

FOURTH EDITION

HANDBOOK OF
BIOCHEMISTRY
AND MOLECULAR
BIOLOGY

EDITED BY
ROGER L. LUNDBLAD
FIONA M. MACDONALD

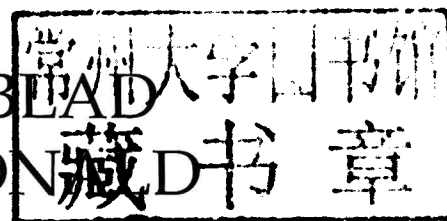


CRC Press
Taylor & Francis Group

FOURTH EDITION

HANDBOOK OF
BIOCHEMISTRY AND
MOLECULAR
BIOLOGY

EDITED BY
ROGER L. LUNDBLAD
FIONA M. MACDONALD



CRC Press

Taylor & Francis Group

Boca Raton London New York

CRC Press is an imprint of the
Taylor & Francis Group, an **informa** business

CRC Press
Taylor & Francis Group
6000 Broken Sound Parkway NW, Suite 300
Boca Raton, FL 33487-2742

© 2010 by Taylor and Francis Group, LLC
CRC Press is an imprint of Taylor & Francis Group, an Informa business

No claim to original U.S. Government works

Printed in the United States of America on acid-free paper
10 9 8 7 6 5 4 3 2 1

International Standard Book Number: 978-0-8493-9168-2 (Hardback)

This book contains information obtained from authentic and highly regarded sources. Reasonable efforts have been made to publish reliable data and information, but the author and publisher cannot assume responsibility for the validity of all materials or the consequences of their use. The authors and publishers have attempted to trace the copyright holders of all material reproduced in this publication and apologize to copyright holders if permission to publish in this form has not been obtained. If any copyright material has not been acknowledged please write and let us know so we may rectify in any future reprint.

Except as permitted under U.S. Copyright Law, no part of this book may be reprinted, reproduced, transmitted, or utilized in any form by any electronic, mechanical, or other means, now known or hereafter invented, including photocopying, microfilming, and recording, or in any information storage or retrieval system, without written permission from the publishers.

For permission to photocopy or use material electronically from this work, please access www.copyright.com (<http://www.copyright.com/>) or contact the Copyright Clearance Center, Inc. (CCC), 222 Rosewood Drive, Danvers, MA 01923, 978-750-8400. CCC is a not-for-profit organization that provides licenses and registration for a variety of users. For organizations that have been granted a photocopy license by the CCC, a separate system of payment has been arranged.

Trademark Notice: Product or corporate names may be trademarks or registered trademarks, and are used only for identification and explanation without intent to infringe.

Library of Congress Cataloging-in-Publication Data

Handbook of biochemistry and molecular biology / edited by Roger L. Lundblad and Fiona M. Macdonald.

p. ; cm.

Includes bibliographical references and index.

ISBN-13: 978-0-8493-9168-2 (alk. paper)

ISBN-10: 0-8493-9168-7 (alk. paper)

1. Biochemistry--Handbooks, manuals, etc. 2. Molecular biology--Handbooks, manuals, etc. I. Lundblad, Roger L. II. Macdonald, Fiona.

[DNLM: 1. Biochemical Phenomena--Tables. QU 16 H2363 2010]

QH345.H347 2010

572--dc22

2009042039

Visit the Taylor & Francis Web site at
<http://www.taylorandfrancis.com>

and the CRC Press Web site at
<http://www.crcpress.com>

F O U R T H E D I T I O N

HANDBOOK OF
BIOCHEMISTRY AND
MOLECULAR
BIOLOGY

This work is dedicated to the many scientists of the “The Greatest Generation” who contributed to the base of our knowledge of biochemistry and molecular biology.

Roger L. Lundblad, Ph.D.

To my parents, Pat and Paul Macdonald, whose unwavering love and support has been my guiding light.

Fiona M. Macdonald, Ph.D., F.R.S.C.

FOREWORD

For almost a century, CRC Press has been a leader in providing concise compilations of scientific data for researchers, teachers, and students. The *CRC Handbook of Chemistry and Physics*, which first appeared in 1913 and is now in its 90th edition, is the basic source of physical science data that most chemists, physicists, and engineers turn to. Other widely used handbooks from CRC Press cover materials science, engineering, and mathematics. Many specialized handbooks have also appeared under the CRC imprint, ranging from semiconductors to lipids.

The 1968 publication of the *CRC Handbook of Biochemistry*, edited by Herbert A. Sober, marked a milestone in bioscience data. Appearing just 15 years after Watson and Crick elucidated the structure of DNA, the subtitle of this work, *Selected Data for Molecular Biology*, was a recognition that molecular biology

was the new frontier of the biosciences. This was followed by the multivolume *Handbook of Biochemistry and Molecular Biology*, edited by Gerald D. Fasman, and its single volume abridged version *Practical Handbook of Biochemistry and Molecular Biology*, which appeared in 1989. The intervening 20 years has seen an explosion of data in this field and an exponential growth in the translation of recent discoveries into new technology. This new *Handbook of Biochemistry*, edited by Roger Lundblad and Fiona M. Macdonald, is thus a welcome addition to the list of handbooks available through CRC Press. I am sure it will find heavy use in both basic research and biotechnology.

David R. Lide

Editor-in-Chief, CRC Handbook of Chemistry and Physics

PREFACE

This is the fourth edition of the *Handbook of Biochemistry and Molecular Biology*. The first edition was published as a single volume in 1968 under the guidance of Herbert Sober. The second edition appeared in 1970 and the third, with Gerald Fasman as editor, appeared in eight volumes published in 1975–6. This increase in size reflected the rapid advances in knowledge in the then relatively new field of molecular biology.

It is intended that current *Handbook of Biochemistry and Molecular Biology* be a companion volume to the *CRC Handbook of Chemistry and Physics*—a single volume ready-reference work that will find a home on the bookshelves of biochemists and molecular biologists everywhere.

This fourth edition contains materials from the previous editions as well as extensive new material. Staying within the confines of a single volume has meant difficult decisions on which tables to include, and the editors welcome feedback from readers. The advent of electronic media allows for more frequent updating and it is hoped that any infelicities in our selection may be

readily rectified. Additionally, suggestions on new topics for this Handbook and notification of errors are always appreciated. Address all comments to Editor, *Handbook of Biochemistry and Molecular Biology*, Taylor & Francis Group, 6000 Broken Sound Parkway NW, Suite 300, Boca Raton, FL 33487.

Much of the current content is derived from the research of the giants of biochemistry and molecular biology in the three decades following World War II. While it seems the vogue to develop new names and descriptions for old, established concepts, biochemistry and molecular biology continue to be the mainstays of current biomedical research.

Roger L. Lundblad
lundblad@bellsouth.net

Fiona M. Macdonald
fiona.macdonald@taylorandfrancis.com
March 2010

ACKNOWLEDGMENTS

This work would not have been possible without the outstanding support of Jill Jurgensen and Glen Butler of Taylor & Francis. The support of Professor Edward A. Dennis is acknowledged. The help of various research librarians at the University of North Carolina at Chapel Hill is also

acknowledged. Professors Charles Craik of the University of California at San Francisco and Bryce Plapp of the University of Iowa provided advice on selection of materials to be included. However, the editors take all responsibility for the selection of content.

EDITORS

Roger L. Lundblad, PhD

Roger L. Lundblad is a native of San Francisco, California. He received his undergraduate education at Pacific Lutheran University and his PhD degree in biochemistry at the University of Washington. After postdoctoral work in the laboratories of Stanford Moore and William Stein at the Rockefeller University, he joined the faculty of the University of North Carolina at Chapel Hill. He joined the Hyland Division of Baxter Healthcare in 1990. Currently Dr. Lundblad is an independent consultant and writer in biotechnology in Chapel Hill, North Carolina. He is an adjunct professor of Pathology at the University of North Carolina at Chapel Hill and editor-in-chief of the Internet Journal of Genomics and Proteomics.

Fiona M. Macdonald, PhD, F.R.S.C.

Fiona M. Macdonald received her BSc in chemistry from Durham University, UK. She obtained her PhD in inorganic biochemistry at Birkbeck College, University of London, studying under Peter Sadler. Having spent most of her career in scientific publishing, she is now at Taylor & Francis and is involved in developing chemical information products.

TABLE OF CONTENTS

Foreword.....	xi
Preface.....	xiii
Acknowledgments.....	xv
Editors.....	xvii

SECTION 1: AMINO ACIDS, PEPTIDES, AND PROTEINS

Properties of Amino Acids	3
Data on the Naturally Occurring Amino Acids	7
Structures and Symbols for Synthetic Amino Acids Incorporated into Synthetic Polypeptides	43
Unnatural Amino Acids for Incorporation into Proteins.....	53
Properties of the α -Keto Acid Analogs of Amino Acids	55
α,β -Unsaturated Amino Acids.....	57
Amino Acid Antagonists.....	59
Coefficients of Solubility Equations of Certain Amino Acids in Water	65
Heat Capacities, Absolute Entropies, and Entropies of Formation of Amino Acids and Related Compounds.....	67
Heat of Combustion, Enthalpy and Free Energy of Formation of Amino Acids and Related Compounds.....	69
Solubilities of Amino Acids in Water at Various Temperatures	71
Heats of Solution of Amino Acids in Aqueous Solution at 25°C	75
Free Energies of Solution and Standard Free Energy of Formation of Amino Acids in Aqueous Solution at 25°C.....	77
Far Ultraviolet Absorption Spectra of Amino Acids.....	79
UV Absorption Characteristics of <i>N</i> -Acetyl Methyl Esters of the Aromatic Amino Acids, Cystine and of <i>N</i> -Acetylcysteine	81
Numerical Values of the Absorbances of the Aromatic Amino Acids in Acid, Neutral and Alkaline Solutions	83
Luminescence of the Aromatic Amino Acids.....	89
Luminescence of Derivatives of the Aromatic Amino Acids.....	91
Luminescence of Proteins Lacking Tryptophan.....	93
Luminescence of Proteins Containing Tryptophan	95
Hydrophobicities of Amino Acids and Proteins	99
Chemical Specificity of Reagents for Protein Modification	115
Reagents for the Chemical Modification of Proteins	117
Protein pK Values.....	137
Protease Inhibitors and Protease Inhibitor Cocktails.....	141
Assay of Solution Protein Concentration.....	155
Spectrophotometric Determination of Protein Concentration in the Short-Wavelength Ultraviolet.....	161

SECTION 2: LIPIDS

A Comprehensive Classification System for Lipids.....	165
Properties of Fatty Acids and Their Methyl Esters.....	189
Densities, Specific Volumes, and Temperature Coefficients of Fatty Acids from C ₈ to C ₁₂	191
Composition and Properties of Common Oils and Fats.....	193
Androgens	199
Bile Acids	201
Corticoids.....	203
Estrogens.....	205
Progestogens	207
Sterols	209
Prostaglandins and Related Fatty-Acid Derived Materials	221

SECTION 3: VITAMINS AND COENZYMES

Properties of Vitamins.....	225
Biological Characteristics of Vitamins	237
Properties for Ascorbic Acid and Ascorbate-2-Sulfate	241
Vitamins.....	243
Vitamin Names Discarded.....	251

SECTION 4: NUCLEIC ACIDS

UV Spectral Characteristics and Acidic Dissociation Constants of 280 Alkyl Bases, Nucleosides, and Nucleotides.....	255
Ultraviolet Absorbance of Oligonucleotides Containing 2'- <i>O</i> -Methylpentose Residues	263

Spectrophotometric Constants of Ribonucleotides.....	265
Purines, Pyrimidines, Nucleosides, and Nucleotides: Physical Constants and Spectral Properties	269
Chemical Modification of Nucleic Acids.....	359
Transfection Technologies.....	373

SECTION 5: CARBOHYDRATES

Introduction to Carbohydrates.....	383
Natural Alditols, Inositols, Inososes, and Amino Alditols and Inosamines	407
Natural Acids of Carbohydrate Derivation.....	417
Natural Aldoses.....	431
Natural Ketoses	457
Carbohydrate Phosphate Esters.....	473
The Naturally Occurring Amino Sugars	491
Oligosaccharides (Including Disaccharides).....	499
Mucopolysaccharides (Glycosaminoglycans).....	533

SECTION 6: PHYSICAL AND CHEMICAL DATA

Recommendations for Nomenclature and Tables in Biochemical Thermodynamics.....	537
Standard Transformed Gibbs Energies of Formation for Biochemical Reactants	551
Enthalpy, Entropy, and Free Energy Values for Biochemical Redox Reactions.....	555
Oxidation-Reduction Potentials, Absorbance Bands and Molar Absorbance of Compounds Used in Biochemical Studies.....	557
Calorimetric ΔH Values Accompanying Conformational Changes of Macromolecules in Solution.....	565
Free Energies of Hydrolysis and Decarboxylation.....	579
Deci-Normal Solutions of Oxidation and Reduction Reagents	585
Guidelines for Potentiometric Measurements in Suspensions Part A. The Suspension Effect.....	587
Ionization Constants of Acids and Bases	595
Guidelines for NMR Measurements for Determination of High and Low pK_a Values	637
Measurement and Interpretation of Electrokinetic Phenomena	645
Measurement of pH Definition, Standards, and Procedures.....	675
General Comments on Buffers.....	693
List of Buffers.....	695
Brønsted Acidities.....	707
Measurement of pH.....	709
Buffer Solutions	715
Amine Buffers Useful for Biological Research	719
Preparation of Buffers for Use in Enzyme Studies	721
Buffer for Acrylamide Gels (Single-Gel Systems).....	725
Buffer for Acrylamide Gels with More Than One Layer	726
Starch Gels.....	729
Indicators for Volumetric Work and pH Determinations	731
Acid and Base Indicators.....	735
Specific Gravity of Liquids.....	739
Viscosity and Density Tables.....	743
A Listing of Log P Values, Water Solubility, and Molecular Weight for Some Selected Chemicals.....	747
Chemicals Commonly Used in Biochemistry and Molecular Biology and Their Properties	751
Common Detergents Used in Biochemical Research	811
Some Properties of Detergents and Surfactants Used in Biochemistry and Molecular Biology	813
Some Biological Stains and Dyes.....	819
Mordant Dyes	843
Metal Chelating Agents	847
Water	855
Stability of Solutions for GLP and cGMP Use.....	857
General Information on Spectroscopy.....	859
Microplates.....	861
Plastics	863
Chemical and Physical Properties of Various Commercial Plastics.....	869
Generic Source-Based Nomenclature for Polymers.....	871
Definitions of Terms Relating to Reactions of Polymers and to Functional Polymeric Materials	877
Definitions of Terms Related to Polymer Blends, Composites, and Multiphase Polymeric Materials.....	887
Organic Name Reactions Useful in Biochemistry and Molecular Biology.....	899
Enzymes in Synthetic Organic Chemistry	927

Therapeutic Enzymes939

Weights of Cells and Cell Constituents 943

Particle Diameter 945

Appendix A: Abbreviations and Acronyms 947

Appendix B: Glossary of Terms Useful in Biochemistry 959

Index..... 1075

Section I

Amino Acids, Peptides, and Proteins

Properties of Amino Acids	3
Data on the Naturally Occurring Amino Acids.....	7
Structures and Symbols for Synthetic Amino Acids Incorporated into Synthetic Polypeptides	43
Unnatural Amino Acids for Incorporation into Proteins	53
Properties of the α -Keto Acid Analogs of Amino Acids.....	55
α,β -Unsaturated Amino Acids.....	57
Amino Acid Antagonists.....	59
Coefficients of Solubility Equations of Certain Amino Acids in Water	65
Heat Capacities, Absolute Entropies, and Entropies of Formation of Amino Acids and Related Compounds	67
Heat of Combustion, Enthalpy and Free Energy of Formation of Amino Acids and Related Compounds.....	69
Solubilities of Amino Acids in Water at Various Temperatures.....	71
Heats of Solution of Amino Acids in Aqueous Solution at 25°C	75
Free Energies of Solution and Standard Free Energy of Formation of Amino Acids in Aqueous Solution at 25°C	77
Far Ultraviolet Absorption Spectra of Amino Acids.....	79
UV Absorption Characteristics of <i>N</i> -Acetyl Methyl Esters of the Aromatic Amino Acids, Cystine and of <i>N</i> -Acetylcysteine	81
Numerical Values of the Absorbances of the Aromatic Amino Acids in Acid, Neutral and Alkaline Solutions	83
Luminescence of the Aromatic Amino Acids.....	89
Luminescence of Derivatives of the Aromatic Amino Acids	91
Luminescence of Proteins Lacking Tryptophan	93
Luminescence of Proteins Containing Tryptophan	95
Hydrophobicities of Amino Acids and Proteins.....	99
Chemical Specificity of Reagents for Protein Modification	115
Reagents for the Chemical Modification of Proteins	117
Protein pK Values	137
Protease Inhibitors and Protease Inhibitor Cocktails.....	141
Assay of Solution Protein Concentration	155
Spectrophotometric Determination of Protein Concentration in the Short-Wavelength Ultraviolet	161

PROPERTIES OF AMINO ACIDS

This table gives selected properties of some important amino acids and closely related compounds. The first part of the table lists the 20 "standard" amino acids that are the basic constituents of proteins. The second part includes other amino acids and related compounds of biochemical importance. Within each part of the table the compounds are listed by name in alphabetical order. Structures are given in the following table.

Symbol : Three-letter symbol for the standard amino acids

M_r : Molecular weight

t_m : Melting point

pK_a , pK_b , pK_c , pK_d : Negative of the logarithm of the acid dissociation constants for the COOH and NH₂ groups (and, in some cases, other groups) in the molecule (at 25°C)

pI: pH at the isoelectric point

S: Solubility in water in units of grams of compound per kilogram of water; a temperature of 25°C is understood unless otherwise stated in a superscript. When quantitative data are not available, the notations sl.s. (for slightly soluble), s. (for soluble), and v.s. (for very soluble) are used.

V_2^0 : Partial molar volume in aqueous solution at infinite dilution (at 25°C)

Data on the enthalpy of formation of many of these compounds are included in the table "Heat of Combustion, Enthalpy and Free

Energy of Formation of Amino Acids and Related Compounds" on p. 69 of this Handbook. Absorption spectra and optical rotation data can be found in Reference 3. Partial molar volume is taken from Reference 5; other thermodynamic properties, including solubility as a function of temperature, are given in References 3 and 5. Most of the pK values come from References 1, 6, and 7.

References

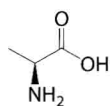
1. Dawson, R. M. C., Elliott, D. C., Elliott, W. H., and Jones, K. M., *Data for Biochemical Research*, Third Edition, Clarendon Press, Oxford, 1986.
2. O'Neil, Maryadele J., Ed., *The Merck Index, Fourteenth Edition*, Merck & Co., Rahway, NJ, 2006.
3. Sober, H. A., Ed., *CRC Handbook of Biochemistry. Selected Data for Molecular Biology*, CRC Press, Boca Raton, FL, 1968.
4. Voet, D., and Voet, J. G., *Biochemistry, Second Edition*, John Wiley & Sons, New York, 1995.
5. Hinz, H. J., Ed., *Thermodynamic Data for Biochemistry and Biotechnology*, Springer-Verlag, Heidelberg, 1986.
6. Fasman, G. D., Ed. *Practical Handbook of Biochemistry and Molecular Biology*, CRC Press, Boca Raton, FL, 1989.
7. Smith, R. M., and Martell, A. E., *NIST Standard Reference Database 46: Critically Selected Stability Constants of Metal Complexes Database*, Version 3.0, National Institute of Standards and Technology, Gaithersburg, MD, 1997.
8. Ramasami, P., *J. Chem. Eng. Data*, 47, 1164, 2002.

Symbol	Name	Mol. Form	M_r	$t_m/^{\circ}\text{C}$	pK_a	pK_b	pK_c	pK_d	pI	S/g kg ⁻¹	$V_2^0/\text{cm}^3 \text{mol}^{-1}$
Ala	L-Alanine	C ₃ H ₇ NO ₂	89.09	297	2.33	9.71			6.00	166.9	60.54
Arg	L-Arginine	C ₆ H ₁₄ N ₄ O ₂	174.20	244	2.03	9.00	12.10		10.76	182.6	127.42
Asn	L-Asparagine	C ₄ H ₈ N ₂ O ₃	132.12	235	2.16	8.73			5.41	25.1	78.0
Asp	L-Aspartic acid	C ₄ H ₇ NO ₄	133.10	270	1.95	9.66	3.71		2.77	5.04	74.8
Cys	L-Cysteine	C ₃ H ₇ NO ₂ S	121.16	240	1.91	10.28	8.14		5.07	v.s.	73.45
Gln	L-Glutamine	C ₅ H ₁₀ N ₂ O ₃	146.14	185	2.18	9.00			5.65	42.5	
Glu	L-Glutamic acid	C ₅ H ₉ NO ₄	147.13	160	2.16	9.58	4.15		3.22	8.6	89.85
Gly	Glycine	C ₂ H ₅ NO ₂	75.07	290	2.34	9.58			5.97	250.2	43.26
His	L-Histidine	C ₆ H ₉ N ₃ O ₂	155.15	287	1.70	9.09	6.04		7.59	43.5	98.3
Ile	L-Isoleucine	C ₆ H ₁₃ NO ₂	131.17	284	2.26	9.60			6.02	34.2	105.80
Leu	L-Leucine	C ₆ H ₁₃ NO ₂	131.17	293	2.32	9.58			5.98	22.0	107.77
Lys	L-Lysine	C ₆ H ₁₄ N ₂ O ₂	146.19	224	2.15	9.16	10.67		9.74	5.8	108.5
Met	L-Methionine	C ₅ H ₁₁ NO ₂ S	149.21	281	2.16	9.08			5.74	56	105.57
Phe	L-Phenylalanine	C ₉ H ₁₁ NO ₂	165.19	283	2.18	9.09			5.48	27.9	121.5
Pro	L-Proline	C ₅ H ₉ NO ₂	115.13	221	1.95	10.47			6.30	1622	82.76
Ser	L-Serine	C ₃ H ₇ NO ₃	105.09	228	2.13	9.05			5.68	250	60.62
Thr	L-Threonine	C ₄ H ₉ NO ₃	119.12	256	2.20	8.96			5.60	98.1	76.90
Trp	L-Tryptophan	C ₁₁ H ₁₂ N ₂ O ₂	204.23	289	2.38	9.34			5.89	13.2	143.8
Tyr	L-Tyrosine	C ₉ H ₁₁ NO ₃	181.19	343	2.24	9.04	10.10		5.66	0.46	
Val	L-Valine	C ₅ H ₁₁ NO ₂	117.15	315	2.27	9.52			5.96	88	90.75
	N-Acetylglutamic acid	C ₇ H ₁₁ NO ₅	189.17	199						s.	
	N ⁶ -Acetyl-L-lysine	C ₈ H ₁₆ N ₂ O ₃	188.22	265	2.12	9.51					
	β-Alanine	C ₃ H ₇ NO ₂	89.09	200	3.51	10.08				723.6	58.28

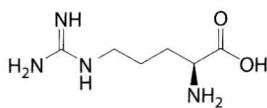
PROPERTIES OF AMINO ACIDS (Continued)

Name	Mol. Form	M_r	$t_m/^\circ\text{C}$	pK_a	pK_b	pK_c	pK_d	pI	$S/\text{g kg}^{-1}$	$V_2^0/\text{cm}^3 \text{mol}^{-1}$
2-Aminoadipic acid	$\text{C}_6\text{H}_{11}\text{NO}_4$	161.16	207	2.14	4.21	9.77		3.18	2.2 ⁴⁰	
D,L-2-Aminobutanoic acid	$\text{C}_4\text{H}_9\text{NO}_2$	103.12	304	2.30	9.63			6.06	210	75.6
D,L-3-Aminobutanoic acid	$\text{C}_4\text{H}_9\text{NO}_2$	103.12	194.3	3.43	10.05			7.30	1250	76.3
4-Aminobutanoic acid	$\text{C}_4\text{H}_9\text{NO}_2$	103.12	203	4.02	10.35				971	73.2
10-Aminodecanoic acid	$\text{C}_{10}\text{H}_{21}\text{NO}_2$	187.28	188.5							167.3
7-Aminoheptanoic acid	$\text{C}_7\text{H}_{15}\text{NO}_2$	145.20	195						v.s.	120.0
6-Aminohexanoic acid	$\text{C}_6\text{H}_{13}\text{NO}_2$	131.17	205					7.29	863	104.2
L-3-Amino-2-methylpropanoic acid	$\text{C}_4\text{H}_9\text{NO}_2$	103.12	185						s.	
2-Amino-2-methylpropanoic acid	$\text{C}_4\text{H}_9\text{NO}_2$	103.12	335	2.36	10.21			5.72	137	77.55
9-Aminononanoic acid	$\text{C}_9\text{H}_{19}\text{NO}_2$	173.26	191							151.3
8-Aminooctanoic acid	$\text{C}_8\text{H}_{17}\text{NO}_2$	159.23	192							136.1
5-Amino-4-oxopentanoic acid	$\text{C}_5\text{H}_9\text{NO}_3$	131.13	118	4.05	8.90					
5-Aminopentanoic acid	$\text{C}_5\text{H}_{11}\text{NO}_2$	117.15	157 dec						s.	87.6
o-Anthranilic acid	$\text{C}_7\text{H}_7\text{NO}_2$	137.14	146	2.05	4.95				3.5 ¹⁴	
Azaserine	$\text{C}_5\text{H}_7\text{N}_3\text{O}_4$	173.13	150		8.55				v.s.	
Canavanine	$\text{C}_5\text{H}_{12}\text{N}_4\text{O}_3$	176.17	172	2.50	6.60	9.25		7.93	v.s.	
L- γ -Carboxyglutamic acid	$\text{C}_6\text{H}_9\text{NO}_6$	191.14	167	1.70	9.90	4.75	3.20			
Carnosine	$\text{C}_9\text{H}_{14}\text{N}_4\text{O}_3$	226.23	260	2.51	9.35	6.76			322	
Citrulline	$\text{C}_6\text{H}_{13}\text{N}_3\text{O}_3$	175.19	222	2.32	9.30			5.92	s.	
Creatine	$\text{C}_4\text{H}_9\text{N}_3\text{O}_2$	131.13	303	2.63	14.30				16	
L-Cysteic acid	$\text{C}_3\text{H}_7\text{NO}_5\text{S}$	169.16	260	1.89	8.70	1.30			v.s.	
L-Cystine	$\text{C}_6\text{H}_{12}\text{N}_2\text{O}_4\text{S}_2$	240.30	260	1.50	8.80	2.05	8.03		0.11	
2,4-Diaminobutanoic acid	$\text{C}_4\text{H}_{10}\text{N}_2\text{O}_2$	118.13	118.1	1.85	8.24	10.44		9.27	s.	
3,5-Dibromo-L-tyrosine	$\text{C}_9\text{H}_9\text{Br}_2\text{NO}_3$	338.98	245						2.72	
3,5-Dichloro-L-tyrosine	$\text{C}_9\text{H}_9\text{Cl}_2\text{NO}_3$	250.08	247						1.97	
3,5-Diiodo-L-tyrosine	$\text{C}_9\text{H}_9\text{I}_2\text{NO}_3$	432.98	213	2.12	9.10	6.16			0.62	
Dopamine	$\text{C}_8\text{H}_{11}\text{NO}_2$	153.18			10.36	8.88			s.	
L-Ethionine	$\text{C}_6\text{H}_{13}\text{NO}_2\text{S}$	163.24	273	2.18	9.05	13.10				
N-Glycylglycine	$\text{C}_4\text{H}_8\text{N}_2\text{O}_3$	132.12	263	3.13	8.10				225	
Guanidinoacetic acid	$\text{C}_3\text{H}_7\text{N}_3\text{O}_2$	117.11	282	2.82					5	
Histamine	$\text{C}_5\text{H}_9\text{N}_3$	111.15	83		9.83	6.11			v.s.	
L-Homocysteine	$\text{C}_4\text{H}_9\text{NO}_2\text{S}$	135.19	232	2.15	8.57	10.38		5.55	s.	
Homocystine	$\text{C}_8\text{H}_{16}\text{N}_2\text{O}_4\text{S}_2$	268.35	264	1.59	9.44	2.54	8.52		0.2	
L-Homoserine	$\text{C}_4\text{H}_9\text{NO}_3$	119.12	203	2.27	9.28			6.17	1100	
3-Hydroxy-D,L-glutamic acid	$\text{C}_5\text{H}_9\text{NO}_5$	163.13	209					3.28		
5-Hydroxylysine	$\text{C}_6\text{H}_{14}\text{N}_2\text{O}_3$	162.19		2.13	8.85	9.83		9.15		
trans-4-Hydroxy-L-proline	$\text{C}_5\text{H}_9\text{NO}_3$	131.13	274	1.82	9.47			5.74	361	84.49
L-3-Iodotyrosine	$\text{C}_9\text{H}_{10}\text{INO}_3$	307.08	205	2.20	9.10	8.70			sl.s.	
L-Kynurenine	$\text{C}_{10}\text{H}_{12}\text{N}_2\text{O}_3$	208.21	194						sl.s.	
L-Lanthionine	$\text{C}_6\text{H}_{12}\text{N}_2\text{O}_4\text{S}$	208.24	294						1.5	
Levodopa	$\text{C}_9\text{H}_{11}\text{NO}_4$	197.19	277	2.32	8.72	9.96	11.79		5 ²⁰	
L-1-Methylhistidine	$\text{C}_7\text{H}_{11}\text{N}_3\text{O}_2$	169.18	249	1.69	8.85	6.48			200	
L-Norleucine	$\text{C}_6\text{H}_{13}\text{NO}_2$	131.17	301	2.31	9.68			6.09	15	107.7
L-Norvaline	$\text{C}_5\text{H}_{11}\text{NO}_2$	117.15	307	2.31	9.65				107	91.8
L-Ornithine	$\text{C}_5\text{H}_{12}\text{N}_2\text{O}_2$	132.16	140	1.94	8.78	10.52		9.73	v.s.	
O-Phosphoserine	$\text{C}_3\text{H}_8\text{NO}_6\text{P}$	185.07	166	2.14	9.80	5.70				
L-Pyroglutamic acid	$\text{C}_5\text{H}_7\text{NO}_3$	129.12	162	3.32						
Sarcosine	$\text{C}_3\text{H}_7\text{NO}_2$	89.09	212	2.18	9.97				428	
Taurine	$\text{C}_2\text{H}_7\text{NO}_3\text{S}$	125.15	328	-0.3	9.06				105	
L-Thyroxine	$\text{C}_{15}\text{H}_{11}\text{I}_4\text{NO}_4$	776.87	235	2.20	10.01	6.45			sl.s.	

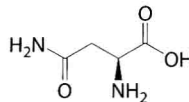
STRUCTURES OF COMMON AMINO ACIDS



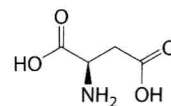
L-Alanine (Ala)



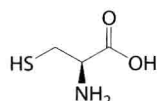
L-Arginine (Arg)



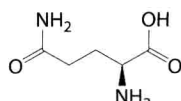
L-Asparagine (Asn)



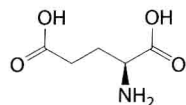
L-Aspartic acid (Asp)



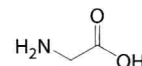
L-Cysteine (Cys)



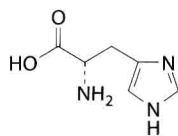
L-Glutamine (Gln)



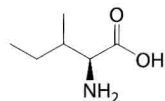
L-Glutamic acid (Glu)



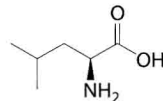
Glycine (Gly)



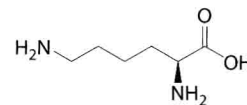
L-Histidine (His)



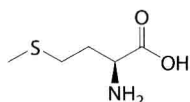
L-Isoleucine (Ile)



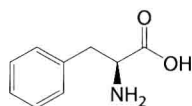
L-Leucine (Leu)



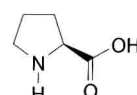
L-Lysine (Lys)



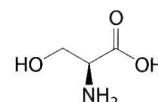
L-Methionine (Met)



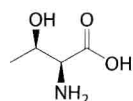
L-Phenylalanine (Phe)



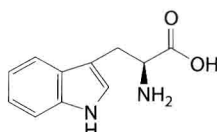
L-Proline (Pro)



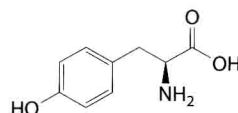
L-Serine (Ser)



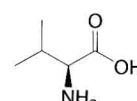
L-Threonine (Thr)



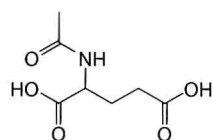
L-Tryptophan (Trp)



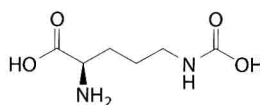
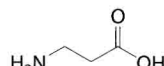
L-Tyrosine (Tyr)



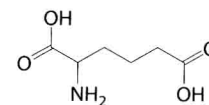
L-Valine (Val)



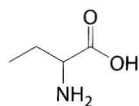
N-Acetylglutamic acid

N⁶-Acetyl-L-lysine

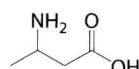
β-Alanine



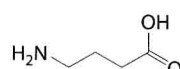
2-Aminoadipic acid



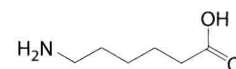
DL-2-Aminobutanoic acid



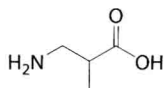
DL-3-Aminobutanoic acid



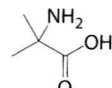
4-Aminobutanoic acid



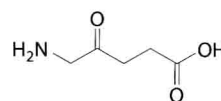
6-Aminohexanoic acid



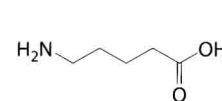
L-3-Amino-2-methylpropanoic acid



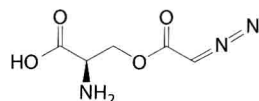
2-Amino-2-methylpropanoic acid



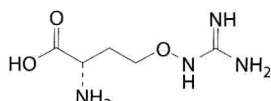
5-Amino-4-oxopentanoic acid



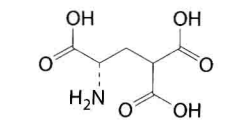
5-Aminopentanoic acid



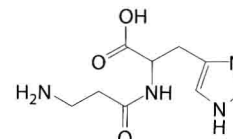
Azaserine



Canavanine



L-γ-Carboxyglutamic acid



Carnosine