CHEM 527 FIRST EXAM FALL 2004

YOUR NAME: Key

NOTES:

1. where appropriate please show work – if in doubt show it anyway.
2. pace yourself – you may want to do the easier questions first.
3. please note the point value of questions – adjust your answers and effort accordingly.
4. some questions may have more data than you need.
5. please be brief – unfocused, rambling answers won't receive as much credit as a few short appropriate phrases.
6. Please write CLEARLY – if I cannot read it – it is wrong.
7. Please refer, as needed, to the chart below.

Properties of the amino acids found in proteins

Name	pK_a of α-Carboxyl Group	pK_a of α-Amino Group	pK_a of Ionizing Side Chain[a]
Alanine	2.3	9.7	—
Arginine	2.2	9.0	12.5
Asparagine	2.0	8.8	—
Aspartic acid	2.1	9.8	3.9
Cysteine	1.8	10.8	8.3
Glutamine	2.2	9.1	—
Glutamic acid	2.2	9.7	4.2
Glycine	2.3	9.6	—
Histidine	1.8	9.2	6.0
Isoleucine	2.4	9.7	—
Leucine	2.4	9.6	—
Lysine	2.2	9.0	10.0
Methionine	2.3	9.2	—
Phenylalanine	1.8	9.1	—
Proline	2.0	10.6	—
Serine	2.2	9.2	—
Threonine	2.6	10.4	—
Tryptophan	2.4	9.4	—
Tyrosine	2.2	9.1	10.1
Valine	2.3	9.6	—

Question 1. (21 pts.) Short problems. Show work, but most credit goes to the correct numerical answer.

a. the pH of a solution is 9.8. What is the hydroxide concentration?

[OH] = 6.3×10^{-5} M

$H^+ = 10^{-9.8} = 1.585 \times 10^{-10}$ M

$([OH^-][H^+] = 10^{-14})$ so $[OH^-] = \frac{1.58 \times 10^{-10} M}{10^{-14}}$

b. You mix 500 mL of 50 mM NaOH with 800 mL of 60 mM HCl. What is the pH of the mixture?

pH = 1.75

0.5 L of .05 M NaOH ≡ .025 moles

0.8 L .06 M HCl ≡ .048 moles

.023 moles "H"

So conc = $\frac{.023 \text{ moles}}{1.3 L}$ = .0177 M

c. You add 0.08 mol of acetic acid (pK = 4.70) in 10 mL of water to 0.03 mol of lithium acetate in 100 mL of water. What is the new pH?

pH = 4.27

$pH = pK + \log A^-/HA$

$4.7 + \log \frac{.03}{.08}$

d. A solution of 0.3 moles of a weak acid in 1 L of water showed a pH of 4.5. What is ~~the pK of~~ the acid.

pK = 8.47

$pH = 4.5 = pK + \log \frac{A^-}{HA}$ → $4.5 = pK + \log \frac{3.16 \times 10^{-5}}{0.3}$

$HA \rightleftharpoons H^+ + A^-$ so $[H^+] = [A^-]$

e. If you add 0.15 moles of sodium hydroxide to a solution of 0.2 moles of formic acid (pK=3.7) in 0.5 L what is the resulting pH?

pH = 4.17

New = .15 A^- (mol) / .05 mol HA

$pH = 3.7 + \log \frac{(.15)}{(.05)}$

f. A human phospholipase contains 8 disulfide bonds and no free cysteine side chains. How many possible combinations of disulfide-bridged phospholipase molecules exist?

16 cys so

Number = 2,027,025

$15 \times 13 \times 11 \times 9 \times 7 \times 5 \times 3 \times 1$

g. An oxygen binding protein is half-saturated ($\theta = 0.5$) at a dissolved oxygen concentration of 10 µM. What is the K_d for oxygen binding?

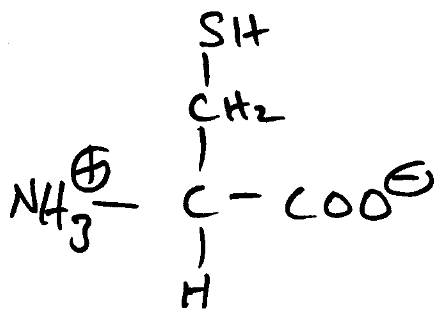
K_d = 10 µM

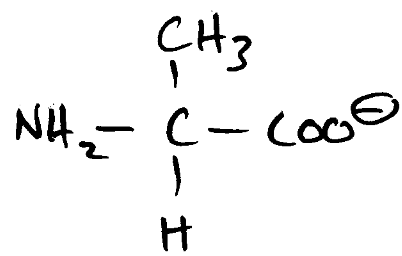
$$\theta = \frac{[O_2]}{K_D + [O_2]} \qquad 0.5 = \frac{10\mu M}{K_D + 10\mu M}$$

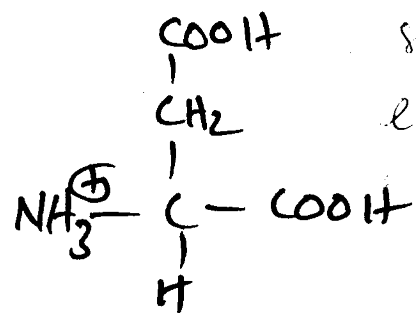
Question 2 (9 pts) Draw CLEAR structures of the following amino acids in the form that predominates at the pH indicated (refer to the list of pKs on page 1)

CYSTEINE at pH 5 | **ALANINE at pH 12** | **ASPARTIC ACID, pH 1**

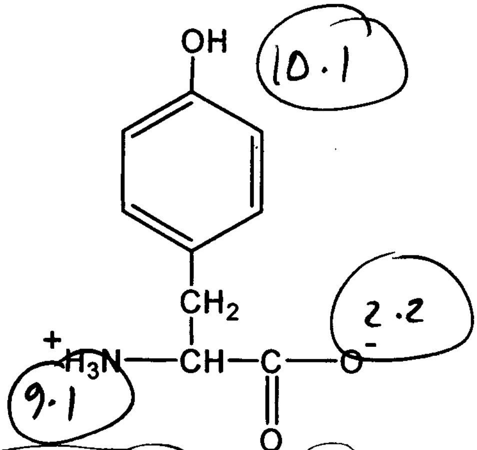
-1 each sig. error







Question 3 (8 pts) One form of tyrosine is shown at the right.
(pK 2.2, 9.1, 10.1)



a. You have 0.6 moles of tyrosine in the form shown at the right. How much KOH in moles do you need to take the original 0.6 moles to a pH of:

9.1 0.3 (2) **10.1** 0.9 (2)

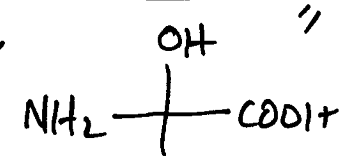
b. What is the pH of the solution of 0.6 moles of this form of tyrosine in 0.5 L of water?

pH = 5.65 (2)

c. Is there a pH value at which tyrosine would penetrate biological membranes?

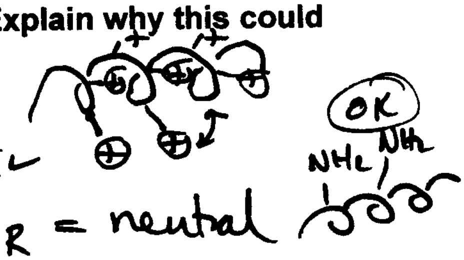
Circle either "YES" : at pH = ________ or "NO", at no pH (2)

Explain your answer:

(1) No pH at which no charges e.g. "  " etc

Question 4 (6 pts.) A peptide composed of 30 lysine residues (LYS-LYS-LYS- ... etc) is an alpha helix at pH 13 but a random, disordered, structure at pH 1. Explain why this could be.

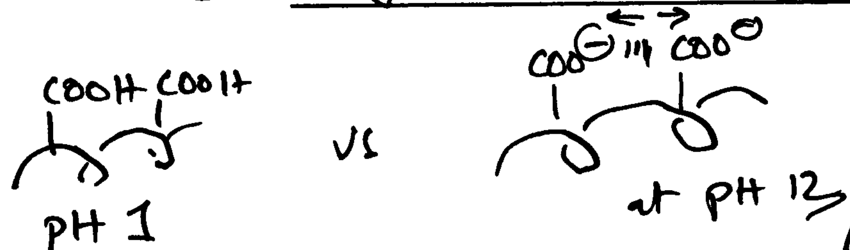
(2) Charge repulsion at pH 1 (from side chains) destabilizes α-helix. Sidechains move further apart in random. At pH 13 lys_R = neutral



What peptide would show exactly the opposite behavior. It is ...

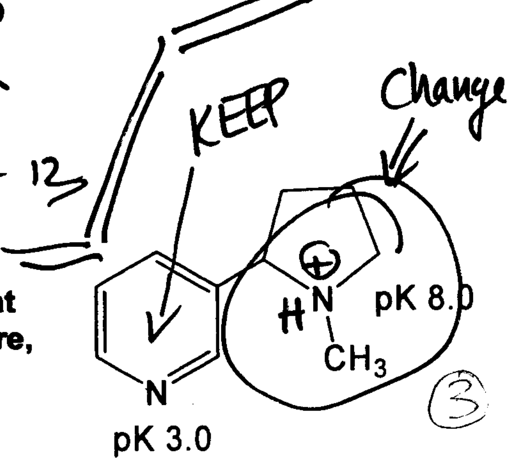
(2) poly ASP or poly GLU

Explain why:



(2)

Question 5 (6 pts). Here is the structure of nicotine – an active ingredient in tobacco. What form of nicotine will predominate at the pH of tobacco leaves (about 6). If it is the same as the figure, <u>circle it</u>, if it is different, change structure as necessary.

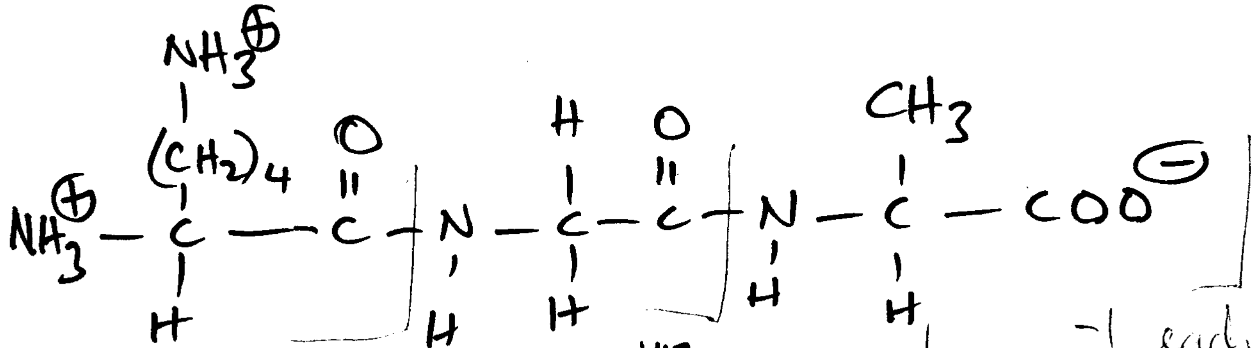


(3)

Tobacco companies treat tobacco leaves with NH_3 - they say "to improve the taste" – prior to packaging into cigarettes. Give a more reasonable answer.

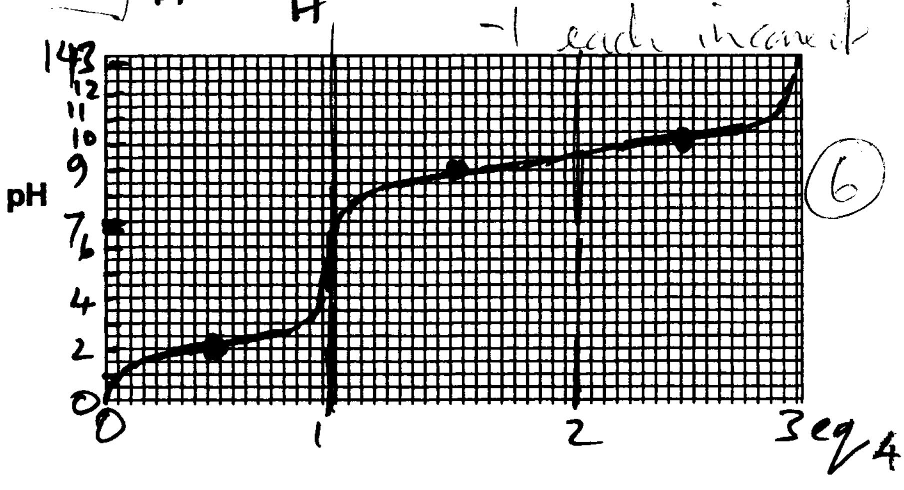
(3) NH_3 is base – will remove proton added to fig & then "neutral" nicotine more rapidly absorbed.

Question 6 (12 pts) Draw the tripeptide LYS-GLY-ALA in the form appropriate for pH 7.



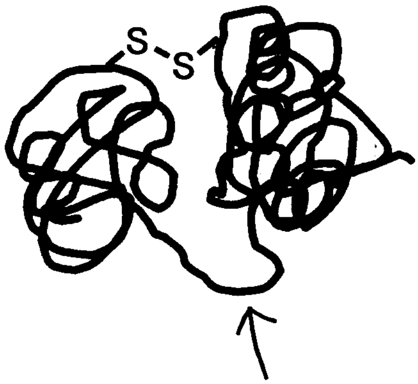
(+6)

At the right, draw an ACCURATE titration curve of this tripeptide starting with the most protonated form you could obtain at the left. Include number of equivalents and pKs etc. Where necessary, use pK values on page 1



(6)

Protein P



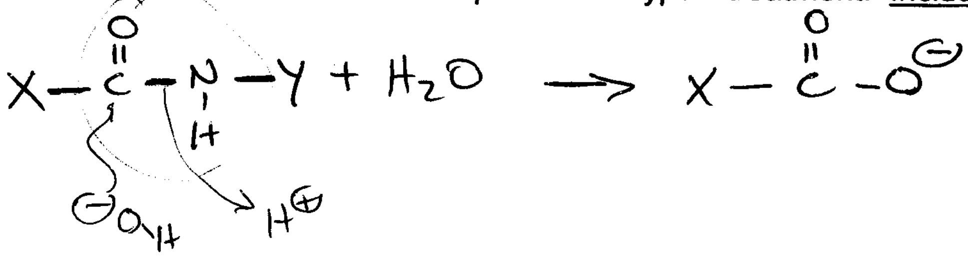
Question 7 (25 pts) The protein "P" (40,000 MW; or 40 kDa) shown to the right is a single polypeptide chain. The protein is a monomer and contains: 4 cysteine residues (2 of them in a disulfide bond as shown) and 7 ARG and 3 LYS (including a LYS at the C terminus). Edman degradation of "P" gave the following initial sequence:

MIKEY-

a. What is the **three letter** abbreviations for this sequence:

MET ILE LYS GLU TYR (1 ea) 5

b. P is dissolved in buffer alone and treated with trypsin. Draw an accurate representation of the chemical reaction that takes place with trypsin treatment. Include all relevant species.



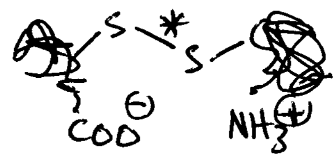
(−1 ea. [illegible]) (4)

c. Only one cleavage site occurs in 'b'. How many might you expect? # = 10 (9) (2)

and why only one? Protein is folded and so tertiary structure protects most sites from trypsin cleavage. Only one on flexible loop ↑ is susceptible (2)

d. the trypsin treated "P" was purified and subjected to very high resolution mass spectrometry. Compared to **P**, treated "P" had gained in molecular weight slightly. Explain **how is this possible**.

Pieces Remain held together w disulfide but have gained MASS OF ONE H_2O (3)



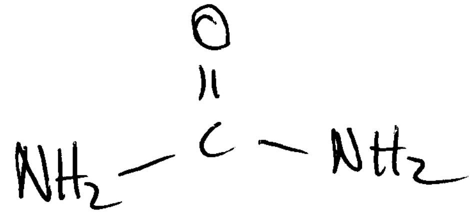
f. treated **'P'** (as in step b) is then exposed to 2-mercaptoethanol (sometimes called β-ME). **Draw the structure of 2-ME.**

H–O–CH2–CH2–SH (2) HO SH

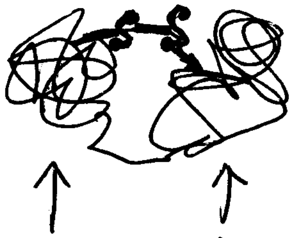
Then, two fragments of treated **'P'** were obtained (of approximately 18 and 22 kDa). **Why?**

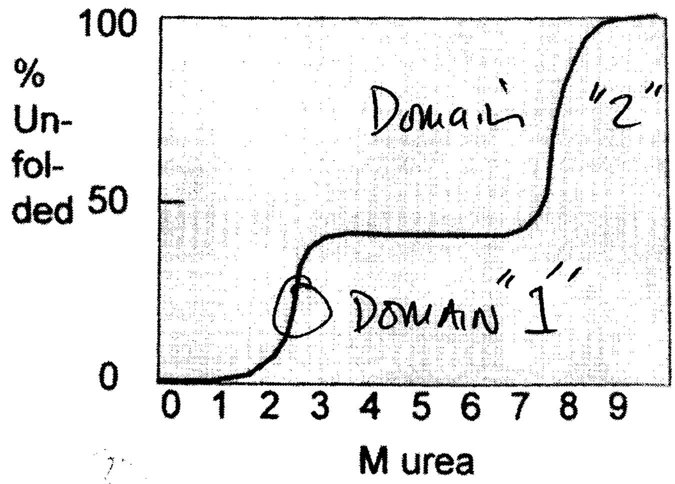
Now disulfide redⁿ (*) releases 2 fragments which add up to ~ 40 kDa (2)

g. Samples of the **original 'P'** were dissolved in increasing concentrations of urea. **Draw the structure of urea:**



The degree of unfolding of the protein was then determined and gave the result shown in the diagram. **Give a short explanation of the behavior of the curve in light of lecture material.**





2 Domains denature independently & at different urea conc.

Question 8 (6 pts.) Proteins A-E show the following pI values:

A = 4.15 B = 6.20 C= 7.50 D= 7.50 E= 8.95

During ion exchange chromatography at pH 7.50

i. which protein will elute fastest on anion exchange E

ii. which protein will elute slowest on anion exchange A

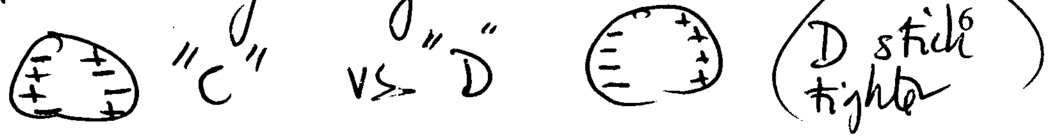
iii. which protein will elute fastest on cation exchange A

iv. which protein will elute slowest on cation exchange E

Protein C elutes much faster than protein D on anion exchange at pH 7.50. Suggest a simple reason for this:

Both proteins have zero net charge. One might have different distribution of charges

e.g



Question 9 (7 pts.) Fill in the blanks with not more than 3 legible words.

accept NMR

a. a technique for determining 3D structure of proteins X-ray crystallography (CRYSTALLOGRAPHY)

b. a method for visualizing complex protein mixtures in proteomics 2-D GELS / 2 dimensional SDS-PAGE

c. oxygen is always bound **directly** to____
in all oxygen-binding proteins (worms to humans) METAL IONS

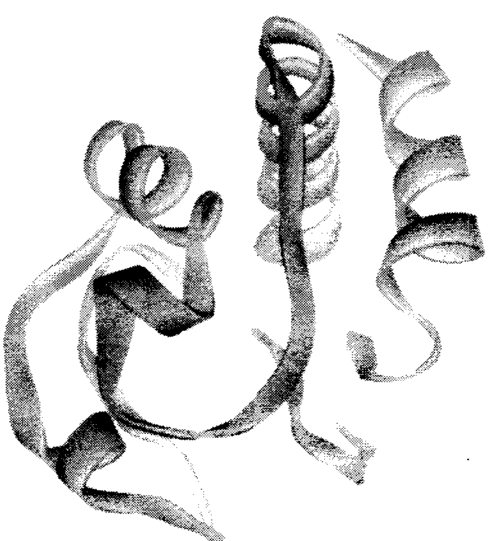
d. these catalysts aid folding of large proteins CHAPERONES FOLDASES

e. every third amino acid in collagen is almost always GLYCINE

f. In one collagen disease, the amino acid in **e** is replaced by a SERINE

zz. the word that best describes this exam OVER

Tea



the end