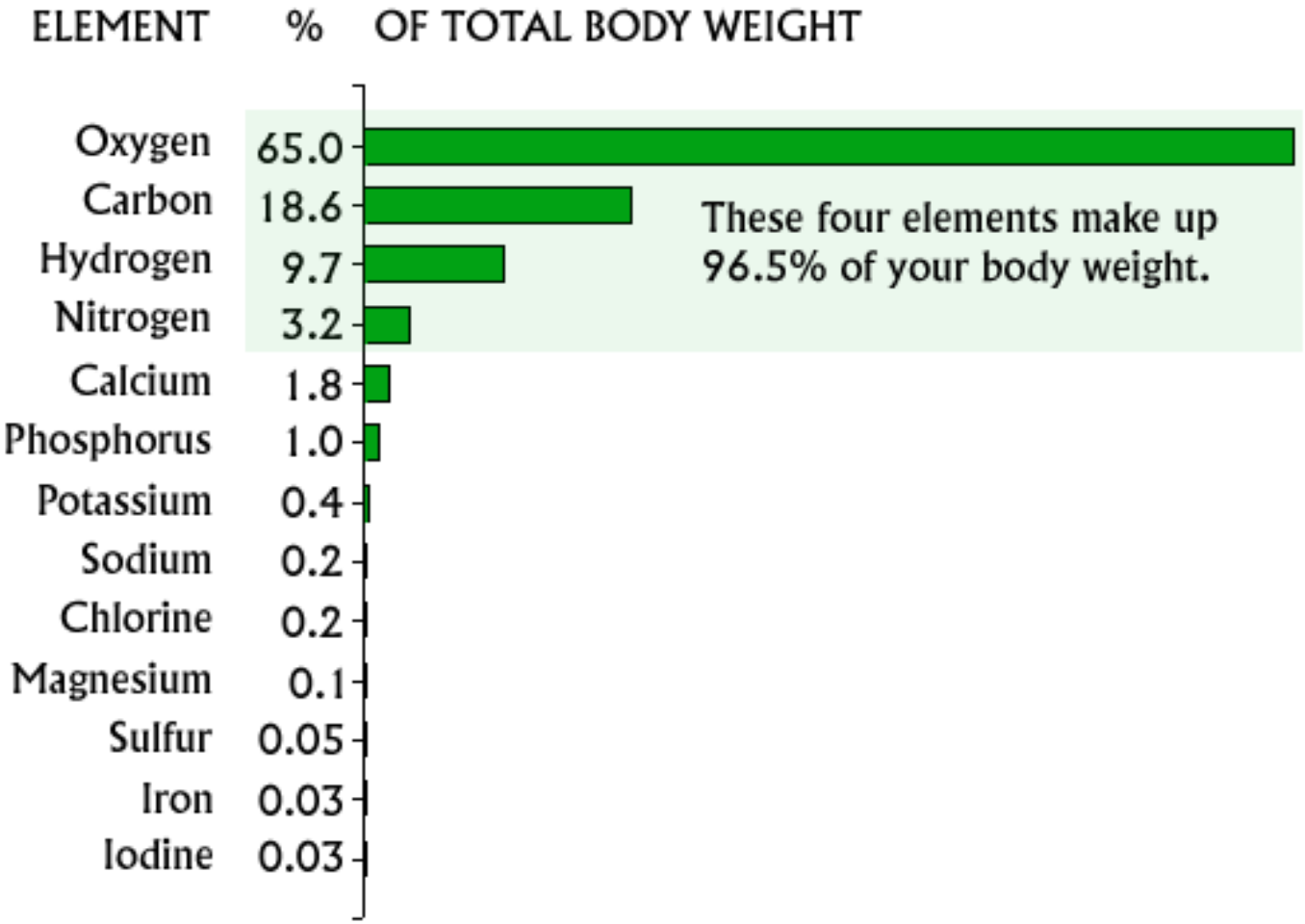


Elements essential to life

- All life forms require 25 elements
- Trace elements
  - Essential in small amounts
  - Make up < 1%

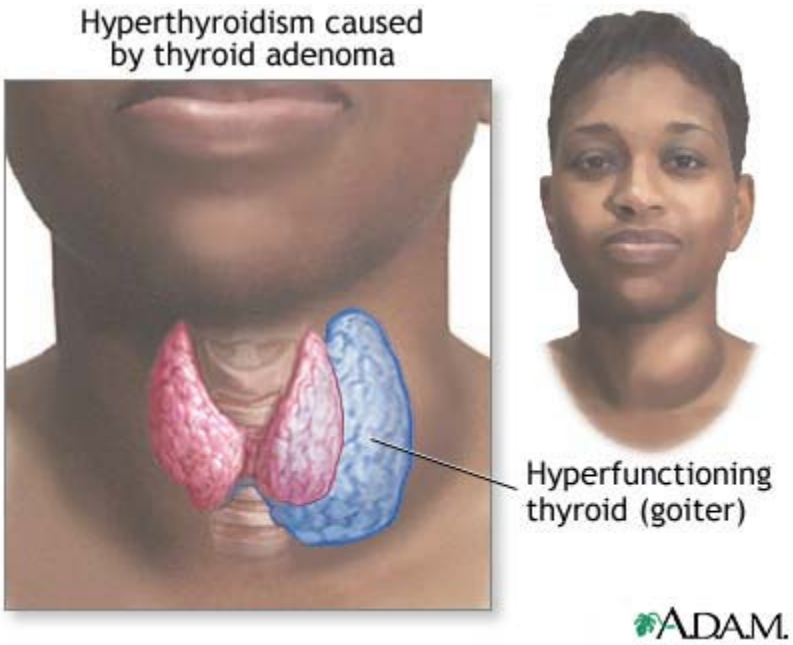


Elements essential to life



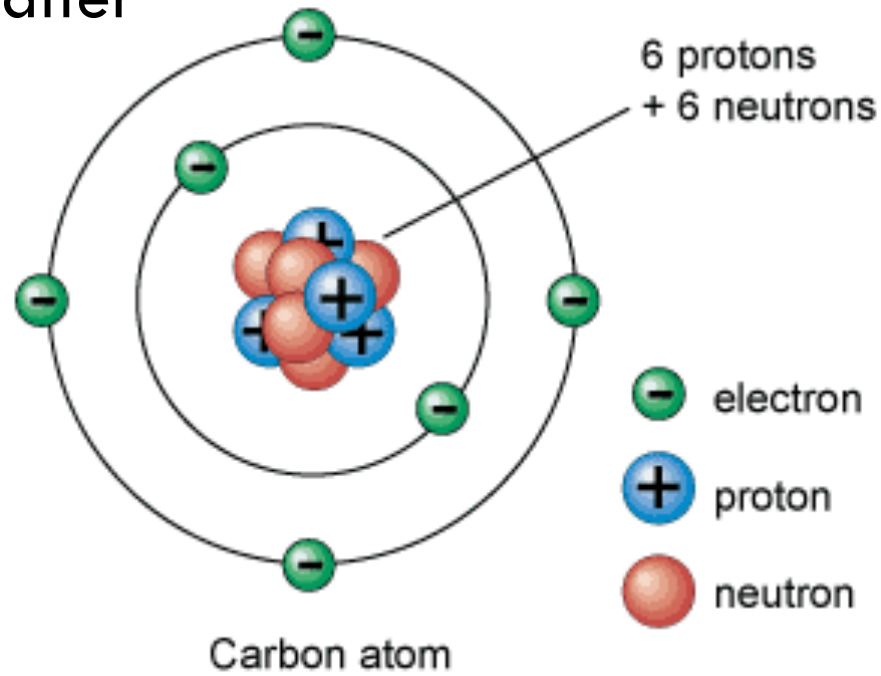
Trace elements are important

- Iodine deficiency
- Iron deficiency



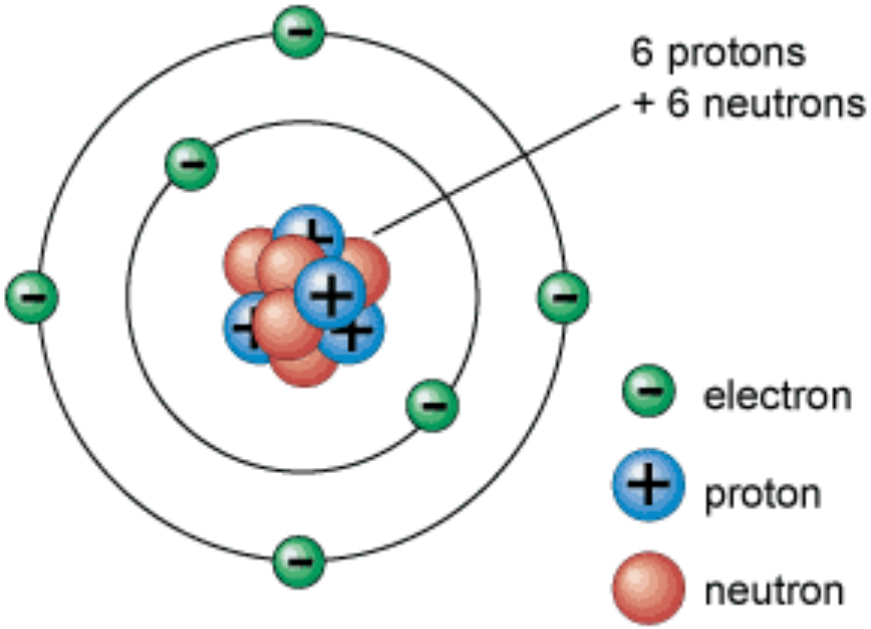
The atom

- Atom
  - = fundamental unit of matter
- Subatomic particles
  - Proton, neutron, electron



The atom

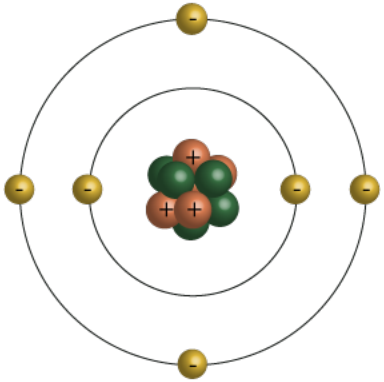
- Nucleus
  - Has > 99.9% mass
  - Proton
    - Positively charged
  - Neutron
    - No charge
- Electron cloud
  - Electron
    - Negatively charged
  - Electron shells (aka orbitals)

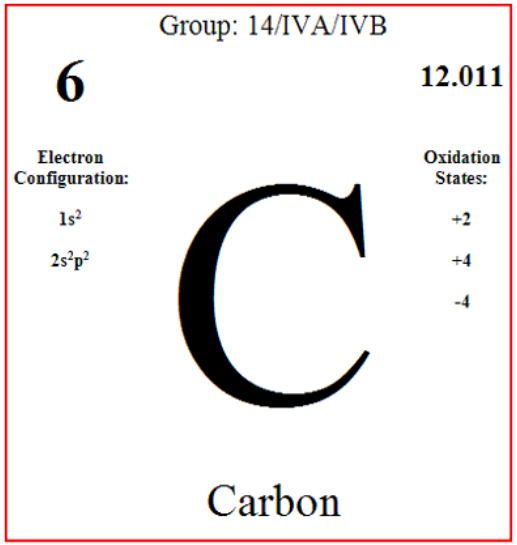


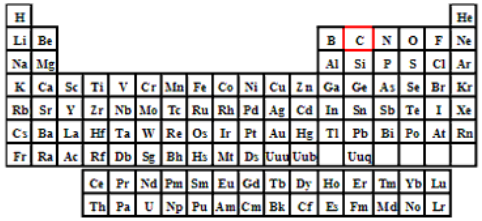
Carbon atom

Calculating subatomic particles

- Atomic number
  - = protons
  - = electrons
- Atomic mass
  - Mass of all subatomic particle
- Neutrons = AM (rounded) – AN
  - i.e. C neutrons = 12-6 = 6
  - Calculate neutrons in Lithium

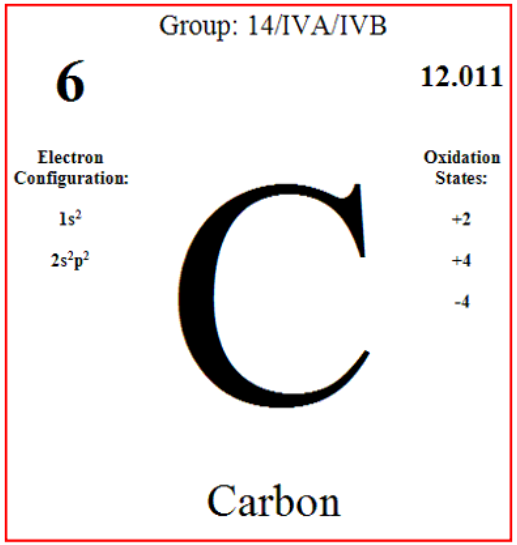


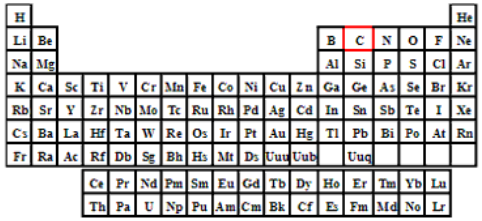




Calculating subatomic particles

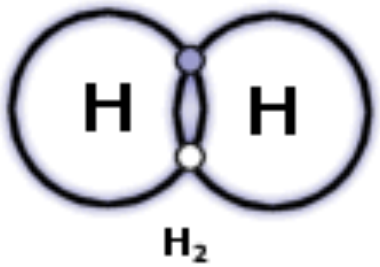
- Electron levels (= orbitals)
  - 1st level: up to 2 electrons
  - 2nd level: up to 8 electrons
  - 3rd level: up to 8 electrons
- The rule:
  - Fill one level before the next
- Draw
  - Hydrogen
  - Carbon
  - Oxygen

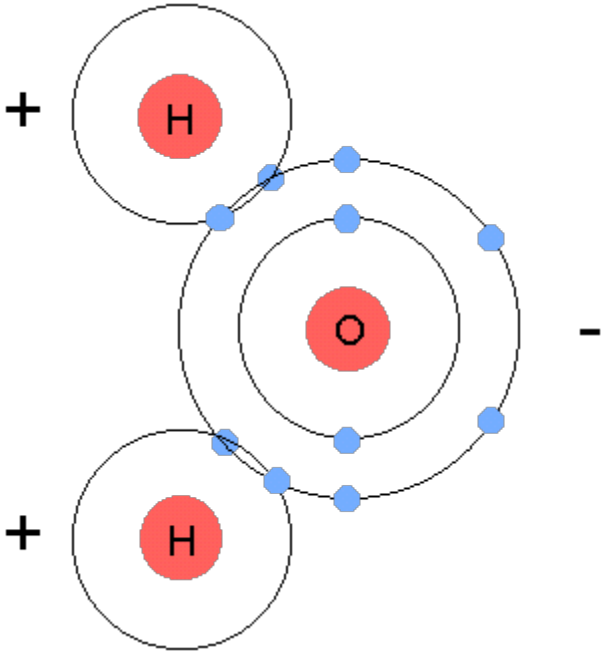




Atomic Bonds

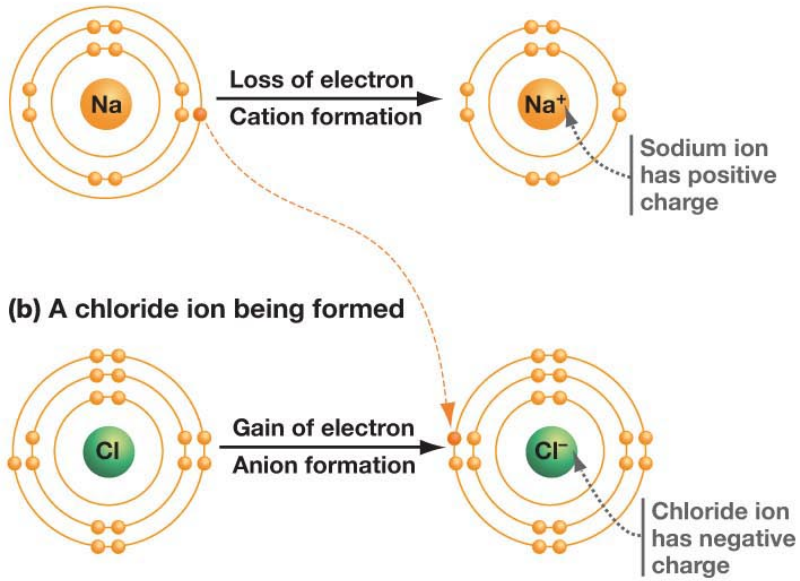
- Molecules
  - More than one atom bonded togeth
- Covalent bond
  - Atoms share electrons
  - Non-polar covalent bonds
    - Equal attraction
    - i.e. H^2
  - Polar covalent bonds
    - Asymmetric attraction
    - i.e. H_20

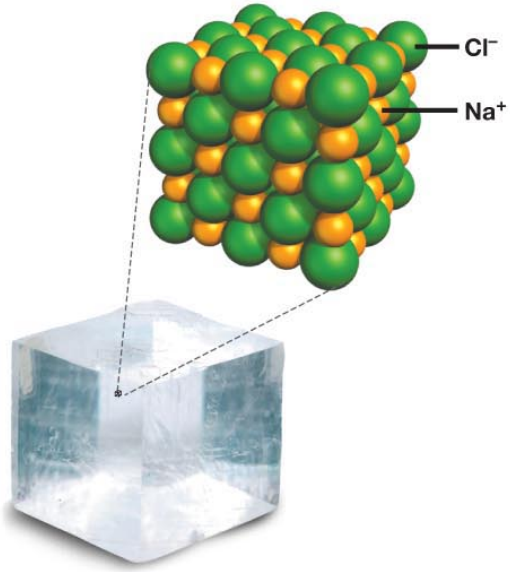




Atomic Bonds

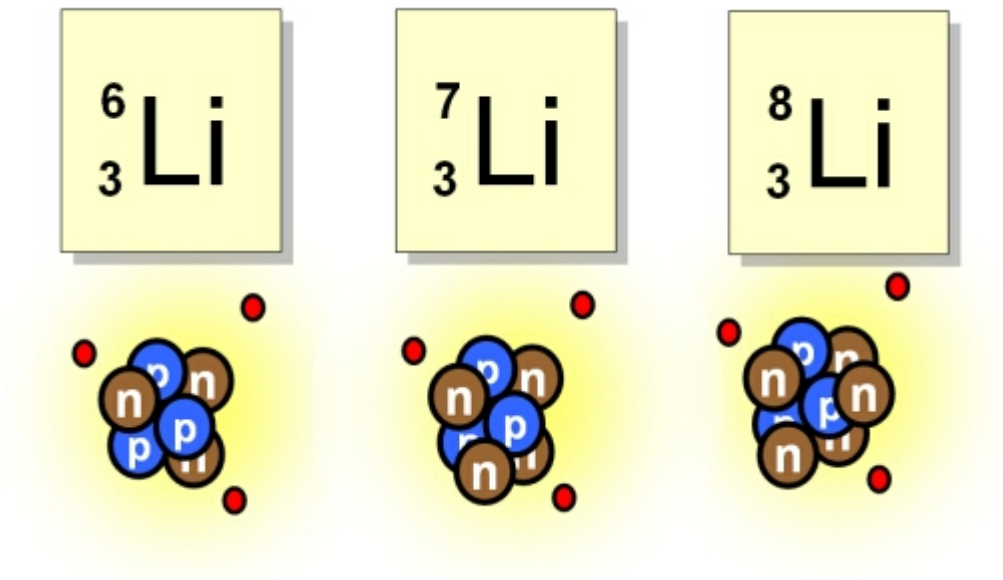
- Ionic bonds
  - One atoms "steals" another e^-
  - Unequal attraction
  - i.e. NaCl





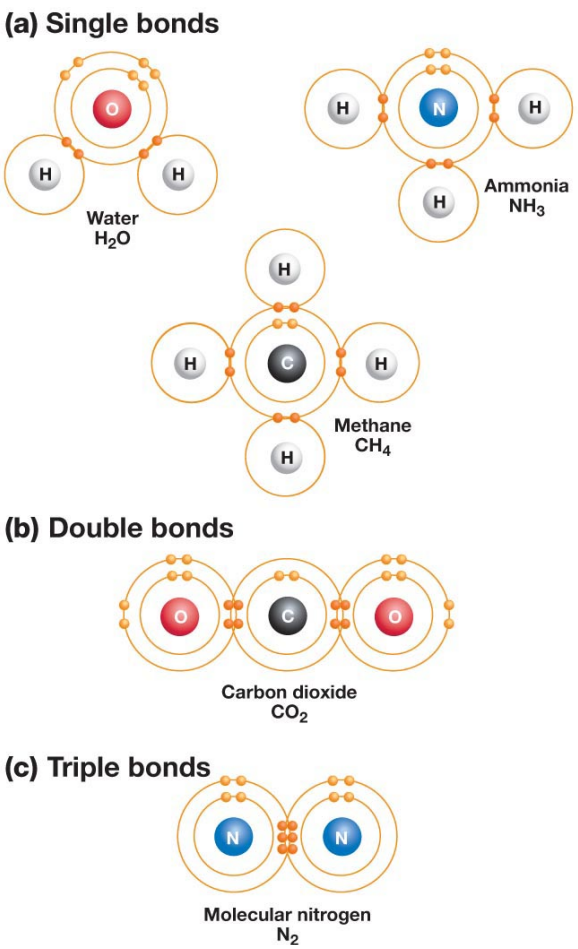
Isotopes

- = atoms with more or less neutrons than protons
- Atomic mass
  - Average of all existing isotopes
  - Lithium (AM) = 6.9



Numbers of bonds

- Depends on number of unpaired electrons
  - If more than one an atom can form
    - Multiple single bonds
    - Double bonds
    - Triple bonds

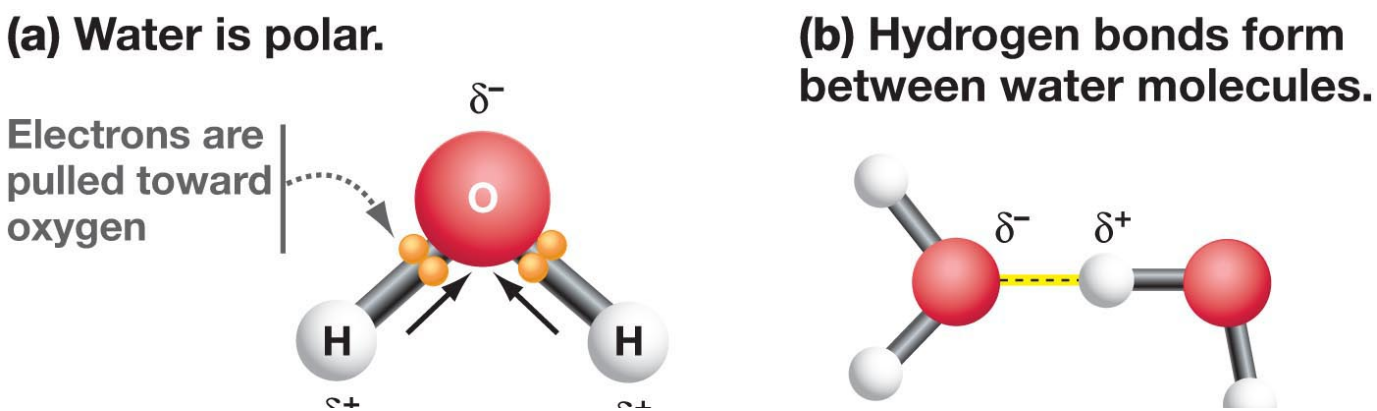


Chemical reactions

- Occurs when
  1. One substance combines with another
  2. One substance is broken down into another
  3. Chemical bonds are broken and other bonds form

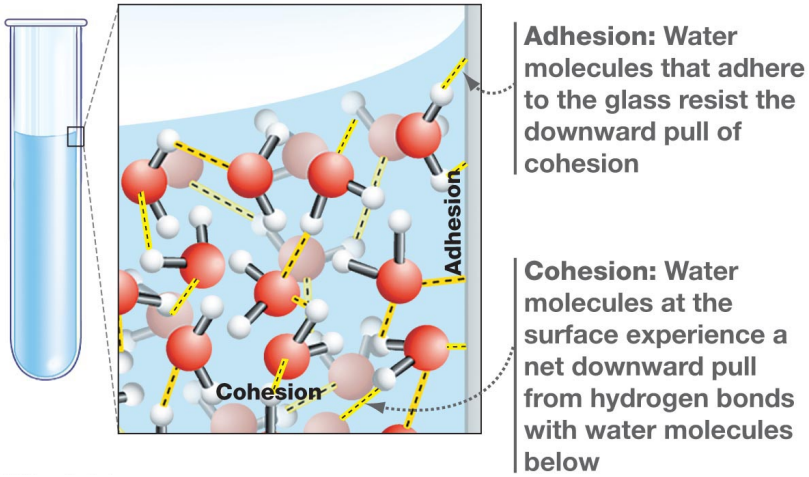
Water as a solvent

- Life is based on water b/c it is a great solvent
  - Dissolves other substances
- Why?
  - Connected by hydrogen bonds
    - Weak attractions b/n partially negative O and partially positive H of another polar molecule (i.e. H_20)



Other properties of water

- b/c of small size, bent shape, and polarity
- It is:
  - Cohesive
    - Binding b/n like molecules
    - Resulting in surface tension
  - Adhesive
    - Binding b/n unlike molecules
  - Denser as liquid than solid
  - Absorb large amounts of E



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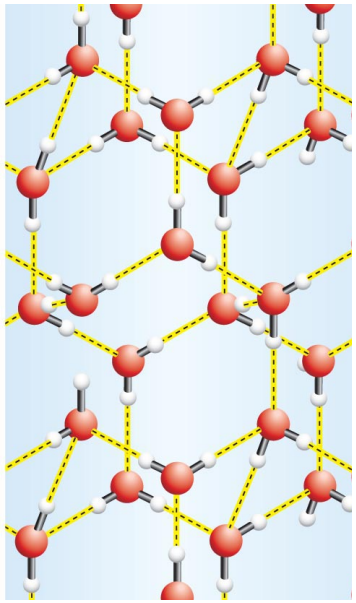
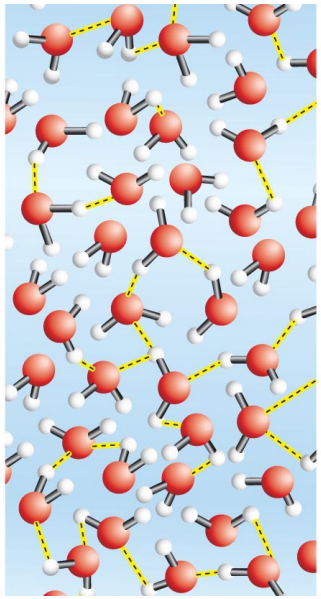


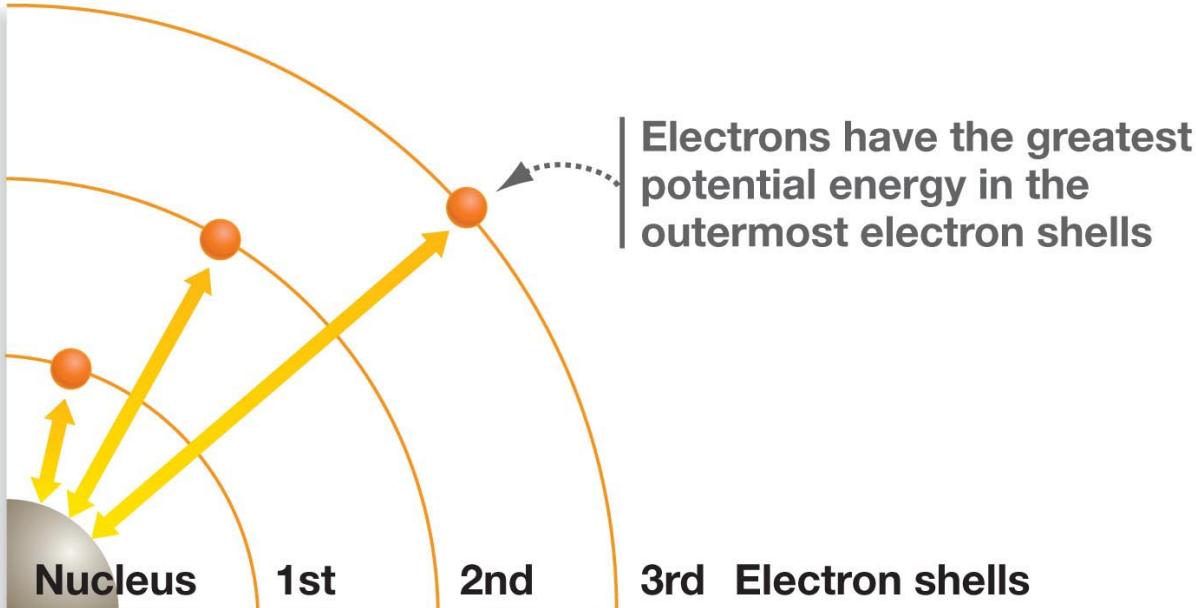
Solid water



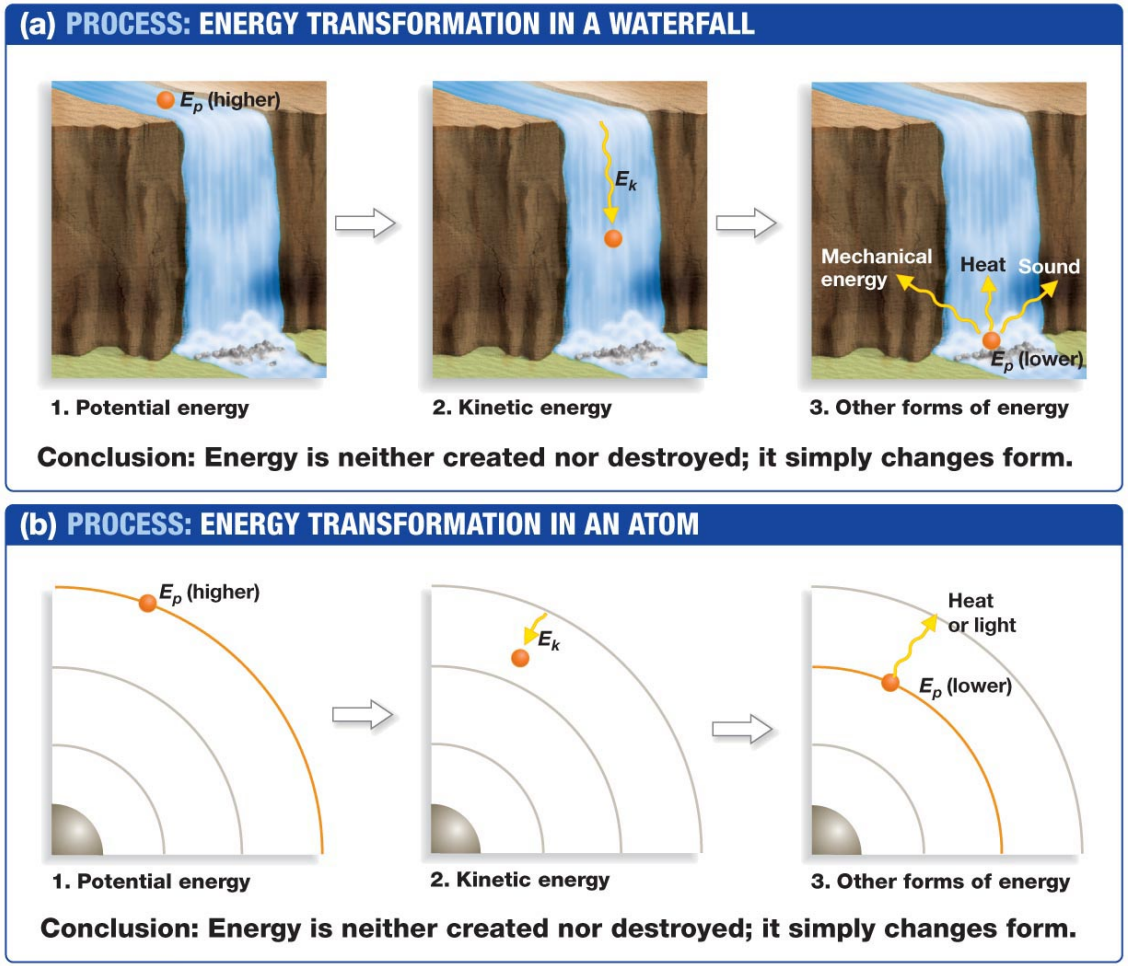
Liquid water

Energy

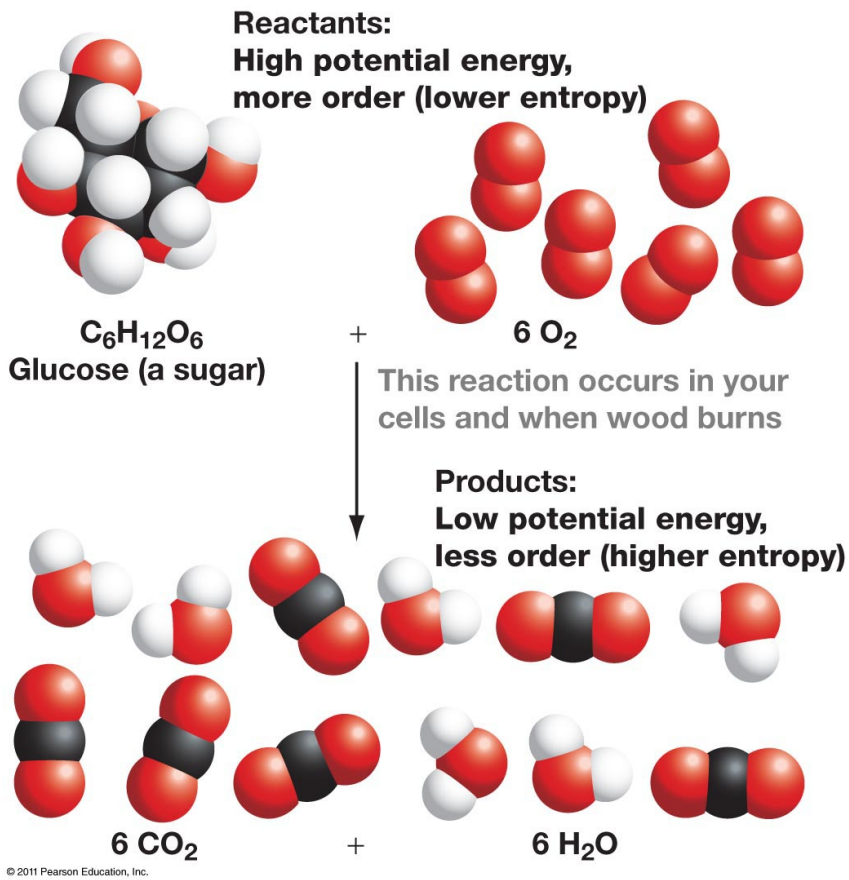
- Is the capacity to do work
- Potential E
  - Stored E
  - e^- in outer shell have more PE
- Kinetic E
  - Energy of movement
  - Measured as temperature
  - Low temp. objects = slower



Energy



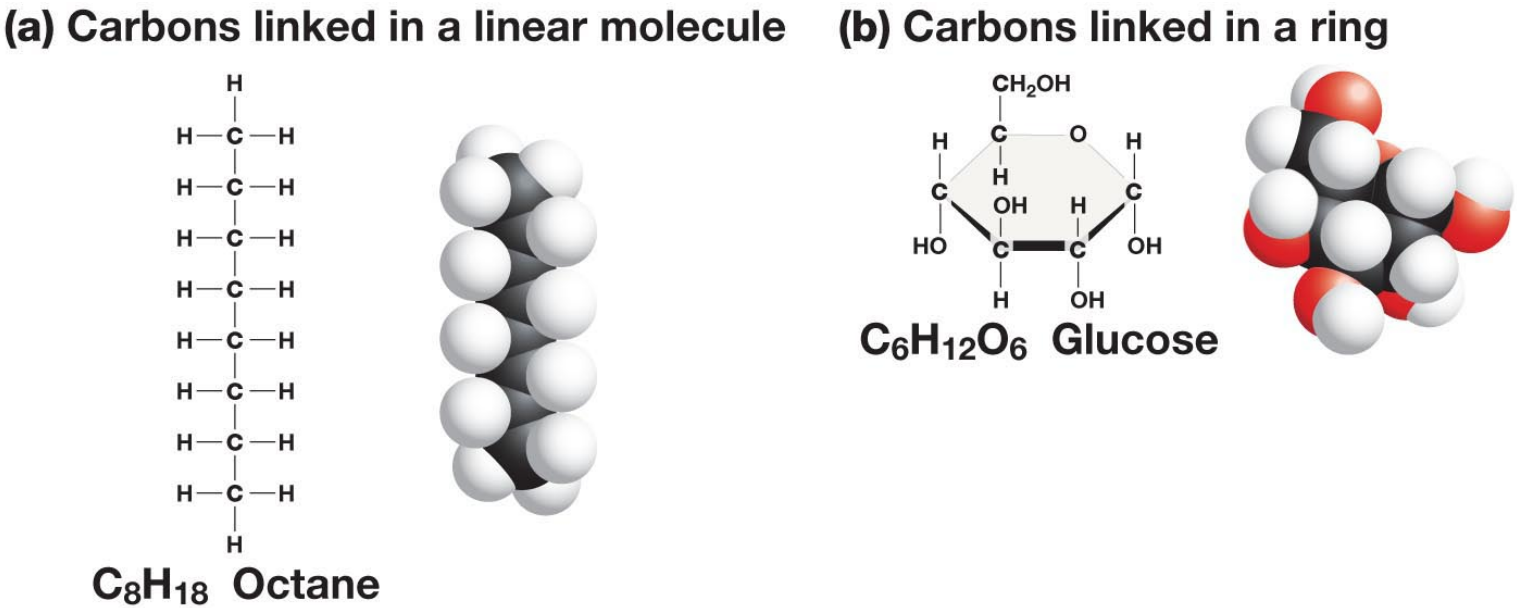
Laws of thermodynamics



- First
  - Energy is conserved (not created nor destroyed)
- Second
  - Chemical reactions result in less usable E

Carbon

- Most versatile atom
  - 4 valence e^-
  - Can form any version of covalent bonds



Beginning of Life?

- Science does not rely on faith
  - It relies on hypothetico-deductive reasoning
- Take home message:
  - No one REALLY knows how we came to be
  - We never will
    - Can't be certain of early Earth environment where life is thought to come into being
- Origin of life is philosophy, not science

Theory of abiogenesis

- Life spontaneously generated
  - from a "primordial soup"
- Chemical processes naturally produced amino acids
  - AA = building blocks of life
- Miller-Urey experiment
  - Reproduced hypothetical environment of early Earth
  - Produced amino acids
- Many problems producing more complex molecules spontaneously
  - i.e. DNA

Life from asteroids

- Pros
  - Amino acids found on asteroids
  - Bacteria persist on outside of space station
  - New missions to Mars take extra steps not to contaminate
- Cons
  - Hard to imagine

Hydrothermal origins

- Life came from deep-sea vents
- Pros
  - Vents are energy-rich source
  - Amino-acid synthesis is possible
    - Raw ingredients
- Cons
  - Lack of stability of organic molecules due to heat