Practice questions and explanations

BIOS 1006

Week 1

Lecture 1: Fundamentals

Functional groups

Question 1: Naming

Answers:

methyl, hydroxyl, thiol, carbonyl, carboxyl, amino, phosphate

Question 2: Roles of functional groups

1. Amino acids and proteins have amine groups & carboxyl groups.
2. Carbohydrates tend to have an abundance of hydroxyl groups and glycosidic linkages.
3. Lipids vary greatly in structure, but fatty acids typically have carboxyl groups.
4. Each nucleotide in a nucleic acid molecule has 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 $[H^+]$:

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

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)

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.