Practice questions and explanations

BIOS 1006

Week 1

Lecture 1: Fundamentals

Functional groups

Question 1: Naming

__________ __________ __________ __________ __________ __________ __________

Answers:

$\boxed{\text{alkyl, hydroxyl, thiol, carbonyl, carboxyl, amino, phosphate}}$

Question 2: Roles of functional groups

1. Amino acids and proteins have $\boxed{\text{amino}}$ groups & $\boxed{\text{carboxyl}}$ groups.
2. Carbohydrates tend to have an abundance of $\boxed{\text{hydroxyl}}$ groups and $\boxed{\text{ether}}$ linkages.
3. Lipids vary greatly in structure, but fatty acids typically have $\boxed{\text{alkyl}}$ groups.
4. Each nucleotide in a nucleic acid molecule has $\boxed{\text{phosphodiester}}$ linkages.

pH and pKa

Question 3: ICE tables and Henderson-Hasselbalch equation

You make a 0.2 M aqueous solution of propionic acid CH_3CH_2COOH by dissolving an appropriate amount of propionic acid in water. The pH of the resulting solution is 4.88. What is the pKa of propionic acid?

$$CH_3COOH \rightleftharpoons CH_3COO^- + H^+$$

Set up the ICE table:

	$[CH_3COOH]$	$[CH_3COO-]$	$[H^+]$
Initial	0.2	O	O
Change	-x	+x	+x
Equilibrium	0.2-x	+x	+x

Given that the concentration of H^+ is equal to x, we can undo the logarithm to find $[H^+]$:

$$\begin{aligned} \mathrm{pH} &= -\log[\mathrm{H}^+] \\ 4.88 &= -\log[\mathrm{H}^+] \\ [\mathrm{H}^+] &= 1.32 \times 10^{-5}\ \mathrm{M} \end{aligned}$$

Now plug this into the Henderson-Hasselbalch equation:

$$\begin{aligned} 4.88 &= pK_a + \log\left(\frac{1.32 \times 10^{-5}}{0.2 - 1.32 \times 10^{-5}}\right) \\ 4.88 &= pK_a + \log(6.6 \times 10^{-5}) \\ 4.88 &= pK_a - 4.18 \\ pK_a &= 4.88 + 4.18 \\ pK_a &= \boxed{9.06} \end{aligned}$$

Lecture 2: Amino acids and peptides

Question 4: Amino acid chemical properties

Which amino acid side chains are ionizable? YECDHKR

Which amino acid has no chiral center? G

Which amino acids have hydrophobic (nonpolar) side chains? AVLIGMPFWY

Which amino acid side chain has an amino group? K

Which amino acids have basic functional groups? RHK

pI

Question 5: Calculating pI of a peptide

A tripeptide formed from tyrosine, valine, and glycine, in the order as stated. Use the following pKa values: α-COOH = 2.2, α-NH_3^+ = 9.4, tyrosine side chain OH = 10.5.

(a) Draw the tripeptide and clearly label where the N-terminus and C-terminus are at pH 7.

$$\text{(N-term) } NH_3^+ - \text{Tyr} - \text{Val} - \text{Gly} - \text{COOH (C-term)}$$

(b) Calculate the charge of this tripeptide at pH 7.

Compare pKa and pH of each ionizable group:

N-term pKa 9.4 > pH 7 $\rightarrow$ protonated, charge = +1

C-term pKa 2.2 < pH 7 $\rightarrow$ deprotonated, charge = -1

Tyrosine side chain pKa 10.5 > pH 7 $\rightarrow$ protonated, charge = 0 (protonated form, -OH, carries neutral charge)

$\boxed{\text{Overall charge: 0}}$

(c) Calculate the pI of this tripeptide at pH 7.

Order all the pKa values:

C-term 2.2
N-term 9.4
Tyr 10.5

Always assume full protonation at the beginning (pH < pKa). When the molecule is fully protonated, the overall charge is +1 (neutral C-terminus and tyrosine, positive N-terminus). As the pH increases, the C-term deprotonates first (pKa 2.2), then the N-term (pKa 9.4), and finally the side chain of tyrosine (pKa 10.5). The pI is the average of the two pKa values that surround the zero charge state.

+1
C-term 2.2
0
N-term 9.4
-1
Tyr 10.5
-2

The flanking pKas at charge 0 are 2.2 and 9.4.

$$\frac{2.2 + 9.4}{2} = 5.8$$

The pKa at pH 7 of the peptide is $\boxed{5.8}$.

(d) Will you be able to use UV light absorbance at 280 nm to detect your tripeptide? Why or why not?

$\boxed{\text{Yes, because the tripeptide contains a tyrosine side chain}}$, which has a phenolic ring that absorbs UV light at 280 nm. The other two amino acids (valine and glycine) do not absorb UV light at this wavelength.