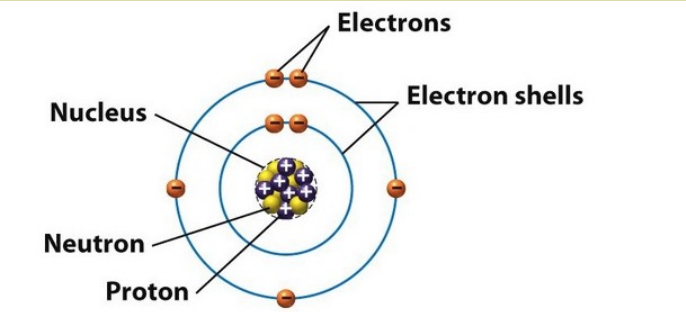
Matter and Energy Science Review

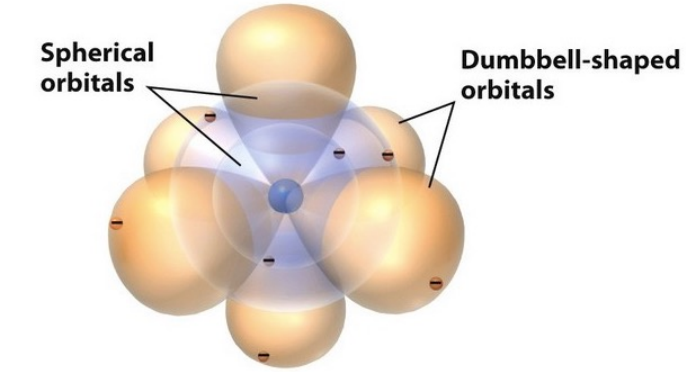
Matter

(anything that has mass and volume)

Building block of matter = atom = smallest particle of an “element”



(a) Nitrogen atom with electrons shown in shells



(b) Nitrogen atom with electrons in orbitals

Elements defined by “atomic number” (AN)
= number of protons in atom nucleus

Mass of atom described by “mass number”
= number of protons + neutrons
(mass is essentially the large nuclear particles - electron mass is negligible)

Matter

$^{12}_{6}C$ or C-12

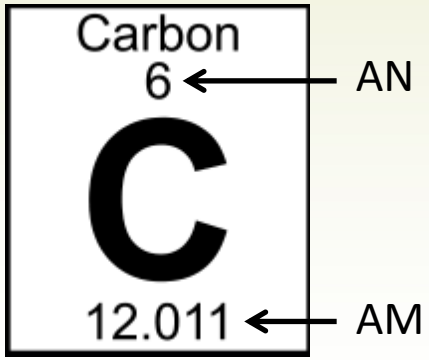
$^{13}_{6}C$ or C-13

$^{14}_{6}C$ or C-14

All are <u>carbon</u> because all have 6 protons (AN=6)

All are <u>isotopes of carbon</u> because mass number differs
= number of neutrons differs

From the periodic table



C-12

C-13

C-14

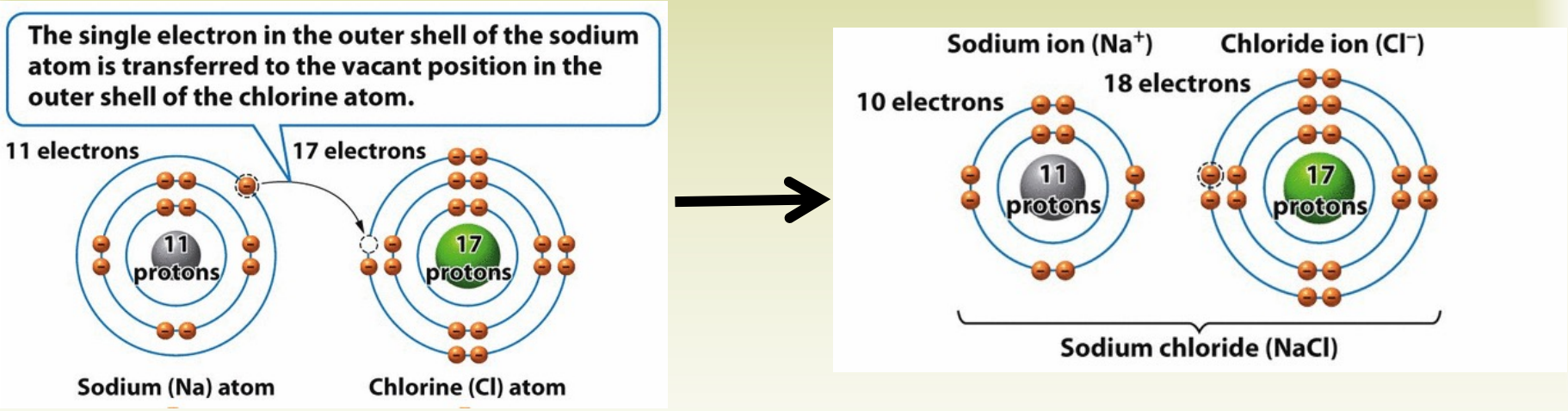
"Carbon atomic mass" (AM) = 12.011
= weighted average mass numbers of carbon isotopes in nature

Majority of carbon in nature is C-12

Matter

Elements form “compounds” through bonding of elements

Ionic Compound

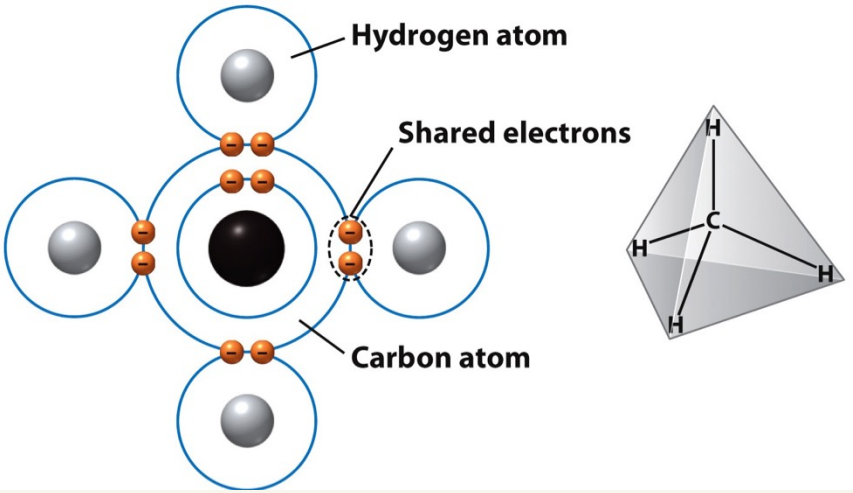


A sodium atom and a chlorine atom can readily form an ionic bond. The sodium atom loses an electron, and the chlorine atom gains one. The ionic bond is the attraction between the oppositely charged ions, and forms the ionic compound NaCl (sodium chloride), or table salt.

Matter

Elements form “compounds” through bonding of elements

Covalent Compound



Elements that do not readily gain or lose electrons can share electrons. Four hydrogen atoms will share electrons with a carbon atom, so that each atom has a complete set of electrons in its outer shell (two for each H and eight for the C) to form the covalent compound CH_4, or natural gas.

Matter

Compounds can be identified as “organic” or “inorganic”

Inorganic compounds

- do not contain carbon **or**
- contain carbon, but not bound to hydrogen
  examples: ammonia (NH_3), sodium chloride (NaCl), water (H_2O), carbon dioxide (CO_2)
- and as you will learn, there are many inorganic chemical pollutants

Organic compounds

- have carbon-carbon **and/or** carbon-hydrogen bonds
  examples: glucose ($C_6H_{12}O_6$), fossil fuels such as natural gas (CH_4)
- you learned in biology that organic compounds are the basis of macromolecules important to life: carbohydrates, proteins, nucleic acids, lipids
- and as you will learn, there are many organic chemical pollutants

Matter as a Resource

(much more detail about this over the year)

Entire biosphere uses matter resources such as air, water, food, shelters

Humans use much more additional matter to produce goods and services

- most of this matter must be mined from the Earth's crust
  minerals (elements and/or compounds)
  rocks (mixtures of minerals)

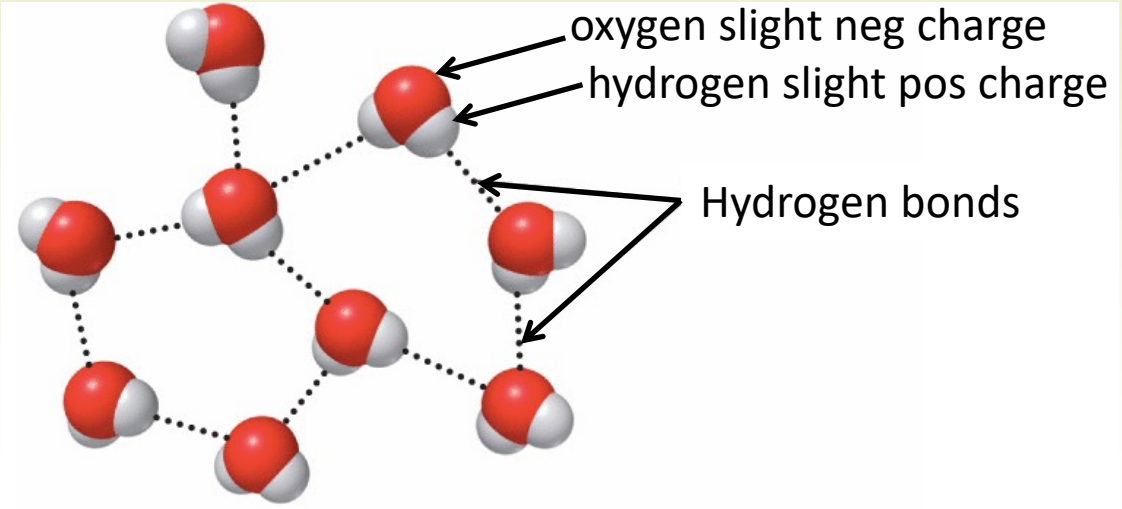
- some minerals and rocks can be used directly
  ex. gemstones, construction material, coal, halite (NaCl)

- some minerals must be processed to extract a desired element
  ex. **Fe**$_2$O$_3$ - iron in the mineral magnetite
  Ca**F**$_2$ - fluorine in the mineral fluorite
  UO$_2$ - uranium in the mineral uraninite

Matter

WATER (H_2O) is a very important compound on Earth

- H_2O is a polar molecule
  covalently bonded, but unevenly-shared electrons between O and H results in "dipole" = slightly more negative charge on O, positive on H
- Electrostatic attraction between H_2O molecules = "hydrogen bonds"



Matter

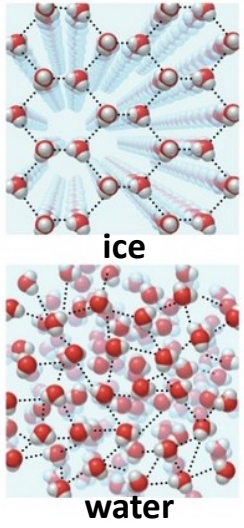
H_2O has collectively unique properties that support condition for life

- Surface tension - cohesion of water molecules at surface, allowing insects to perch on water surfaces.

- Capillary action - in thin tubes, such as water-conducting vessels in plants, adhesion of water to a surface is stronger than cohesion between molecules, allowing water to be “wicked” upward against force of gravity.

- Boiling/Freezing - 100°C boiling point and 0°C freezing point, allowing H_2O to exist as solid, liquid, or gas at Earth’s surface.

- Most dense at 4°C. Cooling further to 0°C, molecules align into lattice structure and volume expands, allowing ice to float on water.



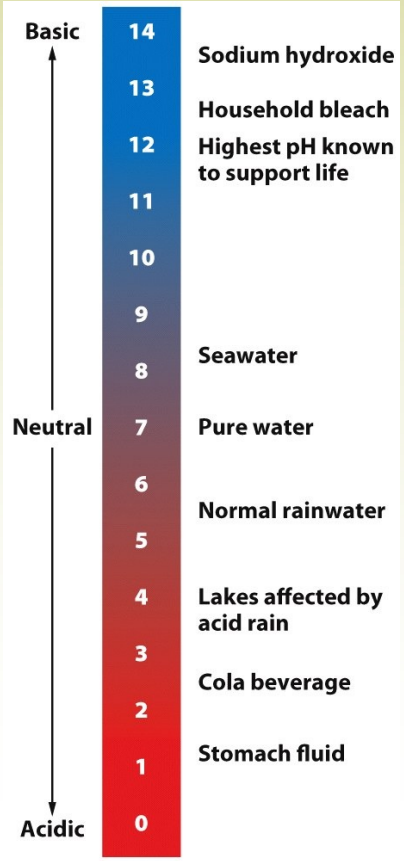
Matter

H_2O has collectively unique properties that support condition for life

- Universal solvent - many substances dissolve well in water, which explains the high concentrations of dissolved ions in seawater, the capacity of organisms to store molecules in solution in their cells, and easy transport of pollutants through the environment.

- Water is able to dissolve hydrogen ion (H^+) containing compounds ("acids") or hydroxyl ion (OH^-) containing compounds ("bases").

The pH scale is a measure of the relative amounts of H^+ and OH^- in a solution. As a "log scale" each number increment is 10x more acidic or basic than the next.



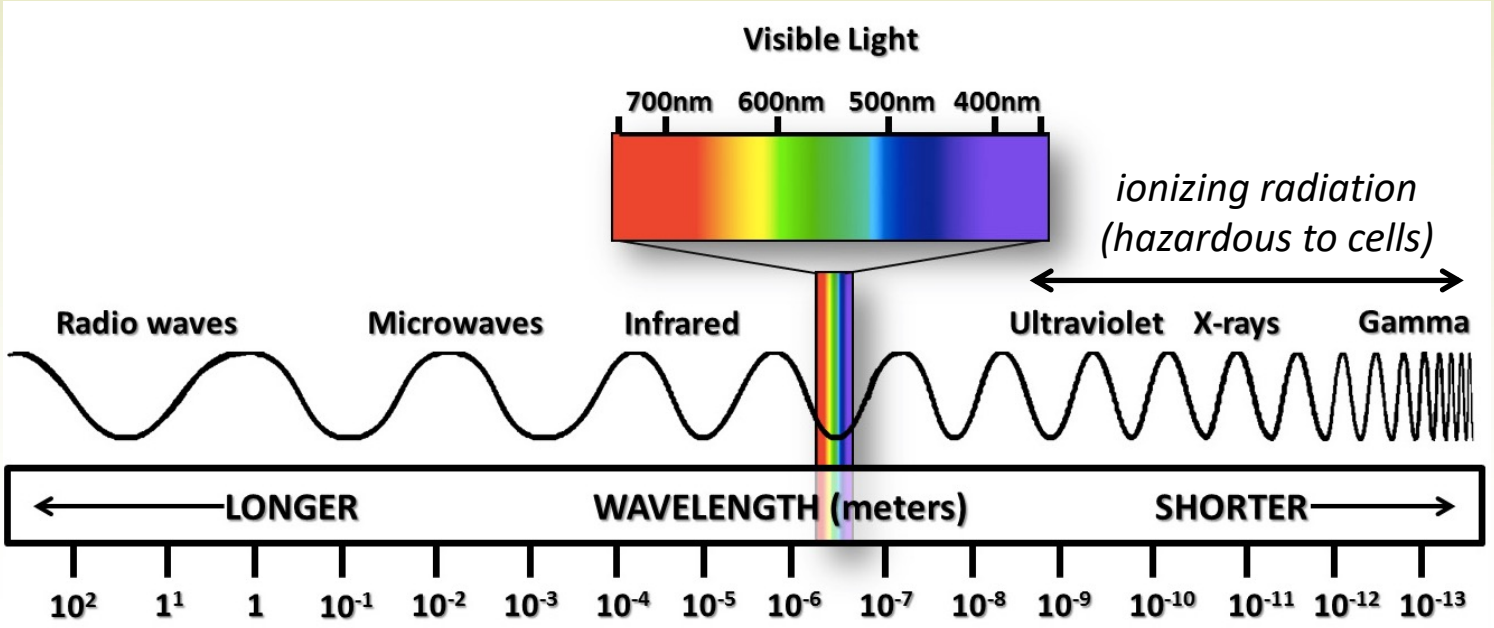
Energy as a Resource

(much more detail about this over the year)

Energy is present in many forms that can be accessed as a resource

<u>Electromagnetic (or radiant) energy</u> = movement of massless particles

- travel in waves at the speed of light
- organized by wavelength into the "electromagnetic spectrum"



Energy as a Resource (cont.)

(much more detail about this over the year)

Energy is present in many forms that can be accessed as a resource

Kinetic energy = energy associated with movement of mass

- electricity (electron flow) - produced using other energy resources
- wind flow
- water flow

  } - produced by solar energy

- heat flow - produced by geothermal or other energy resources

Energy as a Resource (cont.)

(much more detail about this over the year)

Energy is present in many forms that can be accessed as a resource

Potential energy = stored energy

- gravitational - stored by difference in elevation above Earth's surface
  - ex. height of water surface held behind a dam
- chemical - stored in chemical bonds between atoms
  - ex. coal to be combusted
    food to be eaten
- nuclear - stored in nucleus of atom
  - ex. fusion - natural nuclear energy production in stars
    fission - manmade process of nuclear energy production
    radioactive decay - natural radioactivity of unstable isotopes

Matter and Energy Practice!

Some questions are easy and some are "thinkers" based on your reading

1. Pure water has a pH of 7 because
   a. its surface tension equally attracts acids and bases
   b. its polarity results in a molecule with a positive and a negative end
   c. its ability to dissolve carbon dioxide adjusts its natural pH
   d. its capillary action attracts it to the surfaces of solid substances
   e. its H^+ concentration is equal to its OH^- concentration

2. The portion of the electromagnetic spectrum that is hazardous to cells includes
   a. IR, visible b. xray, radio c. radio, UV d. UV, xray e. IR, μwave

3. The polarity of the water molecule is the result of
   a. the slight negative charge of the hydrogen atoms
   b. shared electrons spending more time near the O atom than near the H atoms
   c. shared electrons spending more time near the H atoms than near the O atom
   d. the 100°C difference between the boiling point and freezing point of water
   e. two positively charged sides repelling each other

Matter and Energy Practice! (cont.)

4. Which of the following statements about atoms and molecules is correct?
   a. the mass number of an element is always less than its atomic number
   b. isotopes result from varying numbers of neutrons in atoms of the same element
   c. ionic bonds involve electrons while covalent bonds involve protons
   d. inorganic compounds never contain the element carbon
   e. protons and electrons have roughly the same mass

5. Water reaches its lowest density at
   a. 4°C b. 32°F. c. 100°F d. 100°C e. 0°C.

6. Water is a good solvent. This statement explains which of the following phenomena?
   I. high concentrations of dissolved ions in seawater
   II. capacity of organisms to store many types of molecules in their cells
   III. easy transport of toxic substances through the environment
   a. I only b. II only c. I and II d. I and III e. I, II, and III

Matter and Energy Practice! (cont.)

7. Organic compounds may contain
   I. carbon-carbon bonds
   II. carbon-hydrogen bonds
   III. hydrogen-oxygen bonds

   a. I only b. II only c. III only d. I, II, and III e. I and III

8. A substance pH 4 has __ times the hydrogen ion concentration of a substance pH 6.

   a. 2 b. 5 c. 10 d. 100 e. 1000

9. To form NaCl, a single electron in the outer shell of a Na atom is transferred to the outer shell of a chlorine atom. This is an example of

   a. formation of an ionic bond
   b. formation of a covalent bond
   c. formation of radiant energy
   d. formation of a hydrogen bond
   e. formation of an isotope

Matter and Energy Practice! (cont.)

10. Droplets of dew are spherical due to water's
    a. capillary action
    b. ability to transport dissolved substances
    c. surface tension
    d. expanded volume when the molecules form a lattice structure
    e. 100°C condensation temperature

11. Flowing water, one of the pathways in the water cycle, is a form of kinetic energy. The energy input that drives the water cycle is
    a. gravitational b. kinetic c. radiant d. chemical e. potential

12. A U-235 isotope struck by a neutron can become smaller products, such as Ba-141, Kr-92, and 2 neutrons. The energy released by this energy conversion is from
    a. breaking ionic bonds
    b. nuclear fusion
    c. breaking covalent bonds
    d. nuclear fission
    e. reorganization of hydrogen bonding