Worksheet – Proteins

Proteins are polymers of amino acids, joined by amide linkages. These are also called peptide bonds. A dipeptide is shown below. It was formed in a condensation reaction between phenylalanine and valine, so it would be abbreviated as Phe-Val.

The unreacted amine is called the N-terminus and phenylalanine is amino acid-1 in this sequence. The unreacted carboxylic acid on valine is called the C-terminus, which marks the end of this dipeptide.

The primary structure of proteins is simply the sequence of the amino acids in its structure.

1. Calculate the isoelectric point of Phe-Val, using the pKₐ values given at the end of the worksheet.
   a) pKₐ α-NH₃ of Phe = 9.24  pKₐ α-COOH of Phe = 2.58
   b) Which of these pKₐ values are needed?
   c) initial charge = +1
   d) isoelectric point = \( \frac{9.24 + 2.29}{2} = 5.77 \)

2. Draw the structure of Gly-His-Ala
   a. Label the pKa values the will determine the isoelectric point.
      b. initial charge = +2
      c. isoelectric point = 7.94
The **secondary structure** of proteins is formed by H-bonds between the \( \text{N-H} \) (donor) and \( \text{C=O} \) (acceptor) groups of the amide linkages between amino acids.

3. Label the H-bond donors (\( \delta^+ \)) and acceptors (\( \delta^- \)) used in the secondary structure of the following tripeptide, Ile-Thr-Pro.

   ![Chemical Structure](image)

   a) \# donors = 1
   
   b) \# acceptors = 3

   c) Which of these amino acids can only participate in one H-bond?

   ![Diagram](image)

   In the amide linkage, both the \( \text{C=O} \) and \( \text{C-N} \) bonds behave like double bonds. This means that the \( \text{O} \) (acceptor) and \( \text{H} \) (donor) are always trans to each other.

There are two main types of secondary structure, **\( \alpha \)-helices** and **\( \beta \)-sheets**. In the **\( \alpha \)-helices**, each \( \text{C=O} \) is hydrogen bonded to the \( \text{N-H} \) four amino acids away. These figures represent a 12 amino acid (all alanine \( \text{R} = \text{CH}_3 \)) \( \alpha \)-helix, viewed from the side and top. The \( \text{H} \) are not shown, for simplicity. Notice that the \( \text{R} \)-groups are directed away from the core of the helix.

The structure below is **\( \beta \)-sheet**. Two extended strands of the polypeptide are H-bonded in a side-by-side pattern. The amino acids H-bonded can be very far apart from each other in the primary structure.

d) Draw in the H-bonds in the **\( \beta \)-sheet**.
The **tertiary structure** of proteins involves the interaction of the R-groups. This is governed by the IMF of the side chains. The **non-polar** side chains will interact via LDF. These are also called **hydrophobic** interactions, since these groups can not interact with water. For this reason, they are usually buried in the interior of proteins, away from water. They can be disrupted by the addition of detergent.

The **polar** side chains interact via H bonding since they are all amines, alcohols or amides. H-bonding solvents will disrupt these interactions.

The polar amino acid cysteine has a sulfhydryl group (S – H) which can undergo a redox reaction. The S – H form is the reduced amino acid. It can be oxidized to form S – S bonds, disulfide linkages. Oxidizing and reducing agents will disrupt these interactions.

The **charged** side chains are organic acids and bases which carry pull charges. They interact via ion-ion interactions, called **salt bridges**. These interactions can be disrupted by changing the pH.

4. Show below is a polypeptide comprised of 3 α-helices and 5 β-sheets joined by random coil. Characterize the forces that stabilize the tertiary structure and draw the interacting side chains.

   a) Arg Asp
   
   b) Val Phe
   
   c) Ser Tyr
   
   d) Cys Cys
   
   e) What does Pro do?

   f) Changing the pH would disrupt which interaction?

   g) Adding ethanol would disrupt which interaction?