



# Fundamentals of Organic Chemistry

**CHEM 109**

*For Students of Health Colleges*

Credit hrs.: (2+1)

*King Saud University*

**College of Science, Chemistry Department**

**CHEM 109**

**CHAPTER 9. AMINO ACIDS, PEPTIDES AND PROTEINS**

# Sources, Classification and Structure of Amino Acids



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- **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.

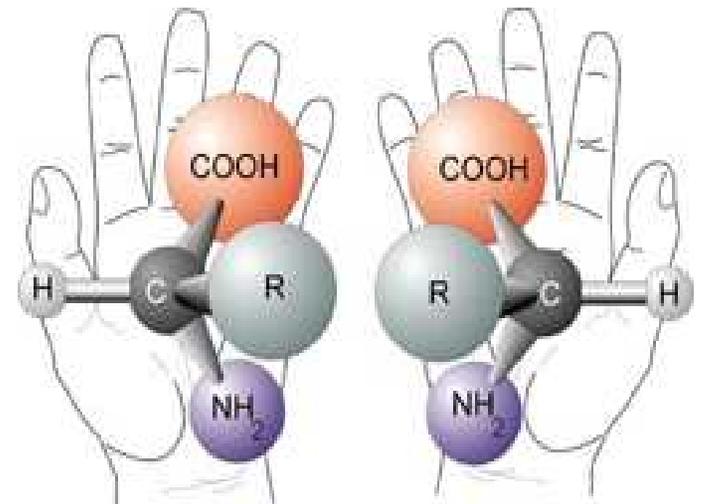
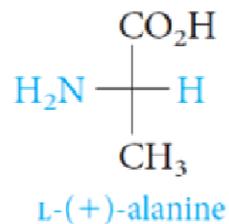
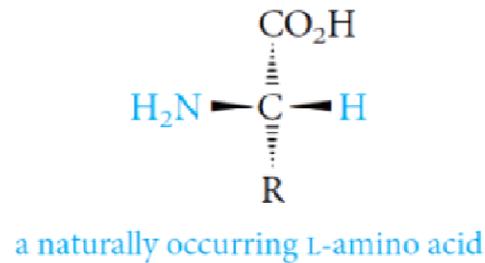
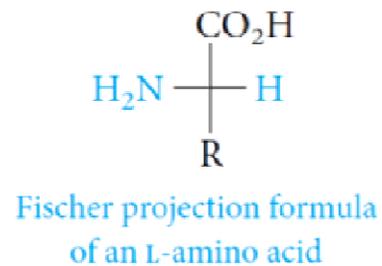
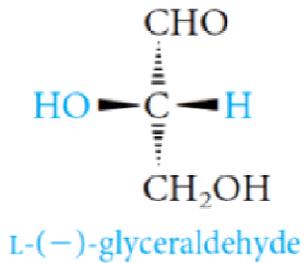
- **Peptides** are oligomers of amino acids that play important roles in many biological processes.

**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



# Sources, Classification and Structure of Amino Acids



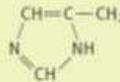
## List of the 20 $\alpha$ -amino acids commonly found in proteins.

Names and Formulas of the Common Amino Acids			
Name	Three-letter abbreviation (isoelectric point) one-letter abbreviation	Formula	R
<b>A. One amino group and one carboxyl group</b>			
1. glycine	Gly (6.0) G	$\text{H}-\underset{\text{NH}_2}{\text{CH}}-\text{CO}_2\text{H}$	
2. alanine	Ala (6.0) A	$\text{CH}_3-\underset{\text{NH}_2}{\text{CH}}-\text{CO}_2\text{H}$	
3. valine	Val (6.0) V	$\text{CH}_3\text{CH}(\text{CH}_3)-\underset{\text{NH}_2}{\text{CH}}-\text{CO}_2\text{H}$	R is hydrogen or an alkyl group.
4. leucine	Leu (6.0) L	$\text{CH}_3\text{CH}(\text{CH}_3)\text{CH}_2-\underset{\text{NH}_2}{\text{CH}}-\text{CO}_2\text{H}$	
5. isoleucine	Ile (6.0) I	$\text{CH}_3\text{CH}_2\text{CH}(\text{CH}_3)-\underset{\text{NH}_2}{\text{CH}}-\text{CO}_2\text{H}$	
6. serine	Ser (5.7) S	$\text{CH}_2(\text{OH})-\underset{\text{NH}_2}{\text{CH}}-\text{CO}_2\text{H}$	
7. threonine	Thr (5.6) T	$\text{CH}_3\text{CH}(\text{OH})-\underset{\text{NH}_2}{\text{CH}}-\text{CO}_2\text{H}$	R contains an alcohol function.

(continued)



# Sources, Classification and Structure of Amino Acids

(continued)			
Name	Three-letter abbreviation (isoelectric point) one-letter abbreviation	Formula	R
<b>B. One amino group and two carboxyl groups</b>			
14. aspartic acid	Asp (3.0) D	$\text{HOOC}-\text{CH}_2-\underset{\text{NH}_2}{\text{CH}}-\text{CO}_2\text{H}$	
15. glutamic acid	Glu (3.2) E	$\text{HOOC}-\text{CH}_2\text{CH}_2-\underset{\text{NH}_2}{\text{CH}}-\text{CO}_2\text{H}$	
16. asparagine	Asn (5.4) N	$\text{H}_2\text{N}-\overset{\text{O}}{\parallel}{\text{C}}-\text{CH}_2-\underset{\text{NH}_2}{\text{CH}}-\text{CO}_2\text{H}$	
17. glutamine	Gln (5.7) Q	$\text{H}_2\text{N}-\overset{\text{O}}{\parallel}{\text{C}}-\text{CH}_2\text{CH}_2-\underset{\text{NH}_2}{\text{CH}}-\text{COOH}$	
<b>C. One carboxyl group and two basic groups</b>			
18. lysine	Lys (9.7) K	$\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2-\underset{\text{NH}_2}{\text{CH}}-\text{CO}_2\text{H}$	} The second basic group is a primary amine, a guanidine, or an imidazole.
19. arginine	Arg (10.8) R	$\text{NH}_2-\text{C}(\text{NH})=\text{NH}-\text{CH}_2\text{CH}_2\text{CH}_2-\underset{\text{NH}_2}{\text{CH}}-\text{CO}_2\text{H}$	
20. histidine	His (7.6) H	$\text{CH}=\text{C}(\text{NH})-\text{CH}_2-\underset{\text{NH}_2}{\text{CH}}-\text{CO}_2\text{H}$ 	

# Sources, Classification and Structure of Amino Acids



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- **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.

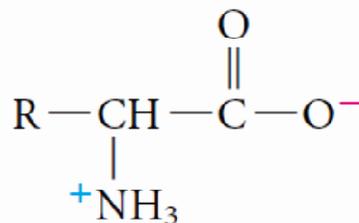
### - Non-essential amino acids

*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.



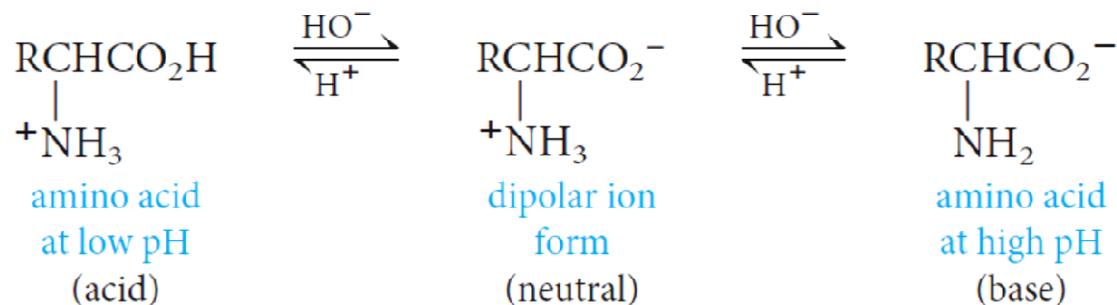
dipolar structure of an  $\alpha$ -amino acid

# The Acid–Base Properties of Amino Acids

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- 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.**

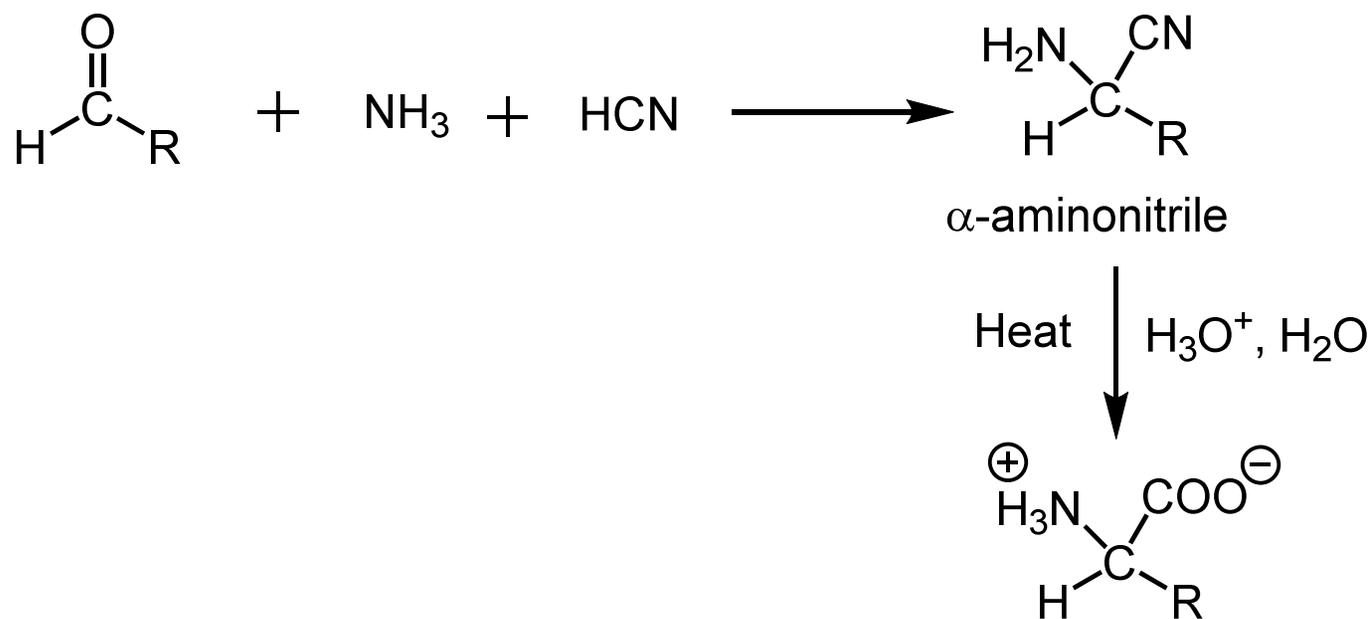
*They can behave as acids and donate a proton to a strong base, or they can behave as bases and accept a proton from a strong acid.*



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

# Synthesis of Amino Acids

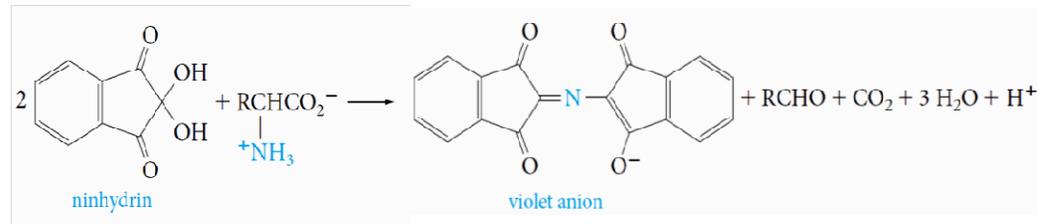
**Strecker Synthesis:** Recall reductive amination and Cyanohydrin formation.



## 1) The Ninhydrin Reaction

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- **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.*

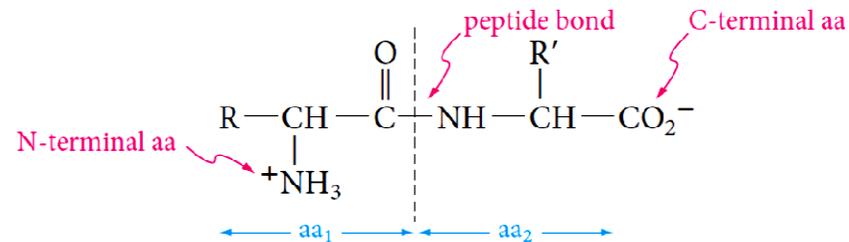


- Only the **nitrogen atom of the violet dye** comes from the amino acid (primary amino group); the rest of the amino acid is converted to an aldehyde and carbon dioxide.
- Only **proline**, which has a secondary amino group, reacts differently to give a **yellow dye**, but this, too, can be used for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

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

## Reactions of Amino Acids

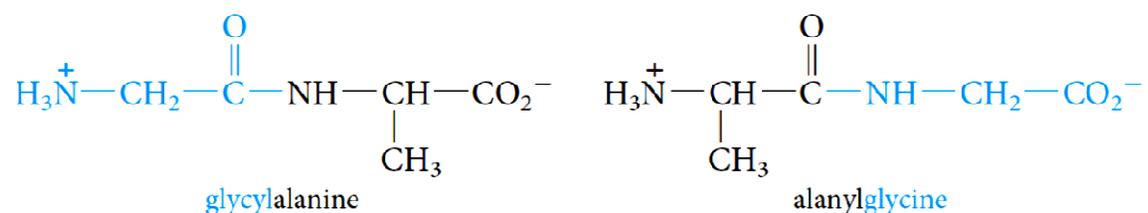
- **Amino acids** are linked in **peptides and proteins** by an amide bond (**peptide bond**) between the carboxyl group of one amino acid and the  $\alpha$ -amino group of another amino acid.
- A molecule containing only *two* amino acids (the shorthand aa is used for amino acid) joined in this way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



- By convention, the **peptide bond** is written with the amino acid having a free  $^+\text{NH}_3$  group at the left and the amino acid with a free  $\text{CO}_2^-$  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)

- 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

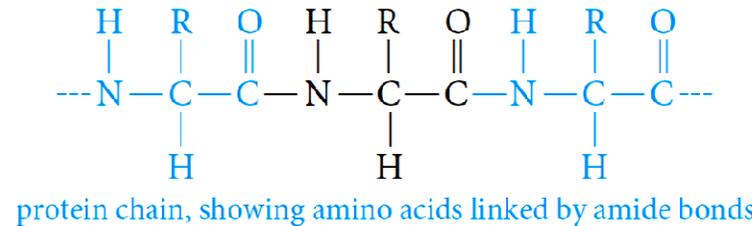


- **Proteins** are biopolymers composed of many amino acids connected to one another through amide (peptide) bonds.
- Some **proteins** are major components of structural tissue (muscle, skin, nails, and hair).
- Others transport molecules from one part of a living system to another.
- **The main features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

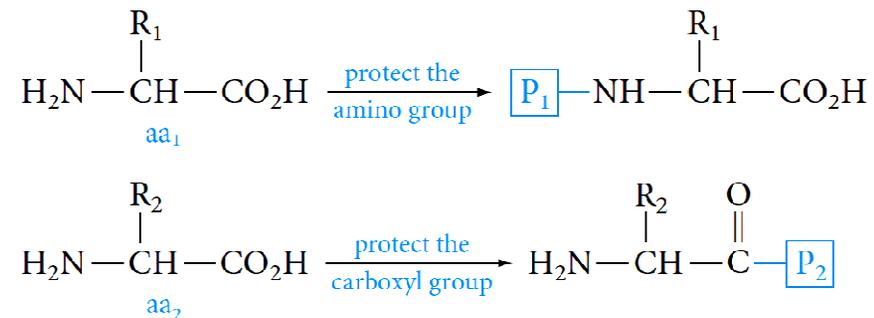


- **Peptides and proteins** can be hydrolyzed to their amino acid components by heating with 6 M HCl.
- An instrument called an **amino acid analyzer** is used to determine the amino acids mixture.

# 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<sub>1</sub> combines with the amino group of aa<sub>2</sub>.

