Answer question 1 or 2 (20 points)

1. (a) How many mL of 0.1 M NaOH must be added to 100 mL of 0.05 M formic acid to make a buffer solution with a pH of 4.25?
   (b) How many mL of 0.1 M sodium formate must be added to 100 mL of 0.05 M formic acid to make a buffer solution with a pH of 4.25?
   (Formic acid has a pK of 3.75.)

2. Draw the structure of the following peptide, showing all dissociable functional groups in their fully protonated form, and indicate the approximate pK of each of the dissociable functional groups:

Lys.Cys.Arg.Tyr.Glu

(a) What is the charge on the fully protonated form of the peptide?
(b) What is the charge on the fully unprotonated form of the peptide?
(c) What is the approximate pI of the peptide?
(d) What is the net charge on the peptide at pH 6.0?
3. You have isolated an octapeptide with the amino acid composition
   (Lys$_2$, Asp, Tyr, Phe, Gly, Ser, Ala)
   Reaction of the intact peptide with FDNB yields DNP-alanine. Cleavage with trypsin yields peptides
   with compositions (Lys, Ala, Ser) and (Gly, Phe, Lys) plus a dipeptide. Reaction with chymotrypsin
   releases free aspartic acid, a tetrapeptide with composition (Lys, Ser, Phe, Ala) and a tripeptide with
   composition (Gly, Lys, Tyr). What is the sequence? (Explain your reasoning).

4. Given the following data on three different proteins:

<table>
<thead>
<tr>
<th>Protein</th>
<th>hemoglobin</th>
<th>chymotrypsinogen</th>
<th>urease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molecular Weight (M)</td>
<td>64,500</td>
<td>23,250</td>
<td>482,000</td>
</tr>
<tr>
<td>Diffusion Coefficient (D)</td>
<td>6.9</td>
<td>9.5</td>
<td>3.5</td>
</tr>
<tr>
<td>Isoelectric pH (pI)</td>
<td>6.8</td>
<td>9.5</td>
<td>5.0</td>
</tr>
</tbody>
</table>

   Indicate in the blanks which of the three proteins will:

   _____________(a) Elute first from a gel filtration column.
   _____________(b) Elute first from a diethylaminoethyl cellulose ion exchange column.
   _____________(c) Have the smallest frictional coefficient (f).
   _____________(d) Migrate fastest upon electrophoresis in sodium dodecyl sulfate (SDS).
   _____________(e) Migrate fastest to the anode in an electrophoresis experiment at pH 6.0.
5. Lactate dehydrogenase catalyzes the following reaction of anaerobic glycolysis:

\[ \text{NADH} + \text{pyruvate} \rightleftharpoons \text{NAD} + \text{lactate} \]

\( \Delta G^\circ \) for this reaction as written is \(-25.2 \text{ kJ/mol} \).

(a) Calculate the equilibrium constant for the reaction. (\( R = 8.314 \text{ J/mol-K} \); \( T = 310 \text{ K} \))

(b) What would \( \Delta G \) be if the lactate/pyruvate ratio were 600 and the NAD/NADH ratio were 10?

(c) What do the letters NAD stand for?

(d) Draw the structure of NADH

6. Give the structures of seven of the following:

- maltose
- linoleic acid
- lipoic acid
- fructose
- phosphatidyl choline
- cyclic AMP
- biotin
- thymidine
Answer question 7 or 8 (20 points)

7. The mechanism of chymotrypsin illustrates several of the factors that are believed to contribute to the rate acceleration obtained by enzymes. Describe each of the following aspects of the chymotrypsin mechanism.

(a) A reaction model that shows ping-pong kinetics. (i.e., specify the identity of A, B, P, Q, E, and E', in the following scheme:)

\[
\begin{align*}
\text{(A)} & \quad \rightarrow \quad \text{EA} \\
\text{E} & \quad \rightarrow \quad \text{(E')} \\
\text{(B)} & \quad \rightarrow \quad \text{EQ} \\
\text{(Q)} & \quad \rightarrow \quad \text{E}
\end{align*}
\]

(b) Transition state stabilization by bonds formed between the enzyme and the transition state that are not found in the binding of substrate or product.

(c) Acid-base catalysis mediated through a "catalytic triad". Describe how the triad assists in the formation of the covalently bound intermediate.

(d) Substrate specificity provided by the nature of the substrate binding site. (Explain how chymotrypsin differs from trypsin in the binding site.)

8. (a) To illustrate the importance of tautomeric structure in the Watson-Crick base pairing, draw base pair structures showing how cytosine in the less stable tautomer can base pair with adenine, and how guanine in a less stable tautomer can base pair with thymine.

(b) Both the Sanger and the Maxam-Gilbert methods of sequencing DNA generate sets of nested oligodeoxynucleotide fragments, each set ending at one of the four deoxynucleotides. The fragments are then separated according to size by electrophoresis. Briefly explain how the fragments are generated in each case.

(c) DNA from a bacterial virus was analyzed and found to have the composition: 21% A, 28% G, 26% T, and 24% C. What is unusual about this composition, and what does it suggest to you about the structure of this DNA?
9. Following is an alphabetical list of the glycolytic and TCA cycle enzymes plus a few other enzymes we have discussed. Choose enzymes from this list that are described by the statements below, and place the number or numbers of the enzyme in the blank to the left of the statement. In most cases, more than one enzyme will apply. Given in parenthesis after the statement is the target number of enzymes for you to identify.

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>(1)</td>
<td>aconitase</td>
<td>(11) malate dehydrogenase</td>
</tr>
<tr>
<td>(2)</td>
<td>aldolase</td>
<td>(12) malic enzyme</td>
</tr>
<tr>
<td>(3)</td>
<td>citrate synthase</td>
<td>(13) phosphoenolpyruvate carboxykinase</td>
</tr>
<tr>
<td>(4)</td>
<td>enolase</td>
<td>(14) phosphofructokinase</td>
</tr>
<tr>
<td>(5)</td>
<td>fumarase</td>
<td>(15) phosphoglycerate mutase</td>
</tr>
<tr>
<td>(6)</td>
<td>glucose-6-phosphate isomerase (phosphoglucoisomerase)</td>
<td>(16) phosphoglycerate kinase</td>
</tr>
<tr>
<td>(7)</td>
<td>glyceraldehyde-3-phosphate dehydrogenase</td>
<td>(17) pyruvate carboxylase</td>
</tr>
<tr>
<td>(8)</td>
<td>hexokinase</td>
<td>(18) pyruvate dehydrogenase complex</td>
</tr>
<tr>
<td>(9)</td>
<td>isocitrate dehydrogenase</td>
<td>(19) pyruvate kinase</td>
</tr>
<tr>
<td>(10)</td>
<td>α-ketoglutarate dehydrogenase complex</td>
<td>(20) succinate dehydrogenase</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(21) succinyl-CoA synthetase</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(22) triose phosphate isomerase</td>
</tr>
</tbody>
</table>

(a) ________________________ CO₂ is a substrate or a product. (six enzymes)
(b) ________________________ ATP or GTP is a substrate or a product. (six enzymes)
(c) ________________________ Coenzyme A is a substrate or a product. (four enzymes)
(d) ________________________ NADH is a substrate or a product. (five enzymes)
(e) ________________________ Thiamine pyrophosphate is a prosthetic group. (two enzymes)
(f) ________________________ Possible anaplerotic reactions. (three enzymes)
(g) ________________________ An oxidoreductase (seven enzymes)
(h) ________________________ Operates removed from equilibrium (eight enzymes)