Study Guide for Unit 1

1. Know the characteristics of living organisms. How do they apply to some organisms? Viruses?
2. Know the steps of the scientific method. Be able to formulate a null hypothesis. What the characteristics of good hypothesis? Limitations? Can you prove a hypothesis false?
3. Be able to interpret scientific data using abstracts and / or a research paper. Including graphs, tables and charts.
4. Know the structure of an atom. What is an element, molecule, compound, mixture, solution, and suspension.
5. Draw and diagram an atom and identify the atomic particles
6. Which atomic particle(s) is/are responsible for the element, its chemical or reactive properties, and mass.
7. Know and understand the following: atomic number, proton, neutron, electron, mass number, molecular weight, isotope, octet rule, covalent bonds, ionic bonds, hydrogen bonds, & polarity.
8. Be able to calculate the molecular weights of molecules given their atomic mass.
9. Be able to diagram the following using electrons: covalent bond, ionic bond, and hydrogen bond.
10. What makes water unique in nature? Ice? Density? Know and understand the properties/behavior of water. What elements form hydrogen bonds? Describe hydrogen bonds in the terms of partial charges and polarity. How does it affect jelly or candy?
11. What makes a molecule hydrophilic and hydrophobic?
12. What is oxidation? What is reduction?
13. What is electronegativity? What elements are the most electronegative? Which are the least electronegative. Where are there positions on the Table of Elements?
14. What is pH? Acid? Base? Understand the relationship between hydrogen ion concentration and pH.
15. Define a buffer? Know an example of a buffer system.
16. Know the functional groups that are attached to carbon atoms: alcohol (hydroxyl), carbonyl (aldehyde & ketone), carboxyl, sulfhydryl, amino, phosphate, four contiguous rings (sterol) & hydrocarbon chain.
17. Know and identify the four classes of biological molecules and their monomers. Know examples of each.
18. Define the following: monosaccharide, disaccharide, polysaccharide, dehydration/condensation, & polymer.
19. Know the functions in living systems of carbohydrates and examples.
20. What are the functional groups in carbohydrates?
21. What is the difference between starch and cellulose?
22. What are the three functions of lipids in living organisms?
23. Be able to draw the following by their functional groups: Fatty acids (saturated and unsaturated), triglyceride, phospholipid, and sterols.
24. How does the amphipathic nature of phospholipid make stable membranes? Understand the nature of phospholipids.
25. What are the three functional groups in a nucleotide?
26. Know the difference between RNA and DNA.
27. Know the nucleotide bases and which bases pair with each other in DNA and RNA. How many H-bonds? Define 5' and 3' in DNA and RNA.
28. Know which bases are purines and which are pyrimidines.
29. When looking at a nucleotide sequence (RNA or DNA), be able to identify the hydrogen bonds, ribose or deoxyribose, and phosphate and bases.
30. What are the functional groups in an amino acid?
31. Identify polar/non-ionizable, polar/ionizable, and nonpolar amino acids based upon functional groups.
32. What is a peptide bond and what functional groups are involved in its formation in the amino acids?
33. Define and explain the four levels of protein structure on a molecular basis with examples of each. Include H-bonding, ionic interactions (salt bridges), covalent bonding (disulfide bridges), and hydrophobic interactions.
34. Know some examples of protein.

Sample problems:

35. Outline the scientific method. Discuss its inherent strengths and its defined limitations.

Ideal answer

Observations must be made repeatedly on phenomena that have a physical or chemical basis.

Hypotheses are generated to explain the phenomena, or at least certain aspects of such events.

Experiments are designed to test the hypotheses or explanations. Experiments must be replicated with controls and treatment or experimental variables. Experiments should be designed to prove the hypotheses false that are being tested.

Where hypotheses are proven wrong, the process starts over with new hypotheses being generated and tested in experiments. If not proven false, the results may be published in meetings, scientific journals, etc.

Widely useful hypotheses are considered theories, and in the fields of chemistry and physics may become laws. However, there is no absolute truth in science. New observations and/or experiments may repudiate theories or even laws (with lots of controversy, of course), and the process begins once more.

Science is restricted to the physical, measurable universe. It cannot address metaphysical or supernatural events. Also, science is amoral. This means that the scientific method is a means of obtaining knowledge only. Morality or ethics come into play in the application of that knowledge. However, scientists should be ethical in conducting and reporting their research. But the knowledge from that research alone cannot violate an ethical code.

36. The chemistry of the hydrogen and oxygen atoms and the shape of the water molecule produce properties of water which appear essential to living organisms as we know them. Outline these properties and indicate how the structure and chemistry of water are involved.

Ideal answer

Water forms when **two H**ydrogen atoms covalently bond with **one O**xygen atom to form an asymmetrical molecule with two lone pairs of electrons opposite the hydrogen atoms. Because oxygen is very electronegative, the pairs of electrons shared in the covalent bonds with the hydrogen atoms spend more time next to the oxygen nucleus. This makes the asymmetrical molecule polar, that is it has a dipole moment. One end or pole is slightly negative (the oxygen side with the lone pairs of electrons) while the other pole, where the hydrogen atoms are, is slightly positive. These small dipole moments make water molecules sticky and the attractions between the hydrogens of one water molecule and the oxygen atoms of different water molecules are called hydrogen bonds.

Water is liquid over a wide temperature range. It can also absorb large quantities of energy with concomitantly small increases in temperature. Temperature is a measure of the average kinetic energy of a system. Kinetic energy is the energy of motion. Water molecules and any other atoms, molecules or ions mixed with the water are constantly moving. The faster these particles move, the more kinetic energy is in the system and the higher the temperature of the system. However, because of hydrogen bonding, the water molecules are sticky. This interferes with the movement of water and some of the energy put into the system is used to break hydrogen bonds instead of imparting energy of motion to the molecule. This energy lost to breaking hydrogen bonds cannot be used for molecular motion so the temperature of the system rises more slowly. Also, the stickiness of the water molecules keeps them together in liquid form greatly reducing the chance escape of water molecules as gas unless great amounts of energy are put into the system. In order for water molecules to escape from the liquid as gaseous water vapor, they must absorb large amounts of kinetic energy. This energy leaves the system as the water molecules evaporate reducing the amount of kinetic energy remaining lowering the temperature of the system. This is evaporative cooling which is important to animal and sometimes plant survival in hot terrestrial habitats.

Another property of water that affects living entities, particularly in the colder regions of the earth, is that of ice formation. Most liquids when they freeze into solids become denser. If water did that, ice would form at the bottom of lakes and ponds and freeze towards the water surface possibly killing the aquatic organisms as well. However, as water molecules slow down with increasingly lower temperatures, more hydrogen bonds are able to form. When all possible hydrogen bonds form, the water molecules are no longer moving but vibrating in place in a crystal lattice or solid that is less dense than liquid water. Water is liquid because although some hydrogen bonds form to hold the molecules together, the water molecules are moving fast enough to break other hydrogen bonds and slip past each other. Thus, in liquid water there are more molecules per unit volume than in the ice crystal lattice. Ice is less dense than water and floats on the surface forming an insulating blanket to reduce heat loss and freezing of the denser water underneath.

Two related properties of water are surface tension and cohesion. Cohesion means that water molecules adhere to other water molecules. In surface tension, the water molecules stick to themselves rather than to the air above (or the waxed car surface below). This forms a dense layer of molecules several thousands of an inch (several hundredths of a millimeter) thick. Insects and some small animals can walk on this surface tension layer as long as they don't break through. This surface tension layer or cohesion can also be seen in overfull glasses of water that do not have water dripping down the sides. Adhesion is where water adheres or sticks to molecules other than itself. In slender columns like capillary tubes, glass graduated cylinders, or in plant xylem tracheids or vessel elements, the water molecules stick to the negative charges of the glass silicates or to the polar alcohols of the cellulose cell walls of xylem pulling other molecules up the columns by cohesion. This is part of the reason water can move up 100 meters or more to the tops of Douglas fir, eucalyptus or redwood trees. The tension forces on the water column exceed those of high tensile steel wire of the same diameter as the water column.

Related to adhesion is the ability of water to dissolve polar and ionic substances and to partition hydrophobic compounds. Water is called the universal solvent because it can orient the slightly positive hydrogen ends or poles of its molecules towards negative ions or slightly negative polar functional groups while at the same time other water molecules are directing their slightly negative oxygen poles to positive ions or weakly positive functional groups to dissolve the compounds, that is to pull the compounds or ions in to mix with the water molecules themselves. Whatever the water molecules cannot pull in among themselves they push into groups separated by water molecules in a partitioning process.

The chemicals of life for the most part are dissolved in aqueous (water-based) solutions. Water molecules are exceptionally stable due to covalent bonds between the hydrogen atoms and oxygen. When the covalent bonds break, the water molecules dissociate into H^+ and OH^- ions, and because these ions can react with the molecules of living organisms, we need to be able to measure their concentrations. pH is the negative log of the H^+ ion concentration in moles per liter (molar or M concentration). In pure water, the $[H^+] = [OH^-] = 10^{-7}$ M. Log_{10} of 10^{-7} is -7, and the negative of -7 is 7 so the pH of pure water is 7. If the H^+ ion concentration $[H^+]$ is 0.1 M or 10^{-1} M, then the pH is 1. If the $[H^+]$ is 0.00000001 M or 10^{-8} M, then pH is 8 and there are more OH^- ions (10^{-6} M) than H^+ ions. Buffers are numerous in physiological systems to moderate pH effects. Buffers are either weak acids or weak bases that absorb or release hydrogen ions to keep pH levels relatively constant to reduce cell damage by attacks of acids (H^+ ions) or bases (OH^- ions).

37.

38. What roles are played by lipids in living organisms? Explain how phospholipid chemical structure permits membrane formation in the cells of living organisms.

Fats are made up of fatty acids ester-bonded to glycerol molecules. Fats are used for long-term energy storage and as a source of carbon skeletons for synthesis of other molecules including steroids. The fatty acids in fats (triglycerides or triacylglycerols) may be saturated or unsaturated. Unsaturated fatty acids have one or more carbon-carbon double bonds that cause the fatty chain to be kinked. Because these chains are kinked they cannot lie close enough for the weak van der Waals forces to hold the fat molecules together in a solid. Unsaturated fats called oils are thus liquid at room temperature. If one of the fatty acids in a fat or oil is replaced with a phosphate group and associated elements, then the resulting molecule is a phospholipid. Phospholipids have two hydrophobic fatty (hydrocarbon) tails from their two fatty acids and a polar, hydrophilic head made up of the phosphate group and the ester bonds of the fatty acids bonding to glycerol. In aqueous solutions, the hydrophobic tails of many phospholipid molecules are repulsed (partitioned) by water molecules to dissolve or mix among themselves while the polar heads face into or mix with the water molecules on either side. This forms a bilayer with polar heads facing water surfaces and the fatty tails sandwiched in the middle. Phospholipids are the main structural molecule of membranes in living organisms. The bilayer functions to separate the internal water and its dissolved contents from the external water and contents. Because the membrane is not totally impermeable, some dissolved contents may cross the phospholipid barrier from one aqueous side to the other. Cholesterol is a steroid lipid with 4 carbon rings that make the molecule rigid. Cholesterol can be found in phospholipid bilayers where it functions to regulate the fluidity and hence the permeability of the membrane. Other steroids have the same auto functional group as cholesterol -- the 4 carbon rings. The sex hormones such as testosterone, progesterone and the estradiols are steroids as is the hormone cortisone involved in regulation of the inflammatory response. Vitamin D is produced in the body when a form of cholesterol, ergosterol, is radiated with ultraviolet light to become calciferol. Vitamin D assists the body in absorbing calcium from the gut. Other lipids formed by terpene subunits include waxes (waterproofing), essential oils (perfumes), some plant hormones, carotenoid pigments and chlorophyll tails, vitamin A, latex (rubber), resin acids from which turpentine may be derived, etc.

39. What roles are played by polypeptides and proteins in living organisms. List and explain the hierarchy of protein structure with appropriate examples.

Proteins or polypeptides are polymers of amino acids hooked together as most macromolecules in a dehydration or condensation synthesis that releases water molecules from the two joining functional groups. In this case peptide bonds form. Proteins have 3 levels of structure, and some have 4 levels of organization. The first or **primary structure** (**1^o**) is the linear order of the amino acids forming the polypeptide chain. This sequence of amino acids largely determines the remaining levels of organization of the protein. **Secondary structure** (**2^o**) is where hydrogen bonds form between carboxyl oxygen atoms of the amino acids and the amine hydrogen atoms of different amino acids. If the hydrogen bonds hold the portions of the polypeptide chain side-by-side, β pleated sheets are formed. If the hydrogen bonds pull a portion of the chain of amino acids into a spiral, then an α helix is formed. **Tertiary structure** (**3^o**) is the functional, 3-dimensional shape of the polypeptide. Here strong bonds such as salt (ionic) bonds between acidic and basic amino acid R groups and the covalent disulfide bonds between two cysteine amino acids stitch the polypeptide string into a final 3-D shape. Once these bonds form, additional hydrogen bonds may form fine-tuning the shape. Also, lipid R group interactions where the R groups fold away from the water to mix together much like the phospholipid fatty tails in the membranes do, affect the final shape of the protein. In **quaternary structure** (**4^o**) two or more polypeptides associate to form the final functional form of the protein.

Proteins or polypeptides may function as structural molecules such as keratin, actin, tubulin, vimentin in the cytoskeleton formation, or collagen in ligaments and tendons and keratin in skin, nails and hair. Some may function in signaling and communication, either bearing sugar molecules to identify the cell, or as receptors receiving chemical signals from other cells. Others act as enzymes in facilitating essential chemical reactions in cell metabolism or in building structural molecules from smaller subunits. Some proteins transport ions or molecules while others store ions or molecules. Some proteins function in defense such as immunoglobulins or toxins. Along with membranes, proteins form the structural elements of cells. Proteins are also the tools of cellular metabolism.

40. What roles are played by carbohydrates in living organisms? Explain how the chemical structure of cellulose relates to plant cell wall functions.

Simple sugars or monosaccharides can function as building blocks for structural molecules like cellulose or chitin, carbon skeletons for the synthesis of amino acids and other molecules, or as readily metabolized energy sources. Monosaccharides can also be attached to membrane proteins or lipids to help signal to other cells the identity of the cell to whose membrane they are attached. Sugars attached to proteins may also affect protein function absorbing much more water by hydrogen bonding to the polar alcohols of the sugars. Sugars attached to channel proteins may provide steric controls on which ions or molecules can successfully enter channel openings. Disaccharide sugars can serve as readily available energy reserves or cell markers. Sucrose is a stable, largely inert form used by plants to translocate energy reserves from one organ (usually leaves) to another organ (roots or rapidly growing shoots, flowers or fruits). Chitin and cellulose are polysaccharides found in the cell walls of fungi and plants, respectively. Chitin is also found in the exoskeletons of arthropods such as insects, spiders, crabs, lobsters, centipedes, etc, in the radulae of mollusks (clams, snails, conches) and in other animal appendages. Starch and glycogen are glucose polysaccharides that function in short-term energy storage. They have spiraling branching chains of glucose molecules hooked together by α (alpha) sugar bonds (glycosidic linkages). Cellulose is also a polysaccharide of glucose, but it forms long straight chains instead of spirals. The reason is that the cellulose subunits of glucose are hooked together by β (beta) glycosidic linkages that cause the glucose sugars to flip-flop from upright to upside-down every two glucose sugars. The resulting straight chains are more readily held together side-by-side by hydrogen bonds forming between the alcohols of the different glucose subunits. Many such cellulose macromolecules held together in such fashion make the relatively strong microfibrils that like cotton thread are spun around the outside of the plasma membrane to form a cell wall. The primary cell wall is glued together with pectins and hemicelluloses that are also carbohydrates, or derived from carbohydrates.

Study questions:

41. Analyze the following experiment.
A farm seed sales representative wants to know what the best fertilizer recommendations will be for a new field corn hybrid that his seed company will release for general sales in two years. The representative has the cooperation of an interested farmer to place 9 treatment plots in two different parts of his cornfields. They do soil testing and find that the average available nitrogen in the plots is 50 pounds per acre while the average available phosphorus in the plots is 25 pounds per acre. They decide on three treatment levels of nitrogen (N) fertilizer and three treatment levels of phosphorus (P) fertilizer in a factorial design with two blocks. The following table illustrates the treatment design.

Fertilizer treatment	**(P) levels**		
(N) levels	25 + 25 = **50** lbs.	25 + 75 = **100** lbs.	25 + 125 = **150** lbs.
50 + 50 = **100** lbs.	**100 N + 50 P**	**100 N + 100 P**	**100 N + 150 P**
50 + 150 = **200** lbs.	**200 N + 50 P**	**200 N + 100 P**	**200 N + 150 P**
50 + 250 = **300** lbs.	**300 N + 50 P**	**300 N + 100 P**	**300 N + 150 P**

The plots yielded the following bushels of dry corn per acre listed in the table below.

Nitrogen levels	corn-field plot	Phosphorus levels 50 lbs.	100 lbs.	150 lbs.
100 lbs.	1	95	100	105
	2	100	95	100
200 lbs.	1	145	135	140
	2	140	145	145
300 lbs.	1	185	180	185
	2	180	185	180

Null hypothesis #1 (Ho#1) Increasing the levels of nitrogen fertilizer did not result in higher yields of dry corn.

Do you **reject** or **fail to reject** the hypothesis #1 ____________________________ (1 pt.)

Why or why not? (1 pt.)

Null hypothesis #2 (Ho#2) Increasing the levels of phosphorus fertilizer did not result in higher yields of dry corn.

Do you **reject** or **fail to reject** the hypothesis #2 ____________________________ (1 pt.)

Why or why not? (1 pt.)

42. Draw a simple diagram of an atom of phosphorus (atomic number of 15) with the electrons in the correct orbitals and shells. (2 pt.)

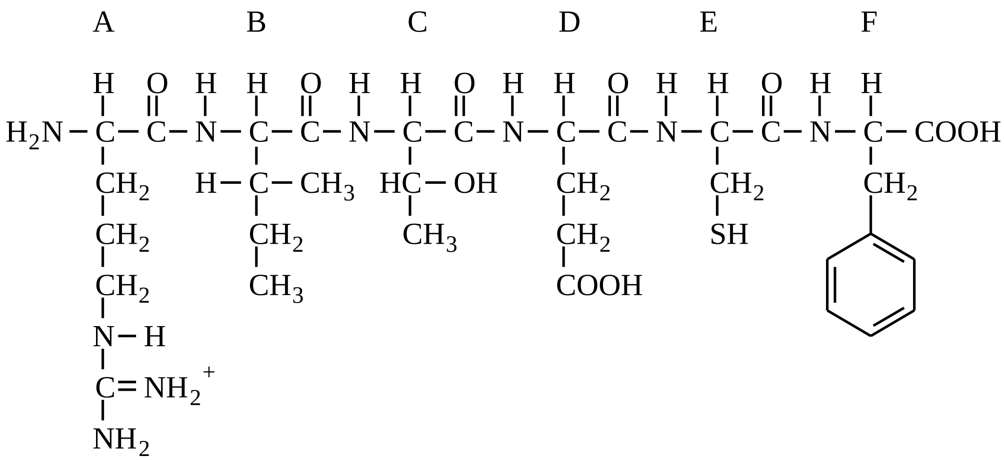
43. How many valence electrons does an atom of phosphorus have? (1 pt.)

44. How many bonds can phosphorus form? (1 pt.)

45. Fill in the chart below with the atomic number, mass number; and the number of protons, neutrons, and electrons for each atom; Then diagram the following molecules indicating the nucleus of the atom and the number of electrons in their appropriate shells **showing bonding**. H_20 (water), CO_2 (carbon dioxide), NaCl (salt or sodium chloride), MgO (magnesium oxide), and H_3CCH_2OH (drinking alcohol or ethanol). (10 pt.)

Atom	Atomic number	Mass number	Number of protons	Number of neutrons	Number of Electrons	Valence electrons
Hydrogen						
Oxygen						
Carbon						
Sodium						
Chlorine						
Magnesium						

46. The diagram below represents a polypeptide consisting of 6 amino acids labeled A, B, C, D, E and F. Answer the following questions about the polypeptide. Hint: the R groups confer the properties that define the polypeptide. (12 pt.)



Which of the amino acids is (are) polar?____

Which of the amino acids is (are) nonpolar?______________________________________

Which of the amino acids is (are) polar ionizable?__________________________________

Which of the amino acids is (are) polar non-ionizable?_______________________________

On the diagram **circle** and **label**: one amino functional group in an R group, one carboxyl functional group in an R group, a sulfhydryl functional group in an R group, and an alcohol functional group in an R group.

47. Draw a straight chain and a ring form of glucose. Circle and label the carbonyl group in the chain form. Circle and label the alcohol on the third carbon in both forms. (4 pt.)

48. Draw a 12-carbon fatty acid lauric acid often used in shampoo. Circle and label the carboxyl or carboxylic acid group. Put a box around and label the fatty hydrocarbon chain. (2 pt.)

49. Draw a triglyceride that is in oil. Put a box on and label the glyceride portion of the molecule. Circle and label one of the three-ester bonds. Place an arrow pointing to carbon-carbon double bond that makes this triglyceride unsaturated. (3 pt.)

50. Redraw the triglyceride as above and replace one of the fatty acid chains with a phosphate group. This will create a phospholipid (2pt.)

51. Draw a cholesterol molecule. Circle the four rings that form the key functional group that keeps the molecule stiff. (2 pt.)

52. Describe the characteristics of water and why it is well suited to support life? (4 pt.)

53. Define pH. Include in your definition/explanation what makes HCl a strong acid and NaOH a strong base. How do buffers affect pH? (4 pt.)

54. Draw uridine monophosphate, i.e. draw uracil hooked to ribose hooked to a phosphate at the 5' end. What other base would uracil form two hydrogen bonds with? ___________________________(3 pt.)

55. Draw 2'-deoxy-guanidine-5', 3'-diphosphate, i.e. draw guanosine hooked to deoxyribose hooked to a phosphate at its 5' end and at its 3' end. What base would guanosine form three hydrogen bonds with? ________________________________ (3 pt.)

56. List common examples of 5 proteins, 5 lipids, 5 carbohydrates, 3 nucleic acids, and 5 nucleotides? (4 pt.)

	proteins	Lipids	Carbohydrates	Nucleic acids	Nucleotides
1					
2					
3					
4					
5					

Fill in the blank. One point each

57. All scientific study begins with observations and the formation of testable ______________.
58. Elements are composed of tiny particles called _________________.
59. A _______________________ is a stable assemble of two or more atoms.
60. Since a molecule consists of a fixed number of atoms, every molecule has a characteristic molecular mass, usually called its _______________________ ______________________.
61. A neutral atom has the same number of electrons and ______________________.
62. For a given amount of heat the temperature of water increases much less than would be expected for other substances because of its high _________________ _____________________.
63. Large molecules that are composed of repeating units of small molecules are called ________________________.
64. Polymers of amino acids are called _______________________.
65. A functional group that produces terrible or unpleasant odors, such as in rotting flesh, is _________________________.
66. A molecule that consists of a nitrogen-containing aromatic ring compound, a 5-carbon sugar, and a molecule of phosphoric acid is a ___________________________.
67. A glycerol molecule with two fatty acid chains and a phosphate group is called a __________________________.
68. The joining of two smaller molecules to make a macromolecule involves the removal of a molecule of ________________________.
69. The three-dimensional arrangement of the polypeptide chains that compose the protein and involve salt bridges and disulfide bonds is the level of protein structure called the __________________________ structure.
70. Every atom except ________________ has one or more neutrons in its nucleus.
71. ___________ ______________ occurs when one atom, such as ^{14}C, is transformed into another atom, such as ^{14}N, with an accompany emission of energy.
72. The water strider skates along the surface of water due to a property of water called ___________ _____________________.
73. The chemical properties of an element are determined by the number of __________________ its atom contains.
74. The attraction between a slight positive charge on a hydrogen atom and the slight negative charge of a nearby atom is a _____________ _____________.
75. Fluidity and melting point of fatty acids are determined in part by the number of ______________ bonds
76. The highly branched polysaccharide that stores glucose in the muscle and the liver of animals is _____________________.
77. In proteins, amino acids are linked together by ________________ bonds.
78. The bonds between the units in a carbohydrate polymer are called ______________ bonds.
79. The linear arrangement of amino acids in the polypeptide chain is referred to as the _______________ structure.
80. Fatty acids with more than one carbon-carbon double bond are called ________________.
81. Cholesterol, vitamin D, and testosterone all have a multiple-ring structure (four contiguous rings) and are member so the family lipids known as _________________.
82. Carbohydrates made of two simple sugars are called __________________.
83. The covalent bond forces between the sulfur atoms of two cysteine side chains is called a ____________ bridge.
84. A(n) ____________ linkage connects the fatty acid molecule to glycerol.