Practical Handbook of
Biochemistry and Molecular Biology

Edited by
Gerald D. Fasman, Ph.D

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PREFACE

New methodologies and databases for biochemistry and molecular biology are constantly being added to current sources. This *Handbook* updates previous handbooks in a format which is easy to use in the laboratory.

New information, in areas such as restriction enzymes, is always being published, so it is impossible to be completely up-to-date. However, the tables in this *Handbook* contain the most relevant data available at the time of publication.

Gerald D. Fasman
Editor

THE EDITOR

Gerald D. Fasman, Ph.D., is the Rosenfield Professor of Biochemistry, Graduate Department of Chemistry, Brandeis University, Waltham, Massachusetts.

Dr. Fasman graduated from the University of Alberta in 1948 with a B.S. Honors Degree in Chemistry, and he received his Ph.D. in Organic Chemistry in 1952 from the California Institute of Techology, Pasadena, California. Dr. Fasman did postdoctoral studies at Cambridge University, England, Eidg. Technische Hochschule, Zurich, Switzerland, and the Weizmann Institute of Science, Rehovoth, Israel. Prior to moving to Brandeis University, he spent several years at the Children's Cancer Research Foundation at the Harvard Medical School. He has been an Established Investigator of the American Heart Association, a National Science Foundation Senior Postdoctoral Fellow in Japan, and has been awarded two John Simon Guggenheim Fellowships.

Dr. Fasman is a member of the American Chemical Society, a Fellow of the American Association for the Advancement of Science, member of Sigma Xi, the Biophysical Society, the American Society of Biological Chemists, the Chemical Society (London), the New York Academy of Science, the Protein Society, and a Fellow of the American Institute of Chemists. He has published 250 research papers.

ACKNOWLEDGMENT

With exceptions as noted, materials in this volume were derived from the multi-volume *CRC Handbook of Biochemistry and Molecular Biology*, edited by Gerald D. Fasman:

Section 1. Proteins: derived from *Proteins*, Volumes I and II (pages 3 to 102 from Volume I and pages 103 to 366 from Volume II) as well as new material, beginning on page 367.

Section 2. Nucleic Acids: derived from *Nucleic Acids*, Volumes I and II (pages 385 to 402 and 403 to 448, respectively), with added new material on pages 449 to 511.

Section 3. Lipids: contains selected tables from *Lipids, Carbohydrates and Steroids*.

Section 4. Physical-Chemical Data: drawn from Volumes I and II (pages 531 to 565 and 566 to 576, respectively) of *Physical and Chemical Data*.

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SECTION 2. NUCLEOSIDES, NUCLEOTIDES, AND NUCLEIC ACIDS

Section 1
Amino Acids and Proteins

AMINO ACIDS

DATA ON THE NATURALLY OCCURRING AMINO ACIDS

Elizabeth Dodd Mooz

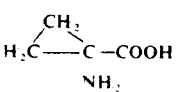
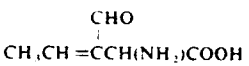
The amino acids included in these tables are those for which reliable evidence exists for their occurrence in nature. These tables are intended as a guide to the primary literature in which the isolation and characterization of the amino acids are reported. Originally, it was planned to include more factual data on the chemical and physical properties of these compounds; however, the many different conditions employed by various authors in measuring these properties (i.e., chromatography and spectral data) made them difficult to arrange into useful tables. The rotation values are as given in the references cited; unfortunately, in some cases there is no information given on temperature, solvent, or concentration.

The investigator employing the data in these tables is urged to refer to the original articles in order to evaluate for himself the reliability of the information reported. These references are intended to be informative to the reader rather than to give credit to individual scientists who published the original reports. Thus not all published material is cited.

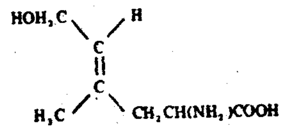
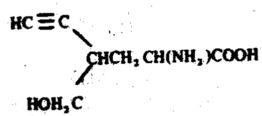
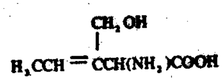
The compounds listed in Sections A to N are known to be of the L configuration. Section O contains some of the D amino acids which occur naturally. This last section is not intended to be complete since most properties of the D amino acids correspond to those of their L enantiomorphs. Therefore, emphasis was placed on including those D amino acids whose L isomers have not been found in nature. The reader will find additional information on the D amino acids in the review by Corrigan[263] and in the book by Meister.[1]

Compilation of data for these tables was completed in December 1974. Appreciation is expressed to Doctors L. Fowden, John F. Thompson, Peter Müller, and M. Bodanszky who were helpful in supplying recent references and to Dr. David Pruess who made review material available to me prior to its publication. A special word of thanks to Dr. Alton Meister who made available reprints of journal articles which I was not able to obtain.

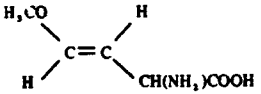
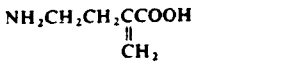
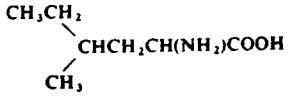
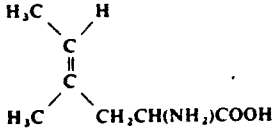
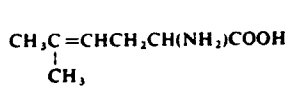
DATA ON THE NATURALLY OCCURRING AMINO ACIDS (continued)

No.	Amino acid (synonym)	Source	Structure	Formula (mol wt)	Melting point °C[a]	$[\alpha]_D$[b]	pK_a	References: Isolation and purification	Chromatography	Chemistry	Spectral data
			A. L-Monoamino, Monocarboxylic Acids								
1	Alanine (α-aminopropionic acid)	Silk fibroin	$CH_3CH(NH_2)COOH$	$C_3H_7NO_2$ (89.09)	297°	$+1.8^{25}$ (c 2, H_2O) (1) $+14.6^{25}$ (c 2, 5 N HCl) (1)	2.34 9.69	2	3	4	4
2	β-Alanine (β-aminopropionic acid)	*Iris tingitana*	$NH_2CH_2CH_2COOH$	$C_3H_7NO_2$ (89.09)	196° (dec)	–	3.55 10.24	5	5	5	–
3	α-Aminobutyric acid	Yeast protein	$CH_3CH_2CH(NH_2)COOH$	$C_4H_9NO_2$ (103.12)	292° (dec)	$+20.5^{25}$ (c 1–2, 5 N HCl) (290) $+9.3^{25}$ (c 1–2, (H_2O) (290) $+42^{25}$ (c 1–2, gl acetic) (290)	2.29 9.83	6	7	6	–
4	γ-Aminobutyric acid (piperidinic acid)	Bacteria	$NH_2CH_2CH_2CH_2COOH$	$C_4H_9NO_2$ (103.12)	203° (dec)	–	4.03 10.56 (290)	8–10	9, 10	11	–
5	1-Aminocyclopropane-1-carboxylic acid	Pears and apples		$C_4H_7NO_2$ (101.11)	–	–	–	11	11	12	12
6	2-Amino-3-formyl-3-pentenoic acid	*Bankera fulgineoalba* (a mushroom)		$C_6H_9NO_3$ (143.15)	–	–	–	13	13	13	13
7	α-Aminoheptanoic acid	*Claviceps purpurea*	$CH_3(CH_2)_4CH(NH_2)COOH$	$C_7H_{15}NO_2$ (145.21)	–	–	–	14	14	–	–

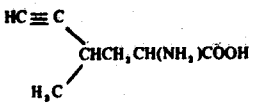
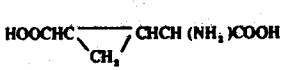
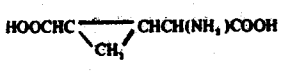
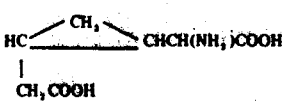
DATA ON THE NATURALLY OCCURRING AMINO ACIDS (continued)

No.	Amino acid (synonym)	Source	Structure	Formula (mol wt)	Melting point °C[a]	$[\alpha]_D$[b]	pK_a	References: Isolation and purification	References: Chromatography	References: Chemistry	References: Spectral data
7a	2-Amino-4,5-hexadienoic acid	*Amanita solitaria*	$H_2C{=}C{=}CHCH_2{-}CH(NH_2)COOH$	$C_6H_9NO_2$ (127.16)	200° (dec) (14a)	–	–	14a	–	–	14a
8	2-Amino-4-hexenoic acid	Ilamycin	$CH_3CH{=}CHCH_2CH(NH_2)COOH$	$C_6H_{11}NO_2$ (129.17)	–	–	–	15	15	–	–
8a	2-Amino-4-hydroxy-hept-6-ynoic acid	*Euphoria longan*	$HC{\equiv}C{-}CH_2CH(OH)CH_2CH(NH_2)COOH$	$C_7H_{11}NO_3$ (157.19)	–	-27^{26} (c 2, H_2O) -8^{26} (c 1, 5 N HCl) (15a)	–	15a	15a	–	15a
8b	2-Amino-6-hydroxy-4-methyl-4-hexenoic acid	*Aesculus Californica* seeds		$C_7H_{13}NO_3$ (159.21)	–	-31^{26} (c 2.2, H_2O) $+2^{26}$ (c 1.1, 5 N HCl) (23b)	–	23b	23b	–	15b
8c	2-Amino-4-hydroxy-5-methyl hexenoic acid	*Euphoria longan*		$C_7H_{11}NO_3$ (157.19)	–	-27^{26} (c 2, H_2O) -13^{26} (c 1, 5 N HCl) (15a)	–	15a	–	15a	15a
8d	2-Amino-3-hydroxy-methyl-3-pentenoic acid	*Bankera fuligineoalba*		$C_6H_{11}NO_3$ (145.18)	160–161° (dec) (13)	$+182^{25}$ (c 0.8, H_2O) $+201^{25}$ (c 0.8, 0.3 N HCl) (13)	–	13	13	13	13
9	α-Aminoisobutyric acid	*Iris tingitana*, muscle protein	$(CH_3)_2C(NH_2)COOH$	$C_4H_9NO_2$ (103.12)	200° (dec)	–	2.36 10.21 (298)	16	16	–	–
10	β-Aminoisobutyric acid	*Iris tingitana*	$NH_2CH_2CH(CH_3)COOH$	$C_4H_9NO_2$ (103.12)	179° (17)	-21^{26} (c 0.43, H_2O) (17)	–	17	17	17	17

DATA ON THE NATURALLY OCCURRING AMINO ACIDS (continued)

No.	Amino acid (synonym)	Source	Structure	Formula (mol wt)	Melting point °C[a]	$[\alpha]_D$[b]	pK_a	References: Isolation and purification	Chromatography	Chemistry	Spectral data
10a	2-Amino-4-methoxy-*trans*-3-butenoic acid	*Pseudomonas aeruginosa*		$C_5H_9NO_3$ (131.15)	–	–	–	17a	17b	–	17a, 17b
11	γ-Amino-α-methylene butyric acid	*Arachis hypogaea* (groundnut plants)		$C_5H_9NO_2$ (115.13)	152° (18)	–	–	18	18	18	–
12	2-Amino-4-methyl-hexanoic acid (homoisoleucine)	*Aesculus Californica* seeds		$C_7H_{15}NO_2$ (145.21)	–	−2°[20] (*c* 1, H_2O) (19) +24°[20] (*c* 0.87, 5 *N* HCl) (19)	–	19	19	19	19
13	2-Amino-4-methyl-4-hexenoic acid	*Aesculus Californica* seeds		$C_7H_{13}NO_2$ (143.19)	–	−61°[20] (*c* 2.4, H_2O) (19) −36 (*c* 1.2, 6 *N* HCl) (19)	–	19	19	19	19
13a	2-Amino-4-methyl-5-hexenoic acid	*Streptomyces* species	$CH_2{=}CHCH(CH_3)CH_2CH(NH_2)COOH$	$C_7H_{13}NO_2$ (143.21)	260° (dec) (19a)	−9.6° (*c* 1.78, H_2O) +5.7° (*c* 0.7, 1 *N* HCl) (99a)	–	19a	19a	–	19a
14	2-Amino-5-methyl-4-hexenoic acid	*Leucocortinarius bulbiger*		$C_7H_{13}NO_2$ (143.19)	260–270° (dec) (22a)	−45.9°[25] (*c* 0.47, H_2O) −7°[25] (*c* 0.4, 1 *N* HCl) (22a)	–	22, 22a	22a	–	22a

DATA ON THE NATURALLY OCCURRING AMINO ACIDS (continued)

No.	Amino acid (synonym)	Source	Structure	Formula (mol wt)	Melting point °C[a]	$[\alpha]_D$[b]	pK_a	References: Isolation and purification	References: Chromatography	References: Chemistry	References: Spectral data
14a	2-Amino-4-methyl-5-hexenoic acid	*Euphoria longan*		$C_7H_{11}NO_2$ (141.19)	–	-33^{20} (*c* 2, H_2O) -27^{20} (*c* 1, 5 *N* HCl) (15a)	–	15a	–	15a	15a
15	α-Amino-octanoic acid	*Aspergillus atypique*	$CH_3(CH_2)_5CH(NH_2)COOH$	$C_8H_{17}NO_2$ (159.23)	–	–	–	23	23	23	23
15a	2-Amino-4-pentynoic acid	*Streptomyces* sp. #8–4	$HC{\equiv}CCH_2CH(NH_2)COOH$	$C_5H_7NO_2$ (113.13)	241–242° (dec) (23a)	-31.1^{25} (*c* 1, H_2O) -5.5^{25} (*c* 1, 5 *N* HCl) (23a)	–	23a	23a	23a	23a
15a′	*cis*-α-(Carboxycyclopropyl) glycine	*Aesculus parviflora*		$C_6H_9NO_4$ (159.16)	–	$+25^{20}$ (*c* 1, H_2O) +58 (*c* 0.5, 5 *N* HCl) (23a′)	–	23a′	23a′	–	23a′
15b	*trans*-α-(Carboxycyclopropyl) glycine	*Blighia sapida*		$C_6H_9NO_4$ (159.16)	–	$+107^{20}$ (*c* 2, H_2O) $+146^{20}$ (*c* 1, 5 *N* HCl) (23a′)	–	23a′	23a′	–	23a′
15b′	*trans*-α-(2-Carboxy-methylcyclopropyl glycine	*Blighia unijugata*		$C_7H_{11}NO_4$ (173.19)	–	$+12^{20}$ (*c* 1, H_2O) $+45^{20}$ (*c* 0.5, 5 *N* HCl) (99a)	–	99a	99a	–	99a