Fundamentals of Organic Chemistry

CHEM 109

For Students of Health Colleges

Credit hrs.: (2+1)

King Saud University

College of Science, Chemistry Department

Sources, Classification and Structure of Amino Acids

- **Proteins** are naturally occurring polymers composed of amino acid units joined one to another by amide (or peptide) bonds.

  Example, animal hair and muscle, egg whites, and hemoglobin are all proteins.

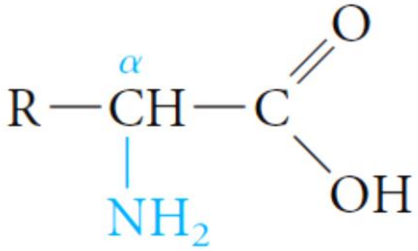
- **Peptides** are oligomers of amino acids that play important roles in many biological processes.

  Example, the peptide hormone insulin controls our blood sugar levels.

- **Proteins, peptides, and amino acids** are essential to the structure, function, and reproduction of living matter.

Sources, Classification and Structure of Amino Acids

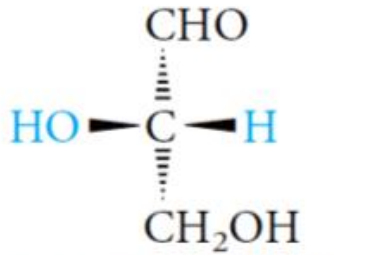
- **The amino acids** obtained from protein hydrolysis are α-amino acids.
- **The amino group** is on the **α -carbon atom**, the one adjacent to the carboxyl group.



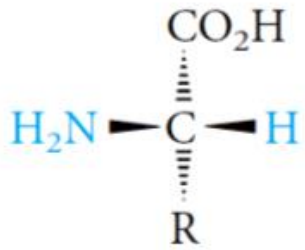
an α-amino acid

- With the exception of glycine, where R = H, a-amino acids have a **stereogenic center at the α -carbon**.
- All except glycine are therefore **optically active**.
- They have the **L-configuration** relative to glyceraldehyde .
- **Note that the Fischer convention**, used with carbohydrates, is also applied to amino acids.

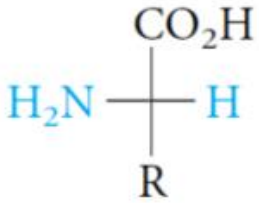
Sources, Classification and Structure of Amino Acids



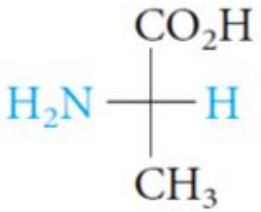
L-(−)-glyceraldehyde



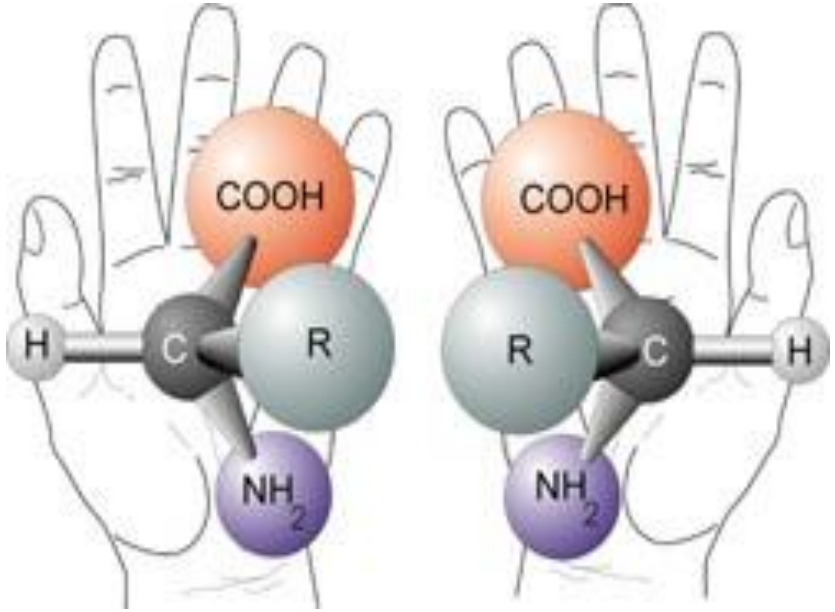
a naturally occurring L-amino acid



Fischer projection formula of an L-amino acid



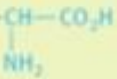
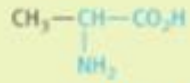
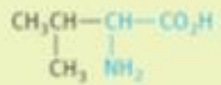
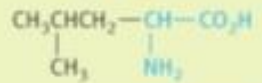
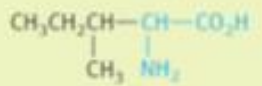
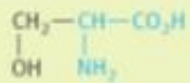
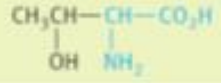
L-(+)-alanine



Sources, Classification and Structure of Amino Acids

List of the 20 α-amino acids commonly found in proteins.

Names and Formulas of the Common Amino Acids

Name	Three-letter abbreviation (isoelectric point) one-letter abbreviation	Formula	R
A. One amino group and one carboxyl group			
1. glycine	Gly (6.0) G		
2. alanine	Ala (6.0) A		
3. valine	Val (6.0) V		R is hydrogen or an alkyl group.
4. leucine	Leu (6.0) L		
5. isoleucine	Ile (6.0) I		
6. serine	Ser (5.7) S		
7. threonine	Thr (5.6) T		R contains an alcohol function.

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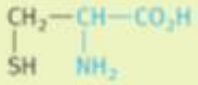
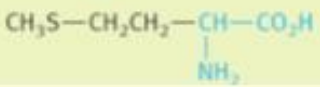
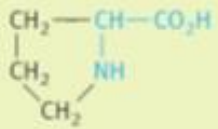
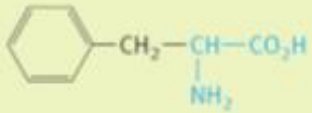
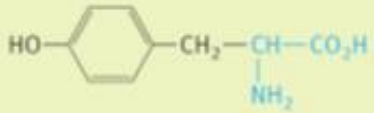
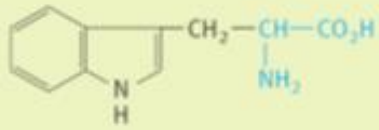
Sources, Classification and Structure of Amino Acids

Names and Formulas of the Common Amino Acids

Name	Three-letter abbreviation (isoelectric point) one-letter abbreviation	Formula	R
8. cysteine	Cys (5.0) C		
9. methionine	Met (5.7) M		R contains sulfur.
10. proline	Pro (6.3) P		The amino group is secondary and part of a ring.
11. phenylalanine	Phe (5.5) F		
12. tyrosine	Tyr (5.7) Y		One hydrogen in alanine is replaced by an aromatic or heteroaromatic (indole) ring.
13. tryptophan	Trp (5.9) W		

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Sources, Classification and Structure of Amino Acids

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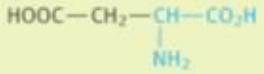
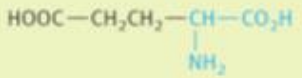
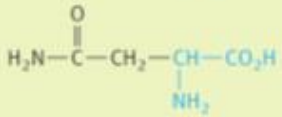
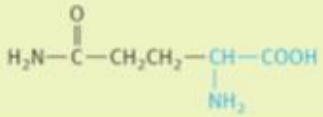
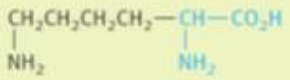
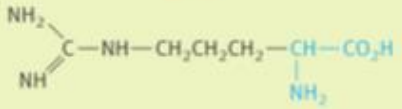
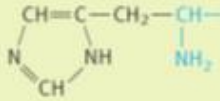
Name	Three-letter abbreviation (isoelectric point) one-letter abbreviation	Formula	R
B. One amino group and two carboxyl groups			
14. aspartic acid	Asp (3.0) D		
15. glutamic acid	Glu (3.2) E		
16. asparagine	Asn (5.4) N		
17. glutamine	Gln (5.7) Q		
C. One carboxyl group and two basic groups			
18. lysine	Lys (9.7) K		The second basic group is a primary amine, a guanidine, or an imidazole.
19. arginine	Arg (10.8) R		
20. histidine	His (7.6) H		

Sources, Classification and Structure of Amino Acids

- **The amino acids** are known by common names.
- Each also has a **three-letter abbreviation** based on this name, which is used when writing the formulas of peptides, and a one-letter abbreviation used to describe the amino acid sequence in a protein.

Sources, Classification and Structure of Amino Acids

- **The amino acids are classified into:**

  - **Essential amino acids**

    Eight amino cannot be synthesized by adult humans and therefore must be included in the diet in the form of proteins.

    e.g. Valine, Leucine, Isoleucine, Threonine, Methionine, Phenylalanine, Tryptophan, and Lysine.

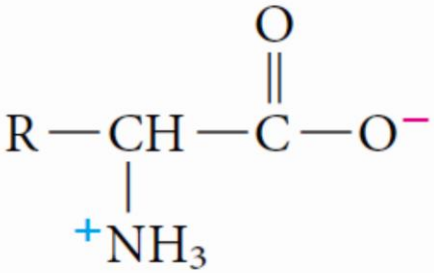
  - **Non-essential amino acids**

    Twelve amino acids can be synthesized in the body from other foods.

    e.g. Glycine, Alanine, Serine, Cysteine, Proline, Tyrosine, Aspartic acid, Glutamic acid, Asparagine, Glutamine, Arginine, and Histidine.

The Acid–Base Properties of Amino Acids

- The **carboxylic acid and amine functional groups** are *simultaneously* present in amino acids, and we might ask whether they are mutually compatible since one group is acidic and the other is basic.
- **Amino acids** with one amino group and one carboxyl group are better represented by a dipolar ion structure.

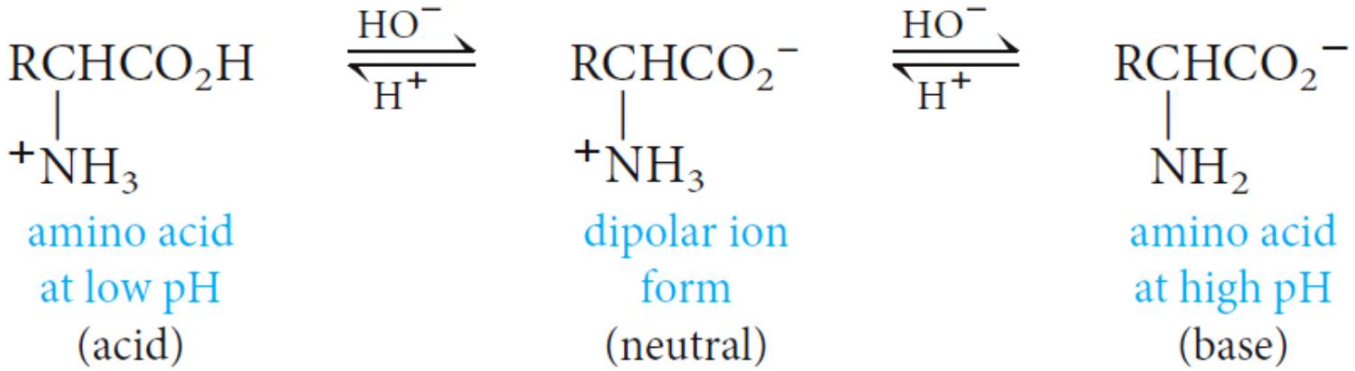


dipolar structure of an α-amino acid

The Acid–Base Properties of Amino Acids

- The **amino group** is protonated and present as an ammonium ion, whereas the carboxyl group has lost its proton and is present as a carboxylate anion.
- This **dipolar structure** is consistent with the salt-like properties of amino acids, which have rather high melting points and relatively low solubility in organic solvents.
- **Amino acids are *amphoteric*.**

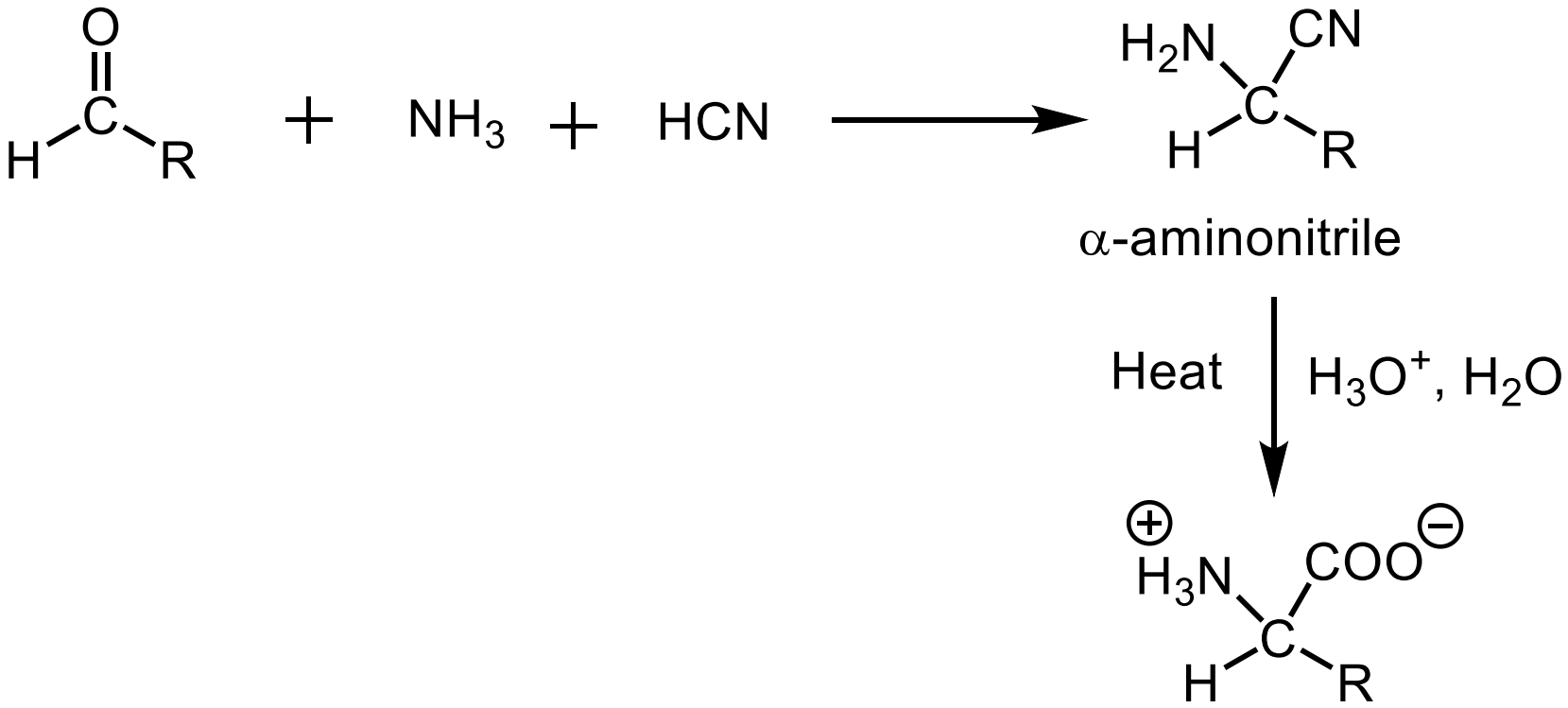
  They can behave as acids and donate a proton to a strong base, or they can behave as bases and accept a proton from a strong acid.



- The **isoelectric point (pI)**, the amino acid will be dipolar and have a net charge of zero.

Synthesis of Amino Acids

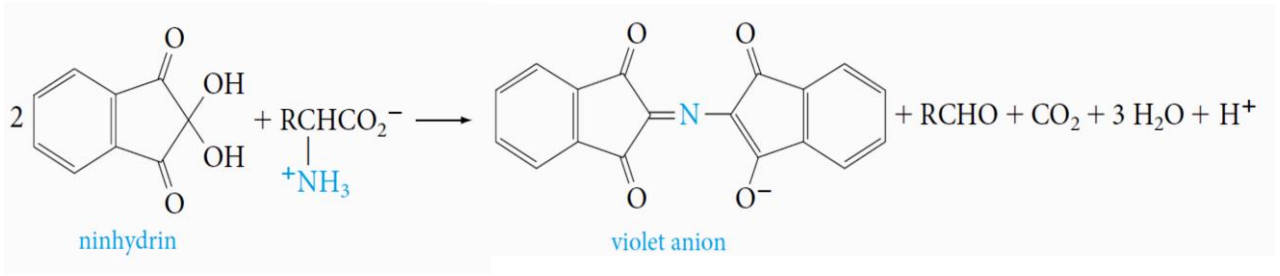
Strecker Synthesis: **Recall reductive amination and Cyanohydrin formation.**



Reactions of Amino Acids

1) The Ninhydrin Reaction

- **Ninhydrin** is a useful reagent for detecting amino acids and determining the concentrations of their solutions.
  - *Ninhydrin is the hydrate of a cyclic triketone, and when it reacts with an amino acid, a violet dye is produced.*

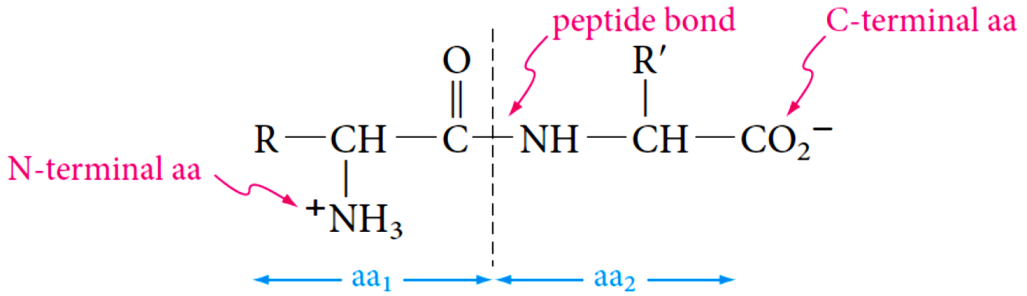


- Only the **nitrogen atom of the violet dye** comes from the amino acid (primary amino group); the rest of the amino acid is converted to an aldehyde and carbon dioxide.
- **Only proline**, which has a secondary amino group, reacts differently to give a **yellow dye**, but this, too, can be used for analysis.

2) Formation of an amide linkage
(The peptide bond: Proteins)

Reactions of Amino Acids

- **Amino acids** are linked in **peptides and proteins** by an amide bond (***peptide bond***) between the carboxyl group of one amino acid and the α-amino group of another amino acid.
- A molecule containing only *two* amino acids (the shorthand aa is used for amino acid) joined in this way is a **dipeptide**:

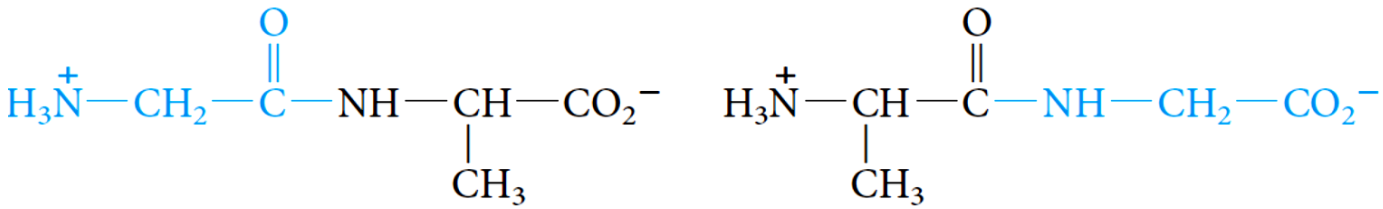


- By convention, the **peptide bond** is written with the amino acid having a free $^{+}NH_3$ group at the left and the amino acid with a free CO_2^- group at the right.
- These amino acids are called, respectively, the **N-terminal amino** acid and the **C-terminal** amino acid.

2) Formation of an amide linkage
(The peptide bond: Proteins)

Reactions of Amino Acids

- We often write the formulas for peptides in a kind of shorthand by simply linking the **three-letter abbreviations for each amino acid**, *starting with the N-terminal one at the left.*
- **For example;** glycylalanine is Gly—Ala, and alanylglycine is Ala—Gly.



Structure of Proteins

- **Proteins** are biopolymers composed of many amino acids connected to one another through amide (peptide) bonds.
- Some **proteins** are major components of structural tissue (muscle, skin, nails, and hair).
- Others transport molecules from one part of a living system to another.

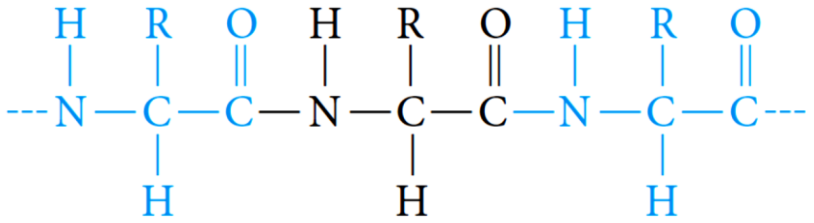
- **The main features of peptide and protein structure.**
  - ***Primary structure;***

    How many amino acids are present and what their sequence is in the peptide or protein chain.
  - ***Secondary, tertiary, and quaternary structures;***

    Three-dimensional aspects of peptide and protein structure, usually referred to as their.

The Primary Structure of Proteins

- The **backbone of proteins** is a repeating sequence of one nitrogen and two carbon atoms.



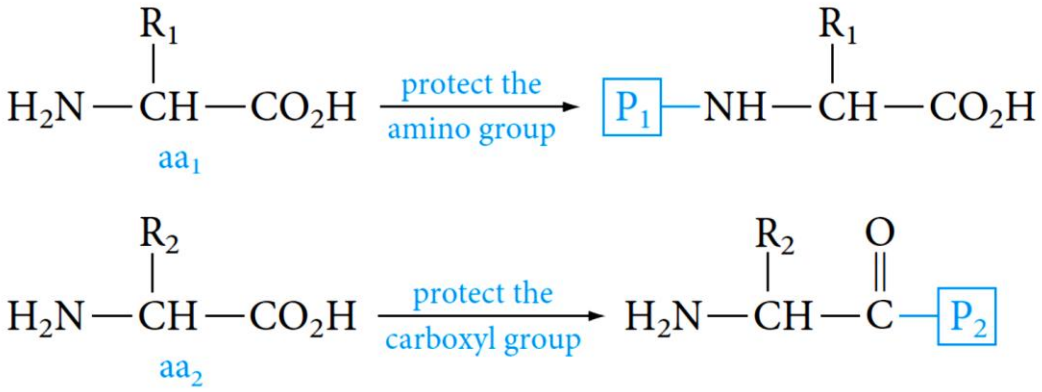
protein chain, showing amino acids linked by amide bonds

- **Peptides and proteins** can be hydrolyzed to their amino acid components by heating with 6 M HCl.
- An instrument called an **amino acid analyzer** is used to determine the amino acids mixture.

Peptide Synthesis

- Many methods have been developed to link amino acids in a controlled manner.

  To link the carboxyl group of one amino acid to the amino group of a second amino acid, we must first prepare each compound by protecting the amino group of the first and the carboxyl group of the second.



Peptide Synthesis

- In this way, we can control the linking of the two amino acids so that the carboxyl group of aa_1 combines with the amino group of aa_2.