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Sample Questions for the Team Round Exam

1. The WUCT Question Writing Team has realized that they are losing muscle mass because they are spending much of their time coming up with difficult questions. To combat their muscle atrophy, they have all decided to start drinking protein shakes, WASHU-MAX, containing leucine hydrochloride, a common amino acid, in supplements. It is a diprotic acid with $pKa_1 = 2.36$ and $pKa_2 = 9.60$. To make the shake, 0.500 M NaOH solution is slowly added to 50.00mL of a 0.100M leucine hydrochloride. Show all work for full credit.

a. What is the initial pH of the solution before any NaOH is added?

b. Parts i and ii relate to the titration of leucine hydrochloride to a pH of 3.50.

i) What volume of NaOH solution must be added to the leucine hydrochloride to reach a pH of 3.50?

ii) At this pH, what charge predominates on leucine ions?

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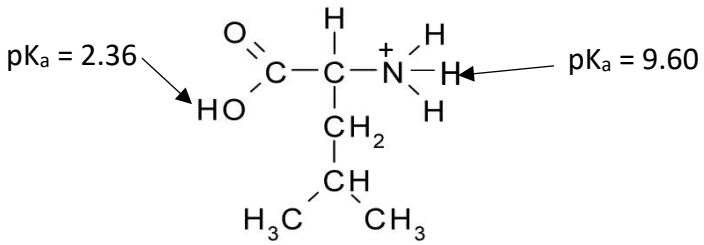
c. Since leucine hydrochloride is a diprotic acid, leucine hydrochloride will go through two deprotonation events in the course of this titration.

i) On the structure given below, circle one of the deprotonation sites.



ii) State with justification whether it is the first or second site of deprotonation.

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d. While writing this question, the WUCT questions writers decided to perform this titration in the lab. They decided to use phenolphthalein, a pH indicator, that changes from colorless to a bright pink color at the second equivalence point. However, while titrating, they overshot the equivalence point and the solution turned a bright pink color and then colorless again. **No** calculations are needed for part d.

i) Given that phenolphthalein (represented by "In") exists in the equilibrium given: $H_2In \rightarrow In^{2-} \rightarrow In(OH)^{3-}$, how might the team return the solution to the pink color they want since they cannot start over? Present one possible solution, and assume their lab professors have granted access to any chemicals that they might need.

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ii) Why do you think pH meters are used when possible, instead of chemical pH indicators?

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e. As one may expect, these chemists are not the best in the laboratory. They made some errors during their titration other than overshooting the second equivalence point. For the errors below, indicate and explain—in 2-3 sentences—how each would affect the results.

i) There was a bubble of air in the tip of the burette before the titration was started

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ii) They left a drop of NaOH hanging on the tip of the burette when they were finished.

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iii) A few drops of NaOH dripped into the burette because they left the funnel they used to fill the burette with NaOH on the top.

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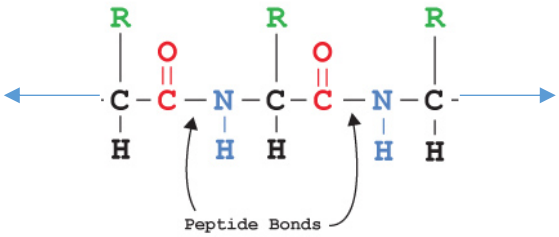
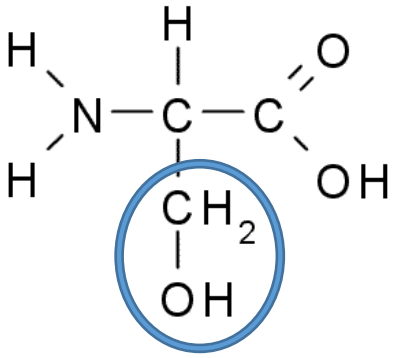
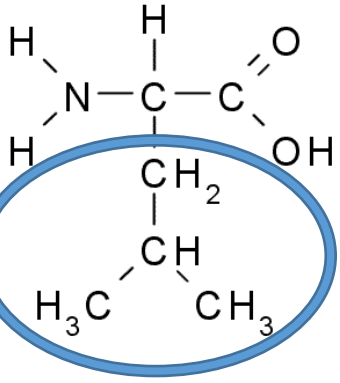
f. Pictured below is a section of a peptide chain (arrows represent a continuation of the chain). The green R's represent the side chain groups of the three amino acids in the given chain. Also given below are the structures of two amino acids, Serine and Leucine, with their side chain groups (R groups) circled.

i) If a peptide chain has a long stretch of several hundred Serine amino acids linked together, and a long stretch of several hundred Leucine amino acids linked together, identify which stretch of amino acids likely be found in a polar (e.g. aqueous) environment, and which will likely be found in a nonpolar environment. Justifications should include discussion about the circled R-groups and their properties.





Serine



Leucine

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2. *Concisely, but completely, explain the following interesting observations:*

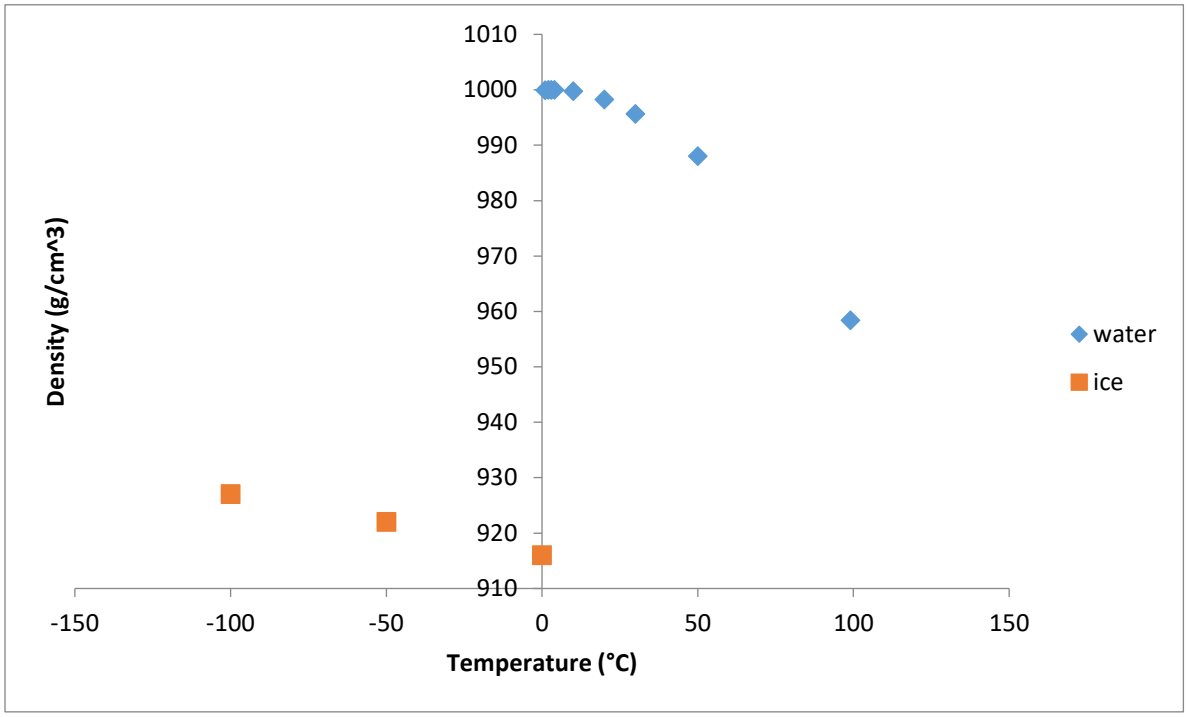

*Figure 1: Density of ice (**red squares**) and water (**blue diamonds**) as a function of temperature.*

a. As the temperature of ice increases to its melting point, a monotonic decrease in density is observed (**Figure 1**). On the other hand, as the temperature of water decreases to its freezing point, the density increases then decreases, reaching a peak density value at around 4 °C. Explanations should account for these observations at a qualitative level.

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b. Carbon dioxide sublimes at 194.7K and will not melt at atmospheric pressure (1 atm). However, when the pressure is increased to 5.12 atm, carbon dioxide will melt at 216.6 K.

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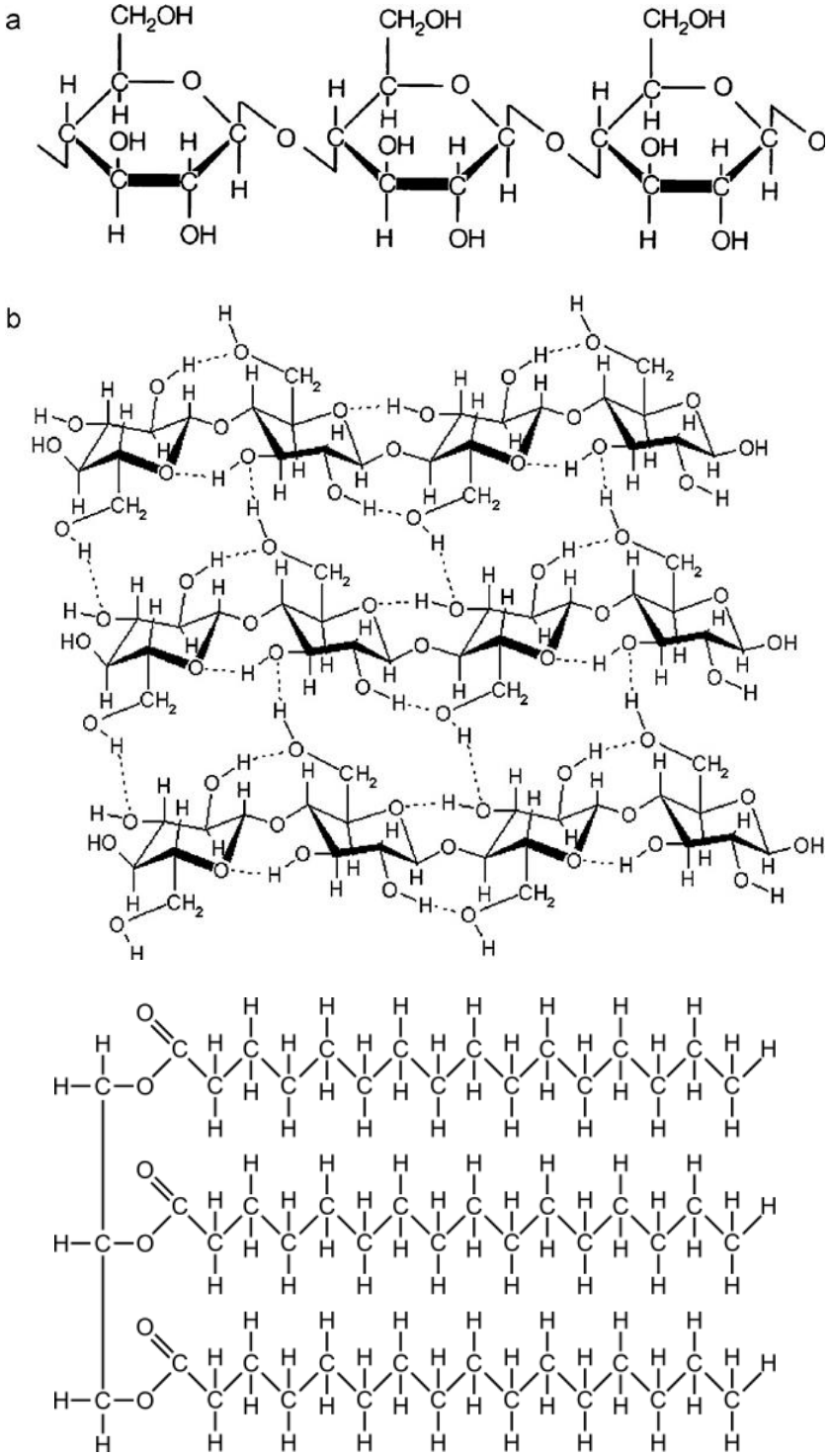

Figure 3: (a)(Top) A polymer of carbohydrates (b)(Middle) hydrogen bonding pattern of the carbohydrates that comprise paper (c)(Bottom) A triglyceride, the main component of oils. ***Note****: In (b), the carbons comprising the carbohydrate rings are not explicitly labeled but are present at the vertices of the rings.*

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Paper consists of a chain of sugars, as shown in Figure 3a and 3b. When paper is dipped in water, it loses its structural integrity (i.e. becomes “mushy”), but when it is dipped in oil, it does not. Use the information from **Figure 3** to support your explanation.

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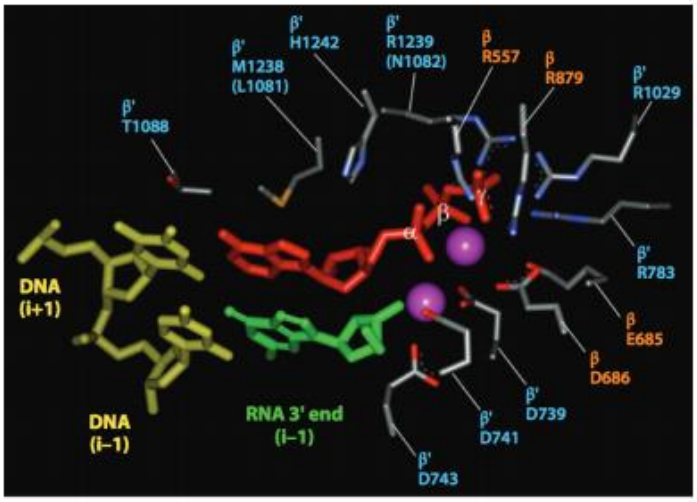
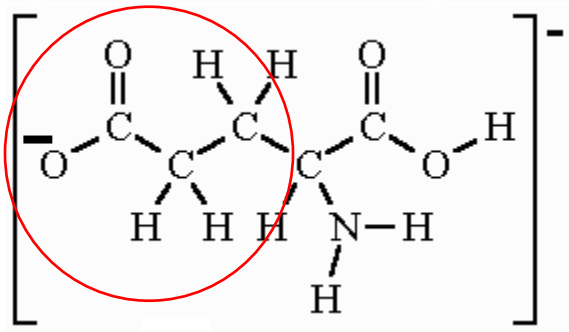
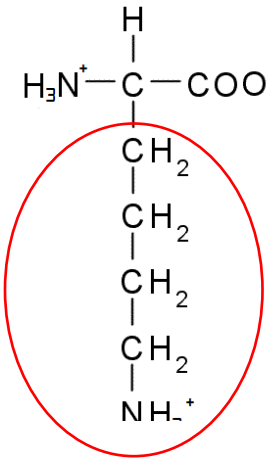




Glutamic acid



Lysine

Figure 3. The active site of RNA polymerase, an enzyme that uses DNA to synthesize ribonucleic acids, long polymers of nucleotides that are the building blocks of life. Two magnesium ions (purple spheres) occupy part of the active site and are surrounded by glutamic acids D743, D741, D739, D686. Part of each glutamic residue is drawn as a stick model, with red portions at the tip indicating oxygen atoms. For your convenience, the structures of glutamic acid and lysine are provided, and the circled parts of each molecule are the parts that interact with magnesium.

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It has been found that the magnesium ions are critical catalysts for the nucleoaddition reaction through which the RNA molecule is extended (you do not have to explain this). It has also been found that mutations that change D739 from a glutamic acid into a lysine (structure above) prevent RNA polymerase from catalyzing the reaction.

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3. A beaker contains 1 L of water in surroundings of temperature -10 °C. 30 grams of NaCl is then added to the water. Assume NaCl dissociates completely. Show all work for full credit.

a. What is the concentration in mol/L of Na^+ and Cl^- ions in the solution?

b. How much of the water will turn into ice? (K_f of water is 1.853 K*kg/mol)

c. If instead of NaCl, we add 30 grams of $CaCl_2$ how much of the water will turn into ice? Assume $CaCl_2$ dissociates completely in water.

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d. If we now drop 30 grams of $AgNO_3$ into the solution of $CaCl_2$ how much of the water will be frozen after equilibrium is reestablished? (K_{sp} for AgCl is $1.77*10^{-10}$ at 10°C, for purposes of this question you can assume it is also $1.77*10^{-10}$ at -10°C). Assume $AgNO_3$ dissociates completely in water.

e. If we now drop 30 grams of Hg_2SO_4 into the solution of $CaCl_2$, what mass (in g) of the water will be frozen after equilibrium is reestablished? (assume that K_{sp} for Hg_2Cl_2 is $1.43*10^{-18}$ at -10°C) Note: Hg_2^{2+} is a dimer and will not dissociate in water.