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Midterm Examination I- Key

1. (20 pts) The changes in enthalpy and entropy during a reaction affect the energy difference between the starting materials and the products of that reaction.

a. Define the "change in enthalpy" and the "change in entropy" as if to your roommate who knows absolutely nothing about them.

The change in enthalpy represents the energy lost or gained in making or breaking bonds. The change is negative when breaking a bond, positive when making a bond. The change in entropy represents the change in the amount of order/disorder in the system during the reaction. The change is positive when the products are more disordered than the starting material, negative when they are more ordered.

b. Completely describe the changes (increase, decrease, why) in enthalpy and entropy that occur as one type of oil is mixed with another type of oil. Do they form a solution? Explain.

First we need to separate the molecules of oil from each other. Because these are non-polar molecules, there are few strong attractive forces between them and so there is little change in enthalpy here.

When we mix the molecules of the two types of oil, we make few bonds since there are few strong attractive forces between them and again there is little change in enthalpy.

However, the solution is far more disordered than the two oils separately so the entropy change is positive. Thus the energy change is negative and the solution is favored.

2. (12 pts) Compare and contrast the structures of a micelle and a vesicle (liposome).

A well labeled picture is worth a thousand words.

In a micelle, the non-polar tails of the lipid molecules all point to the center of the sphere, out of contact with water. The polar head groups all point out, creating a polar surface in contact with water. It is tightly packed, with little room inside.

In a vesicle, we have two layers of lipid in the sphere. The outer layer looks much like a micelle except that there is space for the inner layer. The inner layer molecules are reversed in orientation compared to the outer layer. Their non-polar tails point to the outside, although they contact only the non-polar tails of the outer layer. The polar head groups point in to the center, which is filled with water.

3. (20 pts) It is known that a variety of mutations in hemoglobin lead to total loss of function. The protein is unable to carry any oxygen.

a. What is meant by the term "mutation in hemoglobin"?

A mutation in hemoglobin is a change in the amino acid sequence—a change of one or more amino acids for the normal ones, or the addition or deletion of one or more amino acids.

b. Interestingly, none of these mutations was discovered through the testing of the blood of a patient who went to the doctor/hospital complaining of the symptoms of anemia. Explain.

Any embryo created with a hemoglobin with a mutation of that sort would be completely non viable and either never be born or not survive.

c. It is also true that there are many individuals who have mutations in their hemoglobin but are perfectly healthy and do not exhibit signs of anemia. Propose an explanation.

Many mutations involve the replacement of an amino acid with another amino acid that serves the same function in the protein, thus maintaining its activity. For example, the replacement of a negatively charged amino acid on the surface by another negatively charged amino acid on the surface would likely have no effect on function.

4. (8 pts) Many proteins serve to help transport charged materials into or out of the cell through the cell membrane. As one might expect, these proteins are found in the membrane, with one end protruding into the solution on the inside of the cell and the other end protruding into the solution on the outside of the cell. Why do charged materials have difficulty traveling through the cell membrane?

To get through the membrane a charged molecule would have to pass through the non-polar core of the membrane. This is very unfavorable energetically since all the ionic and hydrogen bonds that the molecule made to the water outside the membrane would be lost—enthalpy change would be very positive and that state would be very high energy and not likely. This is true even though those bonds would be remade once the molecule reached the watery other side of the membrane.

5. (21 pts) Imagine yourself to be the size of an amino acid and you are crawling around on the surface of the transport protein described in question 4.

a. You first crawl around the surface of the portion of this protein that is protruding into the solution outside the cell. Describe the type of amino acid side chains that you encounter. Explain why you see these.

You see amino acids whose side chains are polar or charged. They are in contact with water and if they were non-polar, they would force the water to form the highly ordered, low entropy clathrate structure, which is unfavorable energetically.

b. You then crawl around the surface of the portion of this protein that is inside the membrane. Describe the type of amino acid side chains that you encounter here. Explain why you see these here.

The surface of the protein in the portion that is inside the membrane is in contact with the non-polar core of the membrane. Thus we would expect to see amino acids with non-polar side chains on the surface here. Putting polar or charged amino acids here would be energetically unfavorable. This protein would probably have relatively few polar or charged amino acids and those would likely be in the core, in contact with each other to make hydrogen or ionic bonds.

6. (15 pts) Many commonly observed phenomena can be understood in terms of relatively simple chemical principles. Explain how the molecular bases of the following three phenomena are related. 1) extremely high doses of vitamins A and D are potentially more dangerous than equally high doses of Vitamin C; 2) soap and water are more effective than water alone in washing your hands after playing catch with a fatty piece of raw hamburger meat; 3) organisms at the top of the food chain are found to have much higher levels of PCBs, DDT and other toxic materials that have few if any nitrogen or oxygen atoms, than organisms much lower on the food chain.

Vitamins A and D are non polar and thus do not dissolve in water, but rather find themselves in membranes and fatty tissue. Because they are not soluble in water they are not excreted and thus continue to build up in the organism, eventually reaching toxic levels. Water-soluble vitamins are excreted and thus their levels cannot get high enough to create problems (usually).

Non-polar molecules of the hamburger fat do not dissolve in water. Their being surrounded by water would force water into the ordered, low entropy, high-energy clathrate structure. Thus they do not wash off with water. On the other hand, the core of the micelle is non polar, made up of the non-polar tails of the lipids. Non-polar fat molecules from the hamburger would find their way into the micelle. Since the micelle surface is polar, the micelle as a whole is soluble in water and is washed away.

Non polar molecules are not excreted (see first part above). Thus the lifetime ingestion of these molecules by microorganisms at the bottom of the food chain remains in the organism. These are eaten by larger organisms, which immediately collect all those molecules, and then continue to increase the levels as they eat throughout life and excrete little. At each step up the chain, the concentration increases.