APES CHAPTER 2 NOTES (MRS. BAUCK): ENVIRONMENTAL SYSTEMS

MODULE 4: Systems and Matter

I. Matter

A. general chemistry terms for review

1) **matter**—anything that *takes up space and has mass*
2) **element**
   a) a specific type of atom
   b) *major elements in living things: C, H, N, O, P, S*
3) **compound**—two or more different elements bonded together
4) **periodic table**—organized chart of the elements
5) **atom**—*smallest "building block of matter" which retains the properties of that matter*

B. atomic structure

(APES Atom Review Notes: http://www.kwanga.net/apesnotes/atom-review-notes.pdf)

1) main subatomic particles: protons, neutrons, electrons (p^+, n^o, e^-)
2) **atomic number**—number of *protons* in the nucleus of an atom
3) atomic neutrality—atoms are electrically neutral; # p^+ = # e^-
4) **mass number**
   a) MASS NUMBER = PROTONS + NEUTRONS
   b) # OF NEUTRONS = MASS NUMBER - ATOMIC NUMBER
   c) **mass number** is not the decimal number on the periodic table (that's atomic mass)
5) **isotopes**—atoms of the same element that contain different numbers of neutrons
   a) same number of p^+ but different mass numbers
   b) different atomic masses
   c) most elements occur as a mix of two or more isotopes

C. radioactivity (Ch. 12)

1) **radioactive decay**
   a) release of material from the nucleus
   b) parent substance → daughter substance(s)
   c) can be alpha particles, beta particles, gamma radiation
2) example:

$$^{235}_{92}U \rightarrow {}^{231}_{90}Th + {}^{4}_{2}He$$ (alpha decay of U-235)

3) **half-life**—*the time is takes for one-half of a quantity of parent atom to decay*
4) if an atom is split (fission), it no longer retains its original properties

D. chemical bonds

1) covalent bonds
   a) *nonpolar **covalent bonds**—equal sharing of* e^- (example: N_2)
   b) *polar **covalent bonds**—unequal sharing of* e^- (example: H_2O)

c) **molecule**—*two more atoms covalently chemically bonded*

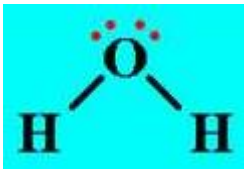
2) **ionic bonds**—*electron(s) transferred from cations to anions*

3) **hydrogen bonds**—*intermolecular attraction between a covalently bonded H on one molecule and unshared electron pair of an electronegative element on a neighboring molecule*

4) polar molecule vs. nonpolar molecule
   a) **polar molecules** (dipoles) are asymmetrical, with partially positive (δ^+) and partially negative (δ^-) ends
   b) **nonpolar molecules** are symmetrical

5) **formula unit—**two or more ions chemically bonded

II. Water and environmental systems



A. general characteristics of water
   1) colorless and odorless
   2) neutral pH of 7
   3) triatomic
   4) angular shape with two unshared electron pairs
   5) *polar (δ+ and δ- areas)*
   6) hexagonal crystals

B. surface tension and capillary action
   1) **surface tension**—*cohesion between molecules on the surface of a liquid*
   2) **(capillary action) capillarity —***moving upward, against gravity*
      a) movement up through roots, etc.
      b) adhesion forces are greater than cohesion forces

C. boiling and freezing
   1) *high specific heat*: 4.184 J/g°C
   2) *high boiling point*: 100 °C
   3) *freezing point*: 0 °C

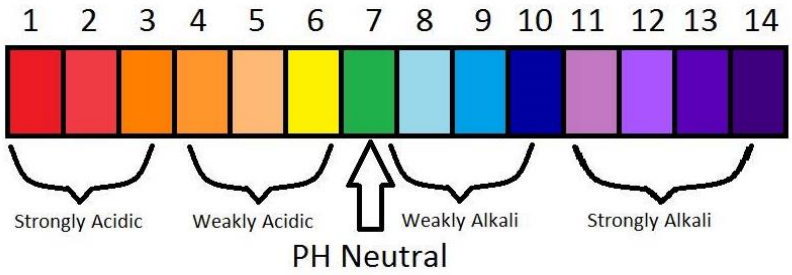
D. water as a solvent
   1) called the "universal solvent" because it dissolves many different substances
   2) water-soluble toxins can get into the water

E. Acids, bases, and pH – an introduction
   1) **Acids** *produce hydrogen ions (H^+) when dissolved in water*
   ... more accurately, they produce hydronium ions = H_3O^+
      a) properties: tart, sour, form electrolytic solutions of ions
      b) examples: citric acid, vinegar, hydrochloric acid, sulfuric acid
      c) *usually written with an H in front of the formula* or COOH at the end: H_2CO_3, H_2SO_4, HNO_3, CH_3COOH
      d) pH less than 7
   2) **Bases** *produce hydroxide ions (OH^-) when dissolved in water*
      a) properties: bitter, slippery, form electrolytic solutions of ions
      b) examples: lye/soap, NH_3, sodium hydroxide, other metal hydroxides
      c) *usually written with OH at the end of the formula*: KOH, NaOH, $Ca(OH)_2$
      d) ammonia (NH_3) is a base, even though for formula doesn't look like one—it forms NH_4OH in water

e) pH greater than 7

3) **pH** = the negative logarithm of the hydrogen ion concentration

$$\mathbf{pH = - \log [H^+]}$$



F. chemical reactions and the conservation of matter

1) **chemical reaction**—an expression showing the *conversion of reactants to products, forming new substances with new properties*
   a) **reactant**—*starting substance* in a rxn.
   b) **product**—*ending substance* in a rxn.

$$2\ C_8H_{18} + 25\ O_2 \rightarrow 16\ CO_2 + 18\ H_2O$$

2) **Law of Conservation of Matter (Mass)**—*matter can neither be created nor destroyed; it merely changes form* (exception: nuclear reactions)

G. biological molecules and cells

1) **organic**—*carbon-based; of living things*
   a) *natural organic*—naturally occurring carbon-based substances
   b) *synthetic organic*—human-made carbon-based substances
   c) *in chemical structure, having C-C and/or C-H bonds* (example: CH_4)
2) **inorganic**—*having no C-C or C-H bonds* (example: CO_2)
3) **carbohydrates**
   a) molecules containing C, H, O
   b) monosaccharide, disaccharide, polysaccharide, etc.
   c) names end in –ose: glucose, sucrose, frustose, lactose, galactose, maltose, cellulose, deoxyribose, etc.
4) **proteins**
   a) molecules containing chains of *amino acids*
   b) enzymes, antibodies, etc.
5) **nucleic acids**
   a) composed of sugar, phosphate, and nitrogen bases
   b) DNA, RNA formed from chains of nucleic acids
6) **lipids**
   a) insoluble with water
   b) waxes, fats, steroids
7) **cell**
   a) smallest unit of life
   b) contains carbs, proteins, nucleic acids, and lipids

MODULE 5: ENERGY, FLOWS, FEEDBACKS

I. Energy as a part of environmental systems

A. energy vs. power

1) **energy**—*the ability to affect matter, do work, and/or transfer heat*

2) **power**—*the rate at which matter is affected, work is done, or heat is transferred*

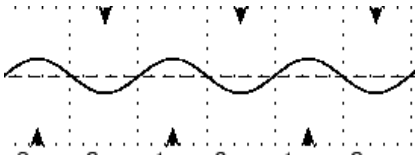
ENERGY = POWER x TIME

B. forms of energy

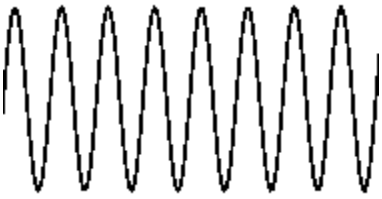
1) **electromagnetic (em) radiation**—*broad radiation spectrum*
(**quantum** = bundle of energy; **photon** = bundle of light energy)

(low energy)
RADIO WAVES
MICROWAVES
INFRARED (IR) RADIATION
VISIBLE LIGHT
"ROYGBIV": red, orange, yellow, green, blue, indigo, violet
ULTRAVIOLET (uv)
X-RAYS
GAMMA RAYS
COSMIC RAYS
(high energy)

Slow wave with low energy, low frequency, small amplitude, and large wavelength



Fast wave with high energy, high frequency, large amplitude, and small wavelength



2) **potential energy**
   a) *energy of position*
   b) examples: chemical, mechanical, nuclear, gravitational
   c) organic matter has high potential energy; breakdown releases energy
   d) inorganic matter has low potential energy

3) **kinetic energy**
   a) *energy in motion*
   b) examples: radiant, thermal, sound, electrical
   c) **temperature** = avg K.E.

B. energy units *** TABLE 5.1 ***

1) **Joule** = **J** . Also known as a Nm; SI energy unit.

2) **calorie = cal** *... the amount of heat energy needed to raise the temp of 1 g of H_2O by 1°C*

3) **Calorie (food) = Cal**
Calorie = diet calorie = 1kcal = 1000 cal

4) **British Thermal Unit = BTU or Btu** *... the amount of heat energy needed to raise the temp of 1 lb of H_2O by 1°F*
5) **Kilowatt-hour = kWh** *... the amount of energy expended by using a kilowatt of electricity for one hour* (IMPORTANT – this is kW x hr, not kW/hr!)

C. energy conversions—the amount of energy available in a natural system ultimately influences biodiversity and population size

International Energy Agency https://www.iea.org/topics/energyefficiency/

II. Laws of Thermodynamics

A. *First Law of Thermodynamics:* **Law of Conservation of Energy**—*energy forms are interconvertible; matter can neither be created nor destroyed; it merely changes form* (exception: nuclear reactions)

B. *Second Law of Thermodynamics (Entropy)*

1) key concepts
   a) *entropy = disorder*
   b) *when energy changes form, the quantity of energy remains constant but its ability to do work decreases*
   c) *systems will move spontaneously toward increased entropy*
   d) *the state of entropy of the entire universe, as an isolated system, will always increase over time*
2) **energy efficiency** % = *(energy output / energy input) x 100*
3) **energy quality**
   a) *the ease with which an energy source can be used for work*
   b) *the contrast between different forms of energy, the different trophic levels in ecological systems, and the tendency of energy to convert from one form to another*

C. Third Law of Thermodynamics (absolute zero)—as temperature drops to 0, entropy becomes constant

III. Matter and energy flow in the environment

A. System dynamics

1) Earth is a **system** with **inputs** and **outputs**
   a) can be matter, energy, information
   b) **inputs**—additions to a system
   c) **outputs**—loses to a system
   d) inputs accumulate in the environment
   e) outputs can be fed back into the system
2) open vs. closed systems
   a) **open system**—matter/energy exchanges across system boundaries (common)
   b) **closed system**—matter/energy exchanges within system boundaries
3) **steady state—**a system at equilibrium
4) **systems analysis—**examination of inputs, outputs, and changes
5) **feedback loop**—when one change produces another change, which reinforces or slows the original change
   a) **positive feedback loop** is a runaway cycle in which a change in a certain direction provides information that causes a system to

change further in the same direction; *enhancement or amplification of changes; this tends to move a system away from its equilibrium state and make it more unstable;* "snowball" effect

Example from https://www.soas.ac.uk/

"For instance, a positive feedback loop occurs when sea ice melts during the polar spring. As ocean and air temperatures increase, the sea ice begins to melt, with the result that the bright white, highly reflective surface of the ice is progressively replaced by open water, which is darker in colour and has a lower reflectivity (albedo). That lower reflectivity has the knock-on effect of increasing the amount of solar radiation that is absorbed at the surface, which in turn raises ocean and air temperatures further, leading to more rapid melting of the remaining sea ice. Hence this positive feedback loop amplifies and accelerates the original perturbation (the initial melting of sea ice)."

b) **negative feedback loop** occurs when one change leads to a
   i. lessening of that change (example: predation)
   ii. also called balancing feedback
c) **homeostasis**— negative feedback loop(s) maintaining favorable internal conditions in spite of fluctuating external conditions

The idea that life on earth helps sustain its own environment is a modified version of the **Gaia hypothesis**, proposed by chemist James Lovelock and microbiologist Lynn Margulis, circa 1969.

B. Changes across space and over time
   1) terrestrial ecosystems: variations in temperature, precipitation, and soil characteristics …
   2) aquatic ecosystems: changes in salinity, average temperature, turbidity, pH, dissolved oxygen…
   3) changes over time: desertification, Arctic warming…