Biology 2.1 General Chemistry

Why Chemistry?

1. All living organisms made of cells.
2. All cells made of atoms and molecules
3. All cell activity is a series of chemical reactions
4. Analytical biology explains physical life in terms of its chemistry.
5. Cannot understand physical life without chemistry.

Matter

1. Anything that occupies space and has mass
2. Matter is a state of energy
3. Six states of matter: Bose-Einstein Condensate, solid, liquid, gas, plasma, filament.
4. The three states of solid, liquid, gas allow life to function.
5. Atoms are the basic building blocks of all matter
6. Element: matter (material) consisting of one kind of atom
7. Most elements in pure form exist as two atoms bonded together
8. Molecule: bonding of 2 or more atoms
9. Substance: matter consisting of one kind of molecule
10. Compound: matter consisting of 2 or more molecules

Atoms

1. Atoms are composed of sub-atomic particles: 1) protons, 2) neutrons and 3) electrons.
2. The atomic nucleus consists of protons and neutrons.
3. All chemical reactions between different atoms occurs between their electrons orbiting the outer shell around the nucleus.
4. The number of protons determine the atom type (Atomic #), mass, and positive charge.
5. There are 92 naturally occurring elements.
6. All other atoms are man-made by adding protons to the nucleus.
7. The number of Electrons (negative charge) determines the charge of the atom.
8. The number of Neutrons affects only the mass of the atom.
9. Atomic mass= total mass of protons, neutrons and electrons.
10. Atoms manifest predictable behavior and are arranged in a Periodic table based on their common characteristics.
    a. Noble gasses (8A) are inert because of full electron shell stability.
    b. Halogens (7A) are highly reactive because they need only to gain one more electron to achieve full shell stability.
    c. Alkali metals (1A) are highly reactive because they need only to be rid of one electron to achieve full shell stability.

d. Alkaline metals (2A) are reactive because they need only to be rid of two electrons to achieve full shell stability.
e. The chalcogens (6A) are reactive because they need only to gain two more electrons to achieve full shell stability.
f. The pinctogens (5A) are somewhat reactive because they need to gain three more electrons to achieve full shell stability.
g. The transition group (3A) is somewhat reactive because they need only to be rid of two electrons to achieve full shell stability.
h. The carbon group (4A) is somewhat reactive and shares electrons because of half shell stability.

11. The elements of life come from the earth. (C HOPKINS CaFe).
12. Carbon, Hydrogen, and Oxygen are the most abundant elements in cells.

Chemical Bonding

1. All chemical interaction involves the electrons
2. Ionic Bonds:
    1. (+) and (-) charged atoms attract each other
    2. Ions= Atoms with a charge (+) or (-)
    3. Ions result from unequal numbers of protons (+) and electrons (-)
    4. Some atoms are prone to become ions due to "full shell stability"
3. Covalent bonding
    1. Bonds form by sharing electrons. (H : O : H, O : C : O)
    2. Very strong, not easily broken
    3. Carbon can share 4 electrons

Chemical changes

1. Chemical changes involve making or breaking bonds between atoms.
2. Results from chemical bonding: ionic or covalent
3. Definite proportions of atoms is determined by the number of electrons (water always a 1O:2H ratio resulting in H_2O). O always wants 2 electrons to fill its shell.
4. New molecules result with new properties.
5. Energy is always involved.

Catalysts

1. Molecules (substances) that affect the rate of a chemical rxn.
2. Reduces the activation energy required to initiate a chemcal reaction. e.g., getting a log to burn.
3. Some rxns have low activation energy and occur spontaneously.
4. Catalysts are not used, changed or affected by the chemical rxn.
5. Biological catalysts are proteins called *enzymes*.
6. The molecules affected by the enzymes are called *substrates*.
7. Very specific. Oftentimes, one enzyme-one substrate.
8. By this specificity, enzymes guide and control cell metabolism.

9. All chemical rxns in cells are controlled by enzymes. The six steps in glycolysis are controlled by six enzymes for each of the six steps of chemical reactions.
10. Further, each enzyme is coded for by one gene on the DNA molecule.

Formulas

1. Empirical: Ratio of atoms
2. Molecular: # and type of atoms $C_5H_{10}O_5$
3. Structural: # and type of atoms and bonds

Energy

1. Energy is described as the ability to do work.
2. Kinetic: energy of action. e.g. falling, heat, light, electric current
3. Potential: stored energy. e.g. rock on a cliff, log waiting to be burned
4. All atoms exhibit kinetic energy. Electrons always orbit the nucleus and are in constant motion.
5. T° affects K.E. Increase T° increase K.E. Decrease T° decrease K.E.
6. There is no atomic motion at absolute zero.
7. Physical state affected by K.E., which is affected by T° (solid, liquid, gas). e.g., condensation.
8. All molecules store potential energy in their bonds.
    - Exothermic: breaking bonds releases E. (e.g. heat, burn log)
    - Endothermic: forming bonds requires E. (e.g. heat, bake cake)
9. Cells store energy in chemical bonds by synthesis. Molecule building
10. Cells obtain E from chemical bonds by catabolism. Molecule breaking
11. The Carbon cycle demonstrates the use of energy through the making and breaking of molecules in photosynthesis and cellular respiration respectively.
12. Metabolism= All of the chemical rxns inside a cell, making and breaking.
13. The Order of Chemical Complexity (sugar + heat => water + C)

Laws of energy

1. First law of thermodynamics: Law of energy conservation. Energy cannot be created nor destroyed.
2. Second law of thermodynamics: Law of entropy. Energy cannot increase in net organized energy in a closed system. Energy will decrease in organization and complexity in a closed system.

Physical Change

1. No electron involvement; no chemical rxn
2. Three primary states of energy affecting life: Solid, liquid, and gas
3. The physical state of matter is affected by T°, which affects Kinetic energy.
4. Mixtures involve mixing two or more substances/compounds that do not react chemically. (e.g., salt and pepper, sugar in water)

5. Mixtures include: solutions, suspensions, and colloids

Solutions

1. A solutions is a mixture of solids (solutes) and liquids (solvent). e.g., sugar in water
2. No chemical rxn
3. Solute molecules are separated and dispersed between solvent molecules
4. Increased T° increases Kinetic energy and the subsequent active distribution of solute.
5. Homogeneous solution occurs when there is an even distribution of solute molecules
6. Saturation occurs when no more solutes can be dissolved into solvent.
7. Water is the universal solvent, and the primary solvent in organisms.

Suspensions

1. Solid particles are temporarily suspended in liquid (e.g., sand in water) as long as there is sufficient motion (kinetic energy).
2. Solids will precipitate or settle out as the movement of particles slows.

Colloids

1. Colloids occur when particles are not small enough to be dissolved but not large enough to settle out.
2. K.E. of solvent keeps particles suspended but not dissolved
3. Dispersion medium is the liquid medium in which particles are suspended.
4. Dispersion particles are the solids that are suspended in the medium.
5. 2 states of a colloid: 1) gel (semisolid) or 2) sol (fluid). (e.g. gelatin at different T°)
6. Phases are affected by T° , salt, pH, pressure, and concentration of solute
7. Reversible phase colloid allows reversal of phases from gel to sol an vice versa: e.g. gelatin.
8. Nonreversible phase colloid allows change only from sol to gel: e.g. cooked egg white.
9. Protoplasm in living cells is a reversible phase colloid.

Diffusion

1. Net movement of molecules from an area of higher concentration to an area of lower concentration.
2. Concentration gradient: unequal concentration. (high to low)
3. Rate of diffusion depends on 1) Kinetic Energy and 2) concentration gradient.
4. Equilibrium= Even distribution of substance. Net movement is zero. Rate of distribution from one side of container to another is equal to the contrary motion.
5. Diffusion Pressure: the pressure to diffuse. Moves with the gradient. (high to low). Closer to euilibrium diffusion pressure decreases.

Osmosis

1. The diffusion of water molecules across a semipermeable membrane.
2. Semipermeable membrane: Permeable only to certain substances.
3. Diffusion and Osmosis are the two very important physical processes for transporting molecules into, out of, and through cells.
4. Cytolysis is bursting the cell membrane due to osmotic imbalance.
5. Plasmolysis is shrinking the cell due to osmotic imbalance.
6. Hypertonic solution refers to increased osmotic pressure outside the cell.
7. Hypotonic solution refers to decreased osmotic pressure outside the cell.
8. Isotonic refers to a balance of osmotic pressure.

Living Cells

1. Cells are living bags of semi-permeable membranes filled with protoplasm, organelles, and a nucleus.
2. Substances in the cell protoplasm may be either colloid or dissolved.
3. Cells obtain nutrients from their environment and eliminate waste by selective diffusion across their membranes.
4. Substances in the cell move by diffusion.

Acids and Bases

1. Acids: Substance that releases H+ when dissolved in water. (HCl)
2. Bases: Substance that releases OH- when dissolved in water. (NaOH)
3. Salts: Substance resulting from rxn of acids and bases. ($NaOH + HCl \rightarrow NaCl + H_2O$)
4. pH: A Numerical index indicating the acidity (H+) or alkalinity (OH-, bases) of a solution.
    1. Scale of 1 to 14
    2. Acid=1-6, neutral=7, alkaline=8-14
    3. Human blood= 7.35 - 7.45; Gastric juices= 1.6 to 2.4
    4. Cell metabolism functions only at certain pH levels
5. Buffers: substances which resist and stabilize change in pH such as carbonate in the body.
    a) Consists of carbon dioxide, water, carbonic acid, Bicarbonate, and Carbonate ion equilibrium that resists changes in water's pH.
    b) $CO_2 + H_2O \Leftrightarrow HCO_3^- + H_2CO_3 + CO_3^{-2}-$
    c) "For example, if acid materials (hydrogen ions) are added to this buffer solution, the equilibrium is shifted and carbonate ions combine with the hydrogen ions to form bicarbonate. Subsequently, the bicarbonate then combines with hydrogen ions to form carbonic acid, which can dissociate into carbon dioxide and water. Thus the system pH is unaltered even though acid was introduced."

Interesting chemistry facts

1. The chemical name for water (H2O) is dihydrogen monoxide.
2. Lightening in the atmosphere produces O_3, which is ozone.

3. A pure element can take many forms. For example, diamond and graphite both are forms of pure carbon.
4. The only elements that are liquid at room temperature are bromine and mercury. You can melt gallium by holding a lump in the warmth of your hand.
5. The only two non-silvery metals are gold and copper.
6. By the time you feel thirsty, you've already lost about 1% of your body's water.
7. Mars is red because its surface contains a lot of iron oxide or rust.
8. Dry ice is the solid form of carbon dioxide, CO_2.
9. The rarest naturally occurring element in the earth's crust may be astatine (#85), which is radioactive. The entire crust appears to contain about 28 g of the element.
10. Hydrogen is the most abundant element in the universe.
11. Oxygen is the most abundant element in the earth's atmosphere, crust, and oceans (about 49.5%).
12. 65% of the human body is made of Oxygen.
13. 18% of the human body is made of Carbon.
14. 10% of the human body is made of Hydrogen.
15. 60% of human body is made of water.
16. There is about 1/2 lb or 250 g of salt (NaCl) in the average adult human body.
17. Bee stings are acidic while wasp stings are alkaline.
18. One bucket full of water contains more atoms than there are buckets of water in the Atlantic ocean.