Biochemistry 461, Summer I, 2015, 0101  Your Name: Key
University of Maryland, College Park  Your SID #:
Biochemistry and Physiology  Prof. Jason Kahn
Exam I (100 points total)  June 12, 2015
You have 75 minutes for this exam.
Exams written in pencil or erasable ink will not be re-graded under any circumstances.
Explanations should be concise and clear. Use the extra space on the last page if you need more space.
You will need a calculator for this exam. No other study aids or materials are permitted.
Partial credit will be given, i.e., if you don’t know, guess.

\[
\Delta S_{\text{system}} - \Delta H_{\text{system}} / T \geq 0 \\
S = k \ln W \\
K_a = [H^+][A^-]/[HA] \\
R = 8.314 \text{ J/mol K} \\
\Delta G = \Delta H - T \Delta S \\
\Delta G^\circ' = -RT \ln K_{eq}' \\
\Delta G = \Delta G^\circ' + RT \ln Q
\]

Honor Pledge: At the end of the examination time, please write out the following sentence and sign it, or talk to me about it:
“I pledge on my honor that I have not given or received any unauthorized assistance on this examination.”

1. (15 pts) Thermodynamics
(a: 5 pts) What is the origin of the hydrophobic effect (at least at room temperature and below)? What is the sign of \( \Delta S \) for dissolving a nonpolar solute like octane in water?

order of a delimit cage around hydrophobes

- \( +3 \) solutes

\[ \text{This means } \Delta H \sim \text{small or } & \text{at low } \Delta S \text{ of stable cage} \]

But \( \Delta S < 0 \)

Score for the page 5
(b: 4 pts) The free energy change for a process is given by $\Delta G = \Delta G^\circ + RT \ln Q$. Why is it especially important for biochemists to be able to calculate $\Delta G$, whereas chemists are often content to just use the fact that $\Delta G^\circ = -RT \ln K$?

Biochemical reactions in the cell are seldom at equilibrium metabolite concentrations are at a steady state set by rates of irreversible reactions. So we need the actual $\Delta G = \Delta G^\circ + RT \ln Q$, where $Q \neq K$.

Chemists look at reactions in isolation and were about $K$.

(c: 6 pts) Give an example of an endothermic disordering process, specify the signs of $\Delta H$ and $\Delta S$, and describe the temperature dependence of the process.

Ice melting or protein unfolding:

+2 Energy input (endothermic) needed to break bonds.

With a resulting loss of order (increase of entropy).

$\Delta H > 0$

$\Delta S < 0$

So $\Delta G = \Delta H - T \Delta S > 0$ at low $T$ - structure is stable;

$< 0$ at high $T$ - structure is disrupted.

Score for the page: 10
2. (24 pts) Peptide Structure
(a: 12 pts) Draw the structure of the dipeptide (phospho-Y)C disulfide-linked to the dipeptide CR. Draw the predominant ionic form at pH 7. The pKa's of protonated phosphotyrosine are about 2 and 5.8. The pKa's for protonated C- and N-termini are about 3 and 8. Assume all trans peptide bonds, and give correct stereochemistry for Cα's.

(b: 12 pts) Fill in the table for the charge of the peptide above, to the nearest integer or half-integer. You do not need a calculator.

<table>
<thead>
<tr>
<th>pH</th>
<th>0</th>
<th>3</th>
<th>7</th>
<th>10</th>
<th>14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charge on peptide</td>
<td>+3</td>
<td>+1</td>
<td>-1</td>
<td>-3</td>
<td>-4</td>
</tr>
</tbody>
</table>

From your table, without doing any more calculations, specify a range for the possible pl of the peptide and give your reasoning.

Between 3 and 7 the average charge must cross 0 - near 4.5 somewhere.

Why is the pl important for protein separation procedures?

Why does the cytoplasm have to be a reducing environment?
3. (15 pts) Lipids and Carbohydrates

(a; 5 pts) Sketch the structural aspect of a lipid molecule determines whether it will form a micelle vs. a lipid bilayer. How does cis-unsaturation in the lipid chain increase membrane fluidity (or cause lipids of the same molecular weight to be liquids rather than solid)?

- Two head groups like PE, PC → bilayer
- One head group like SDS ↔ micelles

vs. prevent membrane oil from solidifying

(b; 4 pts) Give two reasons that fat packs more dietary calories per gram than carbohydrates.

- More electrons per carbon atom (ox # -2 vs. 0)
- More efficient packing because the fat don't carry non-caloric water around with them.

(c; 6 pts) What are the three functions of carbohydrates that we discussed? Name carbohydrate-containing molecules that carry out each of the three functions.

- Integration - blood group glycoproteins
- Fuel - glucose/glycogen/starch
- Structure - cellulose, proteoglycans
4. (36 pts) Secondary Structure in Proteins

(a: 4 pts) What was the point of drawing the simple lattice models for the compaction of chains into small areas (volumes)?

- When a chain is forced into a small volume, there aren't many ways to pack it—regular secondary structure emerges.

(b: 4 pts) List the two essential structural characteristics of stable secondary structures discussed in class.

- All N-hydrogen valences along the backbone are satisfied
- Any side chain can be accepted in a helix or sheet (except Pro), with preference from e.g., (a-helix)

(c: 8 pts) Draw a Newman projection for \( \psi(\Psi) = -90^\circ \), with the Co being the forward end of the bond that is going straight into the page for the Newman projection. Explain why \( \psi \) values between about \(-90^\circ\) and \(-150^\circ\) are a forbidden region of the Ramachandran diagram.

(d: 4 pts) Sketch a picture explaining the direction and structural origin of the macrodipole of the alpha helix.

Score for the page: 120
(e; 8 pts) We emphasized the idea of “sidedness” of alpha helices and beta sheets. **Why is this important in protein folding?**

- **(+)** = hydrophobic tends to face out toward the surface
- **(-)** = adds on one side of a sheet often back to form the hydrophobic core

For the two sequences below, identify which one is more likely to be two strands of a beta sheet: **2** (+) and which one is more likely to be an alpha helix: **1** (+)

**Sketch how each one exhibits sidedness – either draw a picture or add labeling to make your point.**

(1) **PELAKVARTLDQMLENLAGA**

(2) **WRFSINVDAPGLSICWKYSM**
(f; 8 pts) On the extended polypeptides below, sketch in the H-bonding pattern of the parallel beta sheet. Sketch on the picture how and why the backbone is deformed out of the plane to make the pleated sheet conformation. Label the R groups and draw in H bonds on the pleated picture at the bottom.

+3 for H-bonding between chains
+2 for idea of burying R groups
+1 for H-bond labeling

Score for the page 18
5. **(10 pts) Buffers**
(a; 2 pts) Calculate the pH for a solution of acetic acid/Na acetate composed of 50 mM HOAc and 50 mM NaOAc. The pKa of acetic acid (HOAc) is 4.75.

\[ \text{pH} = \text{pKa} + \log \left( \frac{[A^-]}{[HA]} \right) = 4.75 + \log \frac{50}{50} = 4.75 \]

(b; 3 pts) Adding 10 mM HCl will give 60 mM HOAc and 40 mM OAc\(^-\). What is the new pH?

\[ \text{pH} = 4.75 + \log \frac{60}{40} = 4.57 \quad (\Delta = -0.18) \]

(c; 2 pts) Adding an additional 31 mM HCl will give 91 mM HOAc and 9 mM NaOAc. What is the new pH?

\[ \text{pH} = 4.75 + \log \frac{91}{9} = 4.75 - 1.0048 = 3.75 \quad (\Delta = -0.52 \quad \text{for 3x more acid}) \]

(d; 3 pts) What will the pH after the addition of a further 10 mM HCl? [Hint: HCl will be in excess, which we assume will completely suppress the dissociation of HOAc.]

Net concentration of excess HCl = 1 mM

Acetate is fully protonated so does not buffer much (or contribute to additional \([H^+]\))

\[ \text{pH} = -\log (0.001 \text{ M}) = 3 \quad (\Delta = -0.75 \text{ vs. } -0.18 \text{ above}) \]