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PREFACE

In this second volume of the CRC Handbook of Microbiology, an effort has been made to put in the hands of microbiologists basic information about the constituents of microbial cells. The subject matter is covered under sections on amino acids and proteins, carbohydrates, lipids, nucleic acids and minerals. In addition, information is given about methods used to separate microbial components, as well as a wide variety of other pertinent information.

The Editors have been greatly helped in their task by the members of the Advisory Board and by the contributors. Especially helpful has been Dr. F. Persico, who kindly took charge of the section on nucleic acids.

It is the aim of the Publisher and of the Editors of the Handbook to periodically bring the material presented here up to date. In order to furnish the microbiologists with the information they need, the Editors will need all the feedback they can receive. It is thus the Editors' hope that the users of this Handbook will take the time to bring to our attention all the shortcomings of the first edition.

The Editors especially wish to thank Mrs. Lisbeth Hammer and Miss Beryl Tuffyas for their excellent editorial work and Mrs. Verna Lepping for her devoted assistance.

A. I. Laskin
H. A. Lechevalier
New Jersey, 1973

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AMINO ACIDS AND PROTEINS

THE AMINO ACIDS FOUND IN PROTEINS

DR. D. STRUMEYER

I. Neutral Amino Acids

A. Aliphatic side chain

Glycine
Alanine
Valine
Isoleucine
Leucine

B. Polar side chain

1. Hydroxyl-containing

Threonine
Serine

2. Amide-containing

Asparagine
Glutamine

C. Sulfur-containing

Cysteine
Cystine
Methionine

D. Imino amino acids

Proline
Hydroxyproline

E. Aromatic

Phenylalanine
Tyrosine
Tryptophan

II. Acidic Amino Acids

Aspartic
Glutamic

III. Basic Amino Acids

Histidine
Lysine
Arginine

ABBREVIATIONS AND MOLECULAR WEIGHTS OF AMINO ACIDS FOUND IN PROTEINS

Amino Acid	3-Letter Symbol	1-Letter Symbol	M.W.	Amino Acid	3-Letter Symbol	1-Letter Symbol	M.W.
Alanine	Ala	A	89.09	Leucine	Leu	L	131.17
Arginine	Arg	R	179.20	Lysine	Lys	K	146.19
Asparagine	Asn	N	132.12	Methionine	Met	M	141.21
Aspartic acid	Asp	D	133.10	Phenylalanine	Phe	F	165.19
Cysteine	Cys	C	121.15	Proline	Pro	P	115.13
Cystine	$(Cys)_2$		240.29	Serine	Ser	S	105.09
Glutamic acid	Glu	E	147.13	Threonine	Thr	T	119.12
Glutamine	Gln	Q	146.15	Tryptophan	Trp	W	204.24
Glycine	Gly	G	75.07	Tyrosine	Tyr	Y	181.19
Histidine	His	H	155.16	Valine	Val	V	117.15
Isoleucine	Ile	I	131.17	"Other"		X	

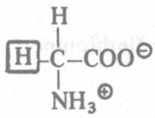
Complete rules affecting amino acid and other biochemical nomenclature may be found in *Handbook of Biochemistry*, 2nd ed., Section A, H. A. Sober, Ed. The Chemical Rubber Co., Cleveland, Ohio (1970).

STRUCTURES OF AMINO ACIDS OCCURRING IN PROTEINS

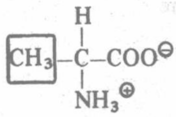
DR. D. STRUMEYER

NEUTRAL AMINO ACIDS

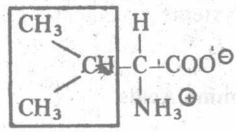
Aliphatic Side Chain



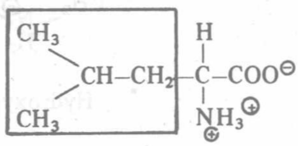
Glycine



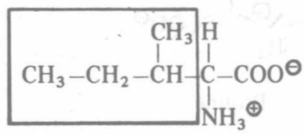
Alanine



Valine

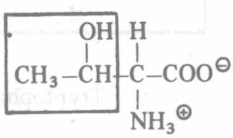


Leucine

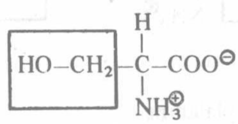


Isoleucine

Hydroxyl-Containing

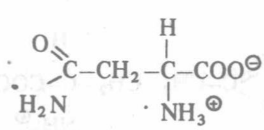


Threonine

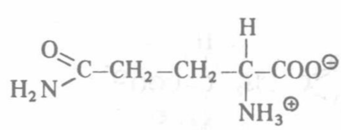


Serine

Amide-Containing

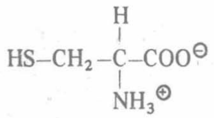


Asparagine

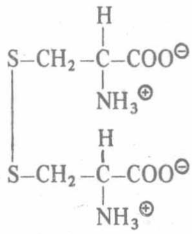


Glutamine

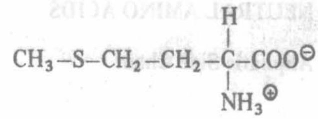
Sulfur-Containing



Cysteine

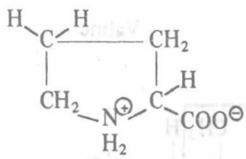


Cystine

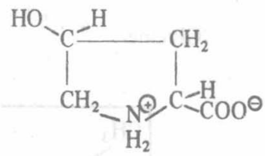


Methionine

Imino Amino Acids

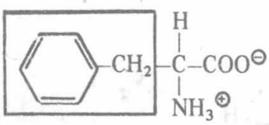


Proline

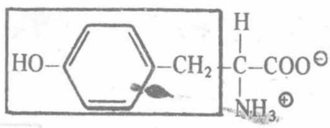


Hydroxyproline

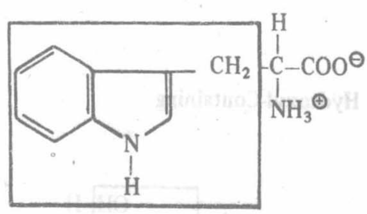
Aromatic



Phenylalanine

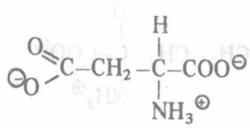


Tyrosine

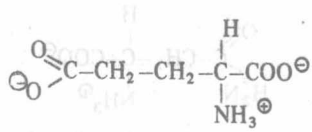


Tryptophan

ACIDIC AMINO ACIDS

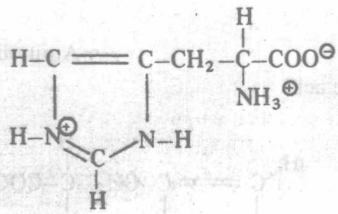


Aspartic acid

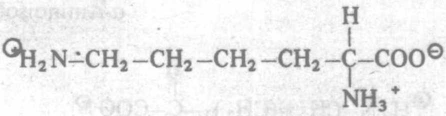


Glutamic acid

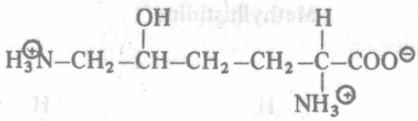
BASIC AMINO ACIDS



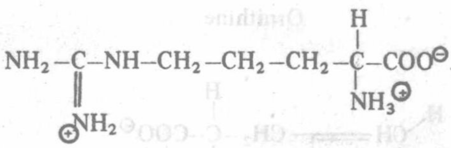
Histidine



Lysine

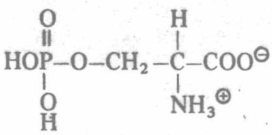


Hydroxylysine

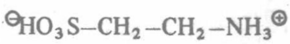


Arginine

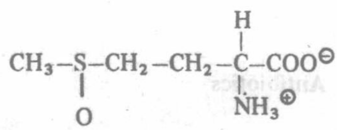
AMINO ACID DERIVATIVES



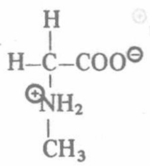
Phosphoserine



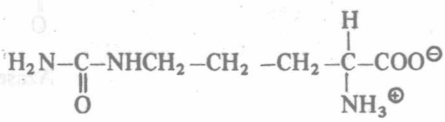
Taurine



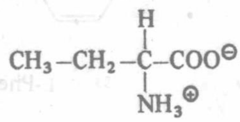
Methionine sulfoxide



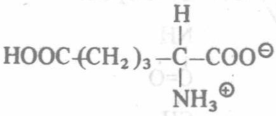
Sarcosine
(N methylglycine)



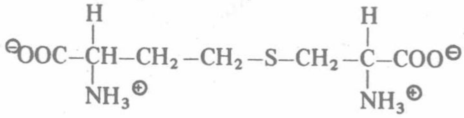
Citrulline



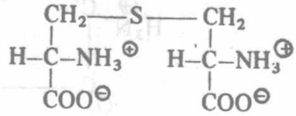
a-Aminobutyric acid



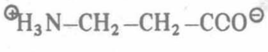
a-Aminoadipic acid



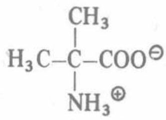
Cystathionine



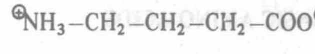
Lanthionine



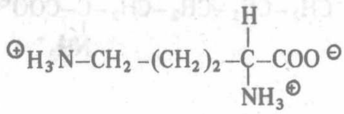
β-Alanine



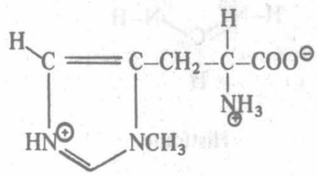
α-Aminoisobutyric acid



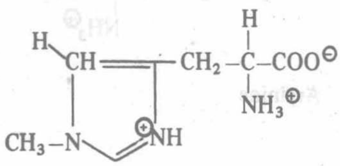
γ-Aminobutyric acid



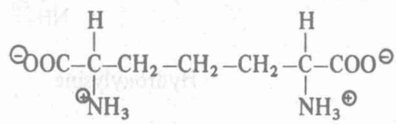
Ornithine



1-Methylhistidine

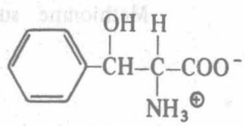


3-Methylhistidine

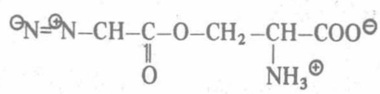


α,ε-Diaminopimelic acid

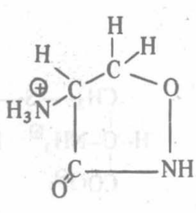
Antibiotics



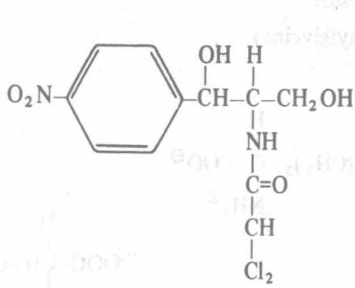
L-Phenylserine



Azaserine



Cycloserine

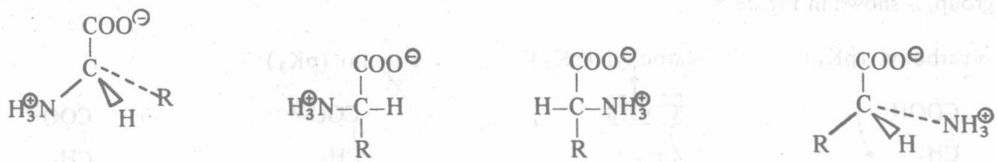


Chloramphenicol

OPTICAL ISOMERS AND IONIZATION CONSTANTS OF AMINO ACIDS

DR. D. STRUMEYER

The proteins of all microorganisms, plants and animals contain the same twenty amino acids, except for a few additional amino acids that occur in some structural proteins, such as collagen. Upon acid hydrolysis of all proteins, free amino acids are released exclusively in the L-enantiomeric form relative to L-glyceraldehyde. Glycine is the only amino acid without an asymmetric α-carbon. D-amino acids are incorporated in cell wall structures and in several antibiotics. Except for proline, all protein amino acids are primary α-amino, α-carboxylic acid derivatives. The isomeric structures of amino acids are shown in Figure 1; alternate forms are shown in Figure 2. The structures are represented as dipolar ions or zwitter ions rather than as the uncharged species, since the amino acids exist in the fully ionized state in the crystal and in neutral solution.



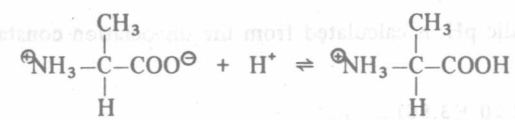
L-Amino acid D-Amino acid

FIGURE 1. Representations of optical isomers of an amino acid.

L-Amino acid D-Amino acid

FIGURE 2. Additional representations of amino acid isomers.

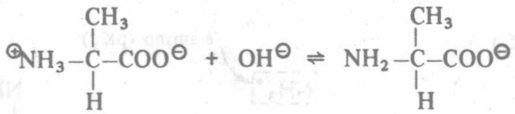
The titration by acid or base of a mono-amino, mono-carboxylic acid, such as alanine (R = CH_3), dissolved in water may be attributed to the reactions of the isolectric forms as shown in Figures 3 and 4.



$K_1 = 10^{-2.35}$, $pK_1 = 2.35$

Isoelectric form (net charge = 0) Net charge = +1

FIGURE 3. Titration by acid of alanine dissolved in water.



$K_2 = 10^{-9.76}$, $pK_2 = 9.87$

Isoelectric form (net charge = 0) Net charge = −1

FIGURE 4. Titration by base of alanine dissolved in water.

Amino acids carry a net charge, which is positive, zero or negative, depending on the pH of the solution. The terms "amphoteric" and "ampholytes" are used in referring to such substances, of which glycine is the simplest. Calculation of the pH at which amino acids carry a net charge of zero and will not migrate in an electric field, the *isoelectric point* (pH_I), can be made from the dissociation constants:

$$pH_I = \frac{pK_1 + pK_2}{2}$$

Applied to alanine, the calculation is made as follows:

$$pH_I = \frac{(2.35 + 9.87)}{2} = 6.11.$$

The same type of treatment may be extended to more complex ampholytes, which contain more than one carboxyl group or more than one amino group. For such substances (e.g., aspartic acid, glutamic acid, lysine, or arginine) the pK values are listed in the same sequence as the order of dissociation of the carboxyl and amino groups.

For a dicarboxylic amino acid, such as aspartic acid, the ionization sequence, beginning with the most acidic group, is shown in Figure 5.

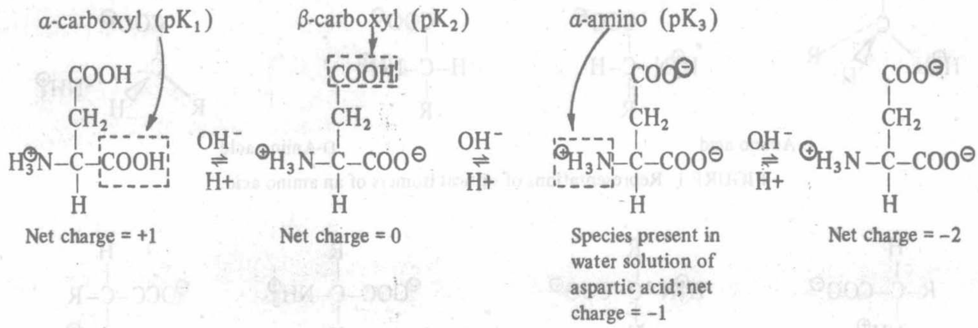


FIGURE 5. Ionization sequence for aspartic acid.

The pK values for the various groups are as follows:

$$pK_1\ (\alpha\text{-carboxyl}) = 2.10$$
$$pK_2\ (\beta\text{-carboxyl}) = 3.86$$
$$pK_3\ (\alpha\text{-amino}) = 9.82$$

The isoelectric point, which must be at an acidic pH, is calculated from the dissociation constants of the two carboxyl groups:

$$pI = \frac{(2.10 + 3.86)}{2} = 2.98.$$

For a diamino (dibasic) amino acid, such as lysine, the ionization sequence also begins with the most acidic group, as shown in Figure 6.

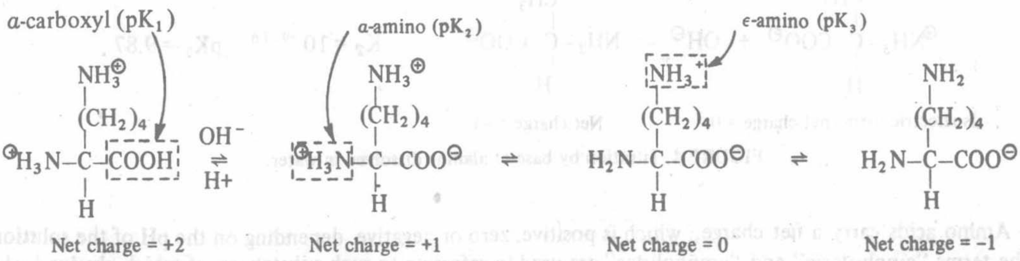


FIGURE 6. Ionization sequence for lysine.