Large Biological Molecules

Organic Chemistry, Hydrocarbons

Classwork

1. Organic life forms must contain atoms of which element?
2. What characteristic of carbon atoms makes it a good element to create complex organic molecules?
3. What abilities of an atom do its valence electrons determine?
4. Suppose carbon had 3 valence electrons instead of the 4. How would this change the bonding characteristics of an atom of carbon?
5. Neon, atomic number 10, is considered an inert gas, because it will not react with atoms of other elements. Briefly compare and contrast neon and carbon.
6. Compare the valence levels of the noble gases with that of carbon. What qualities of these elements are determined by the valence levels?
7. Why do double bonds not exist in a saturated hydrocarbon?
8. Suppose, theoretically, that the bonds that formed hydrocarbons were polar in nature. How would this affect the interaction between oil and water?

Homework

9. Briefly explain the importance of the number of carbon's valence electrons.
10. Knowing what you now know about the qualities and characteristics of carbon, briefly explain why, in science fiction movies, scientists search for "carbon based lifeforms" on other planets.
11. An atom of carbon readily bonds with hydrogen atoms, to form molecules called 'hydrocarbons.' Knowing what you know about chemical bonds, explain why and how carbon would bond with these hydrogen atoms.
12. What is the difference between a saturated and an unsaturated hydrocarbon?
13. What component of an unsaturated hydrocarbon creates the 'bend' in the compound?
14. Is it possible to add new atoms to an unsaturated hydrocarbon? Explain what would need to occur in order for this to take place.
15. Explain, in terms of polarity, why oil (a hydrocarbon) floats on water.
16. Imagine you are working in a lab to determine the nature of an unknown type of polymer. Through your experimentation, you denature (break down) the polymer into monomers, which happen to be amino acids. Under which group of organic polymers would you categorize your polymer? Why did you choose this group?

Carbohydrates, Polysaccharides

Classwork

17. Monosaccharides would be considered monomers of what more complex polymer group?
18. Explain how carbohydrates are structured in a 1:2:1 ratio. Which atom does each number in this ratio represent?
19. If a carbohydrate molecule contains 10 oxygen atoms, how many carbon atoms does it contain? How many hydrogen atoms does it contain?
20. Why are sugars soluble in water?
21. What are three roles for which monosaccharides are commonly used in biological function?
22. Label the components of the following reaction as either monosaccharides or disaccharides.

$$\text{Glucose} + \text{Fructose} \rightarrow \text{Sucrose} + H_2O$$

23. The basic chemical equation in question #22 is an example of what kind of a reaction?
24. Contrast the role of glycogen in humans to the role of cellulose in plants.

Homework

25. Polysaccharides can be broken down into which specific monosaccharide?
26. If a carbohydrate molecule contains 32 hydrogen atoms, how many carbon atoms does it contain?
27. In the carbohydrate represented by the following formula, replace the question mark with a viable coefficient and variable: $C_xH_?O_x$
28. Compare the role of starch in plants to the role of glycogen in animals.
29. Starch and cellulose are both polysaccaharides found in plants. How is the function of each different?
30. Related to question #29, how is the function of the polysaccharides starch and cellulose related to their individual structures?
31. Why do humans not consume cellulose to obtain energy?
32. Why do athletes commonly "carbo-load" (consume a great deal of carbohydrates) prior to a physically strenuous activity? How is this related to the functionality of polysaccharides?
33. Would you rather consume a meal of celery or potatoes the night before a marathon? Defend your answer, being sure to include what you know about the different types of carbohydrates in your response.

Nucleic Acids

Classwork

34. Name the 3 parts of a nucleotide.
35. If a nucleotide is composed of a 5-carbon sugar, how many hydrogen atoms and oxygen atoms does this sugar also contain?
36. What role does the base sequence of a series of bonded nucleotides provide for an organism?
37. Explain how RNA and DNA work like a tag team in the cell in order to complete the task of storing and expressing genetic information.
38. Which quality of a nitrogen base would you investigate by determining the number of rings present in its structure?

Homework

39. What characteristic possessed by RNA exists largely because it is a single stranded molecule, and makes it similar to proteins?
40. If adenine always pairs with thymine (or uracil) and cytosine always pairs with guanine, construct a general statement involving purines and pyrimidines to describe base pairing rules in DNA.
41. What is the appropriate scientific term for the shape of a DNA molecule?
42. Explain why DNA needs the presence of RNA for it to be a functional molecule.
43. Suppose you discover a new type of virus. Your research indicates that the molecular chemistry of the virus includes the nitrogen base *uracil*, but not *thymine*. Which nucleic acid does your research support is utilized by this virus? Why did you come to this conclusion?

Amino Acids, Proteins

Classwork

44. Briefly explain why proteins, carbohydrates and nucleic acids are considered *biomolecular* polymers.
45. Which of the three components of an amino acid is most comparable in functionality to the nitrogen base of a nucleotide?
46. Amino acids each have an H atom on one and an OH group on the other end. What type of reaction do you think could be used to effectively join two amino acids together? What is the product of this reaction?
47. Of the three major components of each amino acid (Carboxyl Group, Amine, R Group Side Chain), which would you use to distinguish between two different amino acids? Why would you choose this particular component?
48. Suppose you took two amino acids, valine and tyrosine, and switched their R-group side chain components. Would this change the identity and function of the amino acids? Why or why not?
49. What is the correct hierarchy of protein structure levels?
50. Briefly explain the importance of having the accurate primary structure for appropriate protein function.
51. The alpha helix shape and pleated sheet formation refer to which level of protein organizational structure?
52. What are two ways in which you could *denature* a protein?
53. Pick two classes of proteins and match them with their specific function.

Homework

54. Amino acids are to Proteins as Bricks are to a Wall. Briefly explain why this analogy works.
55. Compare the role of glucose in polysaccharide formation to that of amino acids in the formation of proteins.
56. Explain the role that dehydration synthesis plays in creating a peptide bond.
57. If you were to swap the carboxyl groups of proline and lysine (two amino acids), how would this impact the structure and function of each amino acid?
58. Explain how the R-Group side chain is like an identification card for each amino acid.
59. Explain how a mutation that affects the primary structure of a protein would change the polymer.
60. If you were a biomolecular biologist studying the tertiary structure of various proteins, which specific part of each amino acid would you focus on? Defend your answer.
61. Explain how the change of shape of a protein can affect its ability to complete a task in the body.
62. Why would *denaturing* a protein affect its ability to function properly?
63. Which level of protein organization involves interaction between multiple polypeptide chains?
64. Which class of proteins would a fortifying shampoo most likely include?

Lipids

Classwork

65. Do amino acids, monosaccharides and nucleotides have a comparable counterpart in lipids? Why or why not?
66. Why is it significant that cell membranes are composed of amphiphilic molecules?
67. Explain the term ‘hydrogenated,’ using its relation to saturation as a guideline.
68. If a lipid is a liquid at room temperature, it is a good assumption that this lipid: does/does not contain double bonds. Explain your answer.

69. Explain, in scientific terms, why a waxy covering may be beneficial to a plant to prevent water loss.

Homework

70. What happens when a hydrophobic molecule is exposed to water?
71. Explain why it is beneficial for a dish soap or detergent to be amphiphillic in nature.
72. Explain the role that phospholipids play in the creation of cell membranes.
73. Suppose you are analyzing an unidentified spread that has qualities of butter and margarine. How could determining whether or not the product was hydrogenated help you to identify the item?
74. Explain the change in appearance that would occur if an unsaturated fat were to be hydrogenated.
75. Why might it be a good idea to avoid trans fats in your diet if you are attempting your eating habits?
76. What type of lipid molecule includes testosterone and cholesterol?

Free Response

1. Compare and contrast the following carbohydrates glucose, starch, glycogen, and cellulose.
   a. What elements are found in all four molecules? How does the proportion of each element differ? Which molecule is a monomer and which are polymers? Explain.
   b. Why is plant fiber (cellulose) important for a healthy human diet even if it cannot be digested? Why are some forms of plant fiber used to treat digestive irregularities? Cotton contains a large amount of cellulose. Explain why the chemical structure of cotton is more ideal for clothing than starch or glycogen.

2. Compare and contrast the differences between DNA and RNA.
   a. Describe sugar phosphate arrangement of both molecules. What are the differences found in RNA and DNA? Be sure to describe the special chemical bond found in these molecules.
   b. The order of bases in DNA is known as the genetic code. Given this half of the double-stranded DNA code, what would the corresponding bases be? Give the names of the bases represented by the letters and explain your answer: ATATCGGCTTAAT
   c. Suppose a strand of RNA was to bind to this portion of DNA, what would the corresponding RNA bases be? Give the names of the bases and explain your answer.

3. Read the following passage from the National Prion Disease Center:

Human Prion Diseases

Prion diseases are also referred to as transmissible spongiform encephalopathies (TSE). They occur in humans and animals, primarily affecting the central nervous system. They can be sporadic (spontaneous), familial (genetic/inherited) or acquired (transmitted by infection). The hallmark of these diseases is the presence of microscopic vacuolization of the brain tissue, called spongiform degeneration (meaning that the tissue deteriorates, developing a spongy texture), and an abnormal protein, called scrapie prion protein (PrP^{Sc}), prion or abnormal prion protein. The PrP^{Sc}, unlike other known infectious diseases, is believed to result from a change in the conformation or shape of a normal

protein called cellular prion protein (PrP^C), which is present in large amounts in the brain as well as in other tissues. Since the abnormal prion protein cannot be broken down through the body's normal process, it aggregates mostly in the brain causing degeneration and disease. The abnormal prion protein is often infectious and, under certain conditions, can transmit the disease. Currently, there are no cures for prion diseases. The average world-wide occurrence of prion diseases is approximately one case per million people per year. (For details, see Caughey B. British Medical Bulletin. 66: 109, 2003.) http://www.cjdsurveillance.com/abouthpd.html

a. Differentiate between the "normal" prion protein and the "infectious" prion protein referred to in the passage. What structural level is affected in the "infectious" prion protein?
b. What happens to the brain of a person infected with this disease? What would be the obstacles necessary to overcome in designing a treatment or medication for this disease?

4. Dishwashing liquids are a specific type of lipid.
   a. Describe how a dishwashing liquid is able to remove a greasy food stain from a dish.
   b. Why do you think that many doctors recommend simple hand washing instead of antibacterial gels to reduce the spread of diseases? Explain how this same principle may cause dry or cracked skin by repeated hand washing.

Large Biological Molecules
Answer Key

1. Carbon
2. The fact that carbon will bond readily with many other elements makes it a good element to create complex molecules. This characteristic exists because of carbon's 4 valence electrons.
3. The valence electrons of an atom determine its bonding properties.
4. Carbon would not bond with the same types of atoms in the same way that it does having 4 valence electrons. The types of compounds formed by carbon atoms would be different.
5. Neon has a full valence level, and therefore is unlikely to bond with other atoms. Carbon needs four electrons to fill its valence level, and is thus likely to bond with other atoms.
6. The noble gases all have full valence levels. Their stability, and their bonding properties (in this case unlikelihood of bonding) are determined by their valence levels.
7. Double bonds do not exist because each carbon is bonded to four other atoms, and therefore there are no free valence electrons to form a double bond.
8. Oil and water would mix, and oil could theoretically be dissolved in water if this were the case.
9. These polymers are the molecules that make up living organisms. More literally, these are the *molecules of life*.
10. All life forms known to science contain carbon. The search for "carbon based life forms" is often used to describe the search for extraterrestrial life as we know it, which must contain carbon.
11. Hydrogen atoms have 1 valence electron. Carbon has 4 valence electrons. Each atom is likely to bond with each other in order to fill its outer shell and become more stable. Hydrogen needs 1 electron, carbon needs 4 to become stable, so carbon atoms form chains surrounded by hydrogen atoms, and both satisfy their need to become more stable.
12. A saturated hydrocarbon consists of carbon atoms that are all bonded to four other atoms. An unsaturated hydrocarbon is a compound that contains carbon atoms that are double or triple bonded to other atoms.
13. The double or triple bonds that exist in an unsaturated hydrocarbon creates the "bend" in such a compound.
14. Yes. The double bond must be broken and then a new atom is bonded to the free electron, creating a saturated hydrocarbon. Hydrogenation is an example of this.
15. The carbon-hydrogen bonds in oil are non-polar(hydrophobic), whereas water is a polar molecule. Therefore the two molecules will not mix, due to the differences in polarity.
16. You would classify the polymer as a protein, because amino acids are the monomers of proteins.
17. Carbohydrates
18. 1-Carbon; 2-Hydrogen; 1-Oxygen
19. 10 carbons; 20 hydrogens
20. Sugars have hydroxyl groups that make them soluble in water
21. Fuel to do work, raw material for carbon backbones, monomers for synthesis of longer polysaccharides
22. Glucose: Monosaccharide; Fructose: Monosaccharide; Sucrose: Disaccharide
23. Dehydration synthesis

24. While both of these are polysaccharides, glycogen is used for energy storage and release, whereas cellulose is used for structure.
25. Glucose
26. 16 Carbons
27. 2x
28. Starch stores energy in plants just as glycogen stores energy in animals.
29. Starch is more utilized for energy storage, whereas cellulose is used to create structure and provide stability for the plant.
30. Cellulose is a stronger polymer, as it contains a different bonding structure than starch. Starch, because it needs to be broken down for energy consumption, is not as strong of a molecule.
31. Humans cannot break down cellulose(fiber) because of the way in which the molecule is bonded. Therefore, it would not yield energy for humans.
32. The carbohydrates consumed are starches, which can be broken down into glucose by the body and used for energy. By eating starches before the event, athletes make sure they have energy storage to support their body through the activity
33. Potatoes. Both celery and potatoes contain carbohydrates, but potatoes contain a high percentage of starch, which can be synthesized into energy for the body, whereas celery contains cellulose, which cannot be broken down like starch and does not yield the same amount of energy.
34. The three parts of a nucleotide are a sugar which is called deoxyribose, a phosphate which is one phosphorus atom with four oxygen atoms and a nitrogenous base.
35. 10 hydrogens; 5 oxygens
36. These bases store genetic information for an organism.
37. DNA is very effective at storing genetic information. RNA is not as stable as DNA, but can accomplish tasks that DNA cannot. DNA stores information, RNA allows DNA to express this information.
38. Whether or not the nitrogen base was a purine or a pyrimidine. Purines have two rings whereas pyrimidines have one ring.
39. RNA is single stranded, and will have different shapes based on the sequence of nucleotides in the molecule, just as the shape of a protein is determined by its sequence of amino acids.
40. Purines always pair with pyrimidines. The number of purines is always equal to the number of pyrimidines in a molecule of DNA.
41. Double helix
42. Because of the structure of DNA, it is more stable than RNA, but it cannot express its information without RNA. DNA is like an archive of information, RNA expresses this information.
43. The virus uses RNA. RNA contains the nitrogen base uracil, but not thymine.
44. These polymers are the molecules that make up living organisms. More literally, these are the *molecules of life*.
45. The R-group. The nitrogen base of a nucleotide is what distinguishes it from other nucleotides, same as an R-group for an amino acid.
46. A dehydration reaction could be used to bond two amino acids together. Water is the byproduct of this reaction
47. The R-Group. The R-Group is the part that differs between amino acids. You would not be able to distinguish between amino acids by analyzing the carboxyl group or amine.
48. Yes. These amino acids are basically identical except for their R-groups. Basically, switching their R-groups is switching their identity. Glycine would now be tyrosine and tyrosine would be glycine.

49. Primary, Secondary, Tertiary, Quaternary
50. The accurate primary structure is absolutely essential. The order of amino acids is the first level of structure and determines larger structure and function of the protein. If the order of proteins is changed, sometimes just by one amino acid (sickle cell anemia), the structure and function of the entire protein may be altered.
51. Secondary structure
52. Changes in heat, ionic strength and salinity (among other things) can all denature a protein.
53. Structure: Hair, Cytoskeleton; Contractile: Muscle function; Storage: Source of amino acids; Defense: Antibodies, membrane proteins; Transport: Hemoglobin, membrane proteins; Signaling: Hormones, membrane proteins; Enzymatic: Speed of chemical reactions
54. Many amino acids are linked together to create a protein, just as many bricks are linked together to create a wall. Amino acids are the building blocks of proteins as bricks are the building blocks of a wall.
55. Many glucose molecules are bonded together to form a polysaccharide, just as many amino acids are bonded together to form a protein
56. Dehydration synthesis occurs between the hydroxyl group of one amino acid and the hydrogen atom of another, resulting in the creation of a peptide bond, joining the two amino acids together and releasing water in the process.
57. Nothing would happen. The carboxyl groups between amino acids are identical, so each amino acid would function as normal.
58. The R-group side chain is the one part that differs between the 20 amino acids. The R-group is basically the identity for each amino acid.
59. The mutation could completely change the structure and function of the polymer. The primary structure is the order of amino acids in the protein. This order determines the folding of the protein, and also the function of the protein as well.
60. You would study the R-groups of the amino acids. The R-groups determine the behavior of the polymer in its tertiary folding structure.
61. In proteins, structure determines function. The shape of a protein directly impacts its ability to complete a specific task. If even one fold or groove is altered, the entire function of the protein may be lost or changed.
62. Denaturing a protein changes its shape, and the shape of a protein determines its function.
63. Quaternary structure
64. Structural Proteins
65. Not really. While lipids are composed of smaller units, they cannot be broken down into monomers like proteins, carbohydrates and nucleic acids can.
66. Cell membranes are amphiphilic. This causes the individual components of the membrane to orient themselves in a specific, uniform way in relationship to its surroundings (water). This orientation results in the isolated environment provided by a cell membrane.
67. Hydrogenated means that a hydrogen atoms have been forced into an unsaturated fat to make it saturated.
68. Does contain double bonds. Unsaturated fats contain double bonds and are liquid at room temperature.
69. Wax is a type of lipid, thus making it nonpolar and hydrophobic. The waxy covering could function to keep water in the plant, as the polar molecules would be contained by the non-polar barrier.
70. Hydrophobic molecules repel water.

71. Dish soap is used to remove oils, such as grease from cooking utensils and kitchen ware. The hydrophobic end of the molecule will be repelled by water, but attracted to the dirt and grease. The hydrophilic end will be attracted to the water, thus allowing it to be washed away, taking the dirt/grease with it.
72. Phospholipids are the individual components of cell membranes. They have a polar head and a non-polar tail, resulting in their amphiphilic nature.
73. Margarine is created through the process of hydrogenation of corn oil. Thus, if the spread is hydrogenated, you could likely identify it as margarine.
74. Hydrogenation of an unsaturated fat turns the fat from a liquid to a solid.
75. Trans fats tend to stay in the bloodstream longer than saturated or unsaturated fats, and have been associated with health risks such as obesity, cancer and diabetes.
76. Steroids

Free Response-Answer Key

1. .

A. Carbon, hydrogen, and oxygen are found in all four molecules. Generally, carbohydrates contain equal amounts of carbon and oxygen, but double the number of hydrogen atoms. The carbons form ring shaped structures. Simple monosaccharides such as glucose are the monomers that compose polysaccharide polymers such as starch, glycogen, and cellulose.
B. Animals need roughage or fiber to push food along the intestinal tract. Because plant fiber is not digested, products containing various types of plant fiber can be used to treat digestive ailments. Even though all three polysaccharides are composed of hydrogen, oxygen, and carbon, the chemical bonds between the atoms in cellulose are more highly branched and cross-linked. This causes cellulose to be stronger. Since cellulose does not dissolve in water and is strong, fabrics composed of cotton can be washed in water several times without tearing. Starch and glycogen would dissolve in water much more readily

2.

A. Both molecules are composed of nucleotides: a five-carbon sugar, a nitrogenous base, and a phosphate group. Both molecules are arranged chemically in a “ladder” formation with the sugars and phosphates forming the “sides” and the nitrogenous bases forming the “rungs” of the ladder arrangement. DNA is a double-stranded

molecule, while RNA is usually single-stranded. The sugar found in RNA is ribose, while the sugar found in DNA is deoxyribose. Nucleotides are joined together by a special bond termed a phosphodiester bond. This bond joins the phosphate groups to the sugar molecules in a dehydration reaction.

B. The corresponding bases to complete the other half of the DNA molecule would be TATAGCCGAATTA, because thymine binds to adenine, and cytosine binds to guanine.

C. The corresponding RNA bases would be UAUAGCCGAAUUA, because uracil binds to adenine, and cytosine binds to guanine in RNA. Thymine is not used in RNA.

3. A. According to the passage, the "normal" prion protein and the "infectious" prion protein are identical in primary structure; that is they are both composed of the same amino acids in the same sequence. The difference seems to be that the "normal" protein's shape; its secondary, tertiary, or possibly quaternary structure has changed.

B. In this disease, the abnormal proteins clump together, and are not removed through normal "waste" processes. The clumps cause holes in the central nervous system. Any treatment or medication would need to differentiate between the "normal" shape and "infectious" shape. If the infectious shape would be able to be attacked, possibly the clumps could be prevented or lessened and the body's waste removal system could be activated. Also, any medication would need to be able to target the nervous system.

4. A. A dishwashing liquid is able to remove a greasy food stain from a dish because the molecules of the detergent are amphiphilic. The hydrophobic portion of the molecule is attracted to the grease in the food because it is non-polar. The hydrophilic end binds with the water carrying the bonded grease down the drain.

B. Many doctors might recommend simple hand washing instead of anti-bacterial gels because the soap binds to the particles and the act of washing will push any disease causing molecules off of the hands and down the drain. This same principle might cause dryness as the soap binds to natural oils on the skin.