Name:

4 points !

Chem 464
Biochemistry

3 points for each multiple choice problem

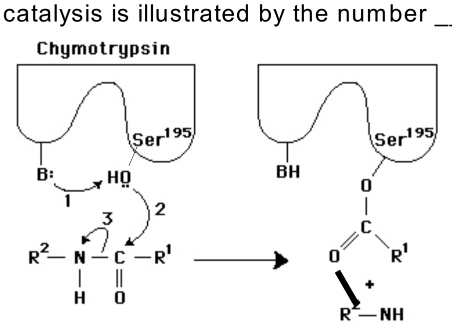
1. In the binding of oxygen to myoglobin, the relationship between the concentration of oxygen and the fraction of binding sites occupied can best be described as:
A) hyperbolic.
B) linear with a negative slope.
C) linear with a positive slope.
D) random.
E) sigmoidal.

2. An allosteric interaction between a ligand and a protein is one in which:
A) binding of a molecule to a binding site affects binding of additional molecules to the same site.
B) binding of a molecule to a binding site affects binding properties of another site on the protein.
C) binding of the ligand to the protein is covalent.
D) multiple molecules of the same ligand can bind to the same binding site.
E) two different ligands can bind to the same binding site.

3. The role of an enzyme in an enzyme-catalyzed reaction is to:
A) bind a transition state intermediate, such that it cannot be converted back to substrate.
B) ensure that all of the substrate is converted to product.
C) ensure that the product is more stable than the substrate.
D) increase the rate at which substrate is converted into product.
E) make the free-energy change for the reaction more favorable.

4. Which one of the following statements is true of enzyme catalysts?
A) Their catalytic activity is independent of pH.
B) They are generally equally active on D and L isomers of a given substrate.
C) They can increase the equilibrium constant for a given reaction by a thousand fold or more.
D) They can increase the reaction rate for a given reaction by a thousand fold or more.
E) To be effective, they must be present at the same concentration as their substrate.

5. In the following diagram of the first step in the reaction catalyzed by the protease chymotrypsin, the process of general base catalysis is illustrated by the number ________, and the process of covalent catalysis is illustrated by the number _________.



A) 1; 2
B) 1; 3
C) 2; 3
D) 2; 3
E) 3; 2

6. The steady state assumption, as applied to enzyme kinetics, implies:
A) $K_m = K_s$.
B) the enzyme is regulated.
C) the ES complex is formed and broken down at equivalent rates.
D) the K_m is equivalent to the cellular substrate concentration.
E) the maximum velocity occurs when the enzyme is saturated.

7. The double-reciprocal transformation of the Michaelis-Menten equation, also called the Lineweaver-Burk plot, is given by

$$1/V_0 = K_m/(V_{max}[S]) + 1/V_{max}.$$

To determine K_m from a double-reciprocal plot, you would:
A) multiply the reciprocal of the x-axis intercept by -1.
B) multiply the reciprocal of the y-axis intercept by -1.
C) take the reciprocal of the x-axis intercept.
D) take the reciprocal of the y-axis intercept.
E) take the x-axis intercept where $V_0 = 1/2\ V_{max}$.

8. Which of the following statements about allosteric control of enzymatic activity is *false*?
A) Allosteric effectors give rise to sigmoidal V_0 *vs.* [S] kinetic plots.
B) Allosteric proteins are generally composed of several subunits.
C) An effector may either inhibit or activate an enzyme.
D) Binding of the effector changes the conformation of the enzyme molecule.
E) Heterotropic allosteric effectors compete with substrate for binding sites.

9. To possess optical activity, a compound must be:
A) a carbohydrate.
B) a hexose.
C) asymmetric.
D) colored.
E) D-glucose.

10. Which of the following pairs is interconverted in the process of mutarotation?
A) D-glucose and D-fructose
B) D-glucose and D-galactose
C) D-glucose and D-glucosamine
D) D-glucose and L-glucose
E) α-D-glucose and β-D-glucose

11. Starch and glycogen are both polymers of:
A) fructose.
B) glucose1-phosphate.
C) sucrose.
D) α-D-glucose.
E) β-D-glucose.

12. In glycoproteins, the carbohydrate moiety is always attached through the amino acid residues:
A) asparagine, serine, or threonine.
B) aspartate or glutamate.
C) glutamine or arginine.
D) glycine, alanine, or aspartate.
E) tryptophan, aspartate, or cysteine.

13. (15 points) Discuss the 'Bohr' effect in the binding of oxygen to hemoglobin. Include as many details as possible. Do you think there is a Bohr effect for the binding of oxygen to myoglobin? Why or why not?

The Bohr effect is the effect of pH and CO_2 on the release of Oxygen from hemoglobin. H^+ can bind and several different amino acids in Hemoglobin, but the main effect comes from its binding to His 146. In the peripheral tissue, the $[H^+]$ is high, and the pH is low, and His 146 is in it's protonated form. In the protonated form His 146 forms one of the ion bridges that stabilizes the Deoxy (T) state of Hemoglobin, and this encourages the release of O_2. In the lungs, the $[H^+]$ is lower, the pH is higher, and His 146 becomes deprotonated, breaking the T state interaction helping the Hemoglobin move to the R state with high O_2 affinity. The effect of CO_2 in theBohr effect comes from the bining of CO_2 as a carbamate group at the N-terminal of each globin chain. The Carbamate ion forms an additional salt bridge that stabilizes the T state and helps lower the affinity of hemoglobin for oxygen.

There would be no Bohr effect in myoglobin, because myoglobin is a monomer, and cannot have T and R states of different oxygen affinity.

14. (10 points) The fructose in honey is mainly in the β-D-pyranose form. This sugar is about twice as sweet as glucose. The β-D-furanose form is much less sweet. The sweetness of honey gradually decreases at a high temperature. Fructose is also found in high-fructose corn syrup, where it is used for sweetening *cold* drinks, but not *hot* drinks. What chemical property of fructose would account for both of these observations.

The sweet form of fructose it the β-D pyranose, or a 6 member ring structure. The less sweet form is a β-D Furanose, or 5 member ring structure. The conversion between the two forms involves the opening of the 6 member ring hemiacetal to a straight chain, then reforming a ring with a different OH to make a 5 member hemiactetal ring, in a manner similar to the shuffling of the α and β forms of a glucose. This is a slow reaction, so heating the sugar increases the rate of reaction, and allows the sweet 6 member ring to shuffle into the less sweet 5 member form more quickly. This would also occur in hot solutions, so use of this form of fructose is only effective when the temperature of the solution is kept cold.

15. (15 points) Carbonic Anhydrase is the enzyme that catalyzes the reaction $CO_2 + H_2O \rightarrow H_2CO_3$. The mechanism for this enzyme is shown below, where Im refers to the imidazole ring of His 96, His 94 or His 119.

A. Discuss this mechanism. What kinds of catalysis are occurring in each step.

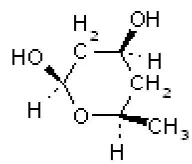
In step 1 your see an OH^- so this would be specific base catalysis. In step 2 there is a Zn^{+2} intermediate so I would call this metal ion catalysis, and I would buy it if you said there was a bond between the substrate and the Zn and the Protein for covalent catalysis. I don't see any specific king of catalysis in step 3.

B. The given mechanism is very sketchy, with no details of nearby residues and or what they are doing. Make some rational guesses as to what other amino acids might be in the active site, and how they might help this mechanism, then propose at least 2 other amino acids that you think could be in the active site, and tell me why they are there and what they are doing in your proposed mechanism. (Note: you are being graded on whether or not your guesses make chemical sense and are consistent with known physical properties of the system, **not** if they look like the 'true' mechanism.)

The first amino acid I would look for would be a + charged AA (His, Lys, or Arg) in step 2 to help stabilize the negative charge on the COO- intermediate. I would probably make this a His, with a pKa near 7 so it could change between the + state to help bind the ion, and the neutral state, so it could release the negative ion at pH 7. Other amino acids I might have in the active site would be Asn or Gln to act as H bond donors to help hold on to the CO_2, although would could also argue that CO_2 is nonpolar, and a site lined with nonpolar resides might also be useful.

16. (20 points) Take home problem, so you can have time to think and build models. You can use your text for help, but you can't discuss with the problem with another student.

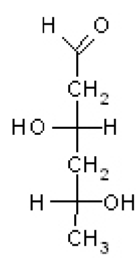
I have isolated a sugar like substance from an organism found on a meteorite. The substance has the following structure, and I have called it zehfulose



1. If possible, draw a linear structure for this compound.
2. Is this an aldose like sugar or a ketose like sugar?
3. Number the carbons in this structure using our normal conventions.
4. Show all the different epimers you could have for this linear structure.
5. Does this substance have an anomeric C ? If it has an anomeric C, then show the structure of the anomer.
6. Does this sugar have a reducing end? If so, point it out on the original structure.
7. Make two chemically reasonable disaccharides using this only sugar and name the disaccharides using standard conventions.

First step, turn the sugar around so it looks more like the normal projections we have used in class

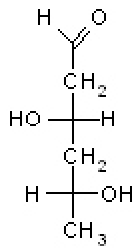
Once it is in this orientation, it should look a lot like the β form of glucose with the 2, 4, and 6 Carbons reduced to methyl or methylene groups. With that in mind, you can then make a linear form in a similar manner

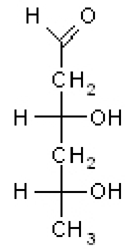


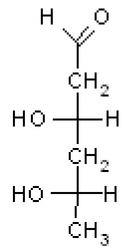
With the C=O in the 1 position ,this is an aldose, and in fact it is a D-Aldose, since the OH on the 5 C is pointed to the right.

As written the C at the top is 1, the one at the bottom is 6. In the original ring structure, the C at the far left is 1, and the CH_3 that is attached to the lower right C is 6

Epimers vary at a single asymetric C so they are:

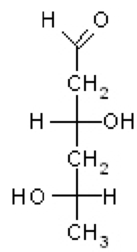




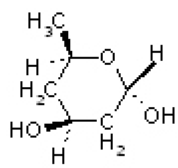


Original
D- Zephulose D-MrsZephulose L-Zephulose

I didn't ask for the diasteromer, (2 optical centers are different) but just for completeness here is L-MrsZephulose



Yes, the Aldehyde C is the anomeric carbon. So the anomer would be α-D-Zephulose



If the sugar and a free anomeric carbon, then it does have a reducing end, so the answer is yes here.

There are lot's of different ways you could make disaccarides of this sugar I would expect to see (1→5), (1→3), and (1→1) linkages and some α and β conformers around the 1 linkage.