NATIONAL ACADEMY OF SCIENCES

# CARL NIEMANN

*1908—1964*

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*A Biographical Memoir by*

JOHN D. ROBERTS



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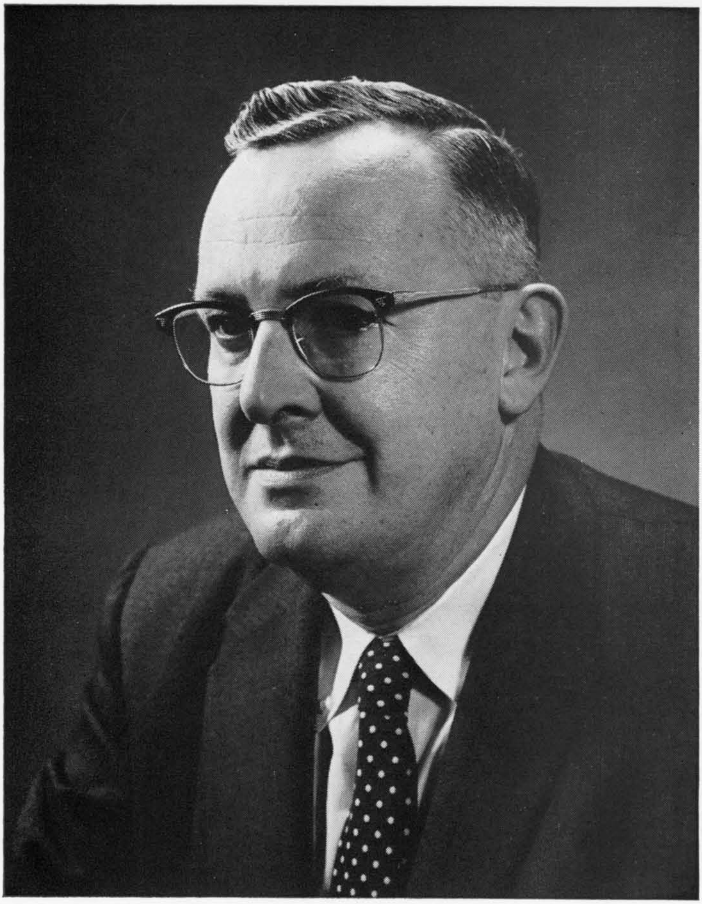

Carl Neumann

# CARL NIEMANN

*July 6, 1908–April 29, 1964*

BY JOHN D. ROBERTS

IN AN ERA when professors of scientific subjects are under heavy pressures to contribute simultaneously to research, to education, to the advancement of the scientific society, and to the advancement of society in general, the life of Carl Niemann provides a fine example of how individualism, tempered and disciplined by responsibility, can lead to an enviable balance of achievements—so much so as to merit description of the man as an "ideal" academic scientist.

Carl Niemann was born on July 6, 1908, in St. Louis, Missouri, the only child of Julius Henry and Ella Danner Niemann. Julius Niemann was a salesman for a local brewery, a large man, fond of hunting, and a strict disciplinarian. Carl took after his mother, to some degree in appearance, but more in having an outwardly quiet temperament, an instinctive feeling for others, and a high degree of manual dexterity. The available accounts indicate that his early childhood was not unusual, although it seems that visits to the households of his mother's relatives often provided a welcome relief from the strictness with which his father regulated his homelife. On entering Cleveland High School in St. Louis, Carl was so competent at carpentry that he started in the manual training rather than the college preparatory curriculum. His orientation changed when he took high school chemistry, as a result of which his interest was kindled to the point that he set up a rather sizable laboratory in his home basement. In this he was encouraged by his uncle, George Danner, who procured chemicals and supplies for him from the Meyer Brothers Drug Company. A crisis seems to have occurred after his graduation from high school because his father wanted him to enroll in business school to learn accounting and this was far from his own inclinations. The intervention of his uncle seems to have been decisive in helping him move toward chemistry by way of arranging with Edgar Queeny, president and founder of Monsanto Chemical Company as well as a onetime employee of Meyer Brothers Drug Company, for a trial position as chemist in the Monsanto laboratories. During this period Niemann worked in his basement laboratory on weekends and attended Washington University night school. In 1926 he entered the University of Wisconsin, but when his father died in 1928 he came back to St. Louis to work another year for Monsanto while helping his mother adjust to their new circumstances.

The research career of Carl Niemann began after his return to Wisconsin in 1929 when he started his association with Karl Paul Link. The next five years, in his progression from undergraduate, to graduate student, to postdoctoral fellow, led to thirteen papers, all concerned with carbohydrates—being principally fundamental studies of the chemistry of uronic acids, substances which occur naturally along with cellulose and starch. Although he and Link were rather different types, they worked very well together and formed a lasting friendship. The last year of Niemann's Wisconsin career began with his marriage to Mary Parkhurst on August 15, 1934. Then, in 1935, the young couple moved to New York for a two-year stay at the Rockefeller Institute. Here, in collaboration with Max Bergmann, Niemann started the work on proteins and enzymes which was to become his major scientific interest.

It was an exciting time in protein research. Accurate analyses of the amino acid compositions of reasonably pure proteins were just being obtained, and Niemann and Bergmann were imbued with the notion that there could be a high degree of regularity in protein composition based on simple numerical rules. Thus, in several papers published between 1936 and 1939, they advocated that the numbers of amino acids in proteins might in general follow a stoichiometric law of $2^m \times 3^n$ where $m$ and $n$ are positive whole numbers. The published discussion of a paper given by Niemann on this subject at a 1938 Cold Spring Harbor symposium indicates substantial differences of opinion on the validity of the hypothesis, with Wrinch, White, and Mirsky in opposition. Niemann's replies were at all times beautifully phrased but had to be largely defensive because of the scarcity of accurate composition data.

Niemann's last general paper on protein structure was published with Linus Pauling in 1939 and was a scathing (and effective) critique of the "cyclol" theory of protein structure proposed by F. C. Frank in 1933 and developed subsequently in detail by D. M. Wrinch. The general question was whether peptide chains are bonded to one another by hydrogen bonds or by addition of N-H of one chain to C=O of another; and the particular question was whether X-ray diffraction data obtained by Dorothy Crowfoot (Hodgkins) on zinc insulin could be interpreted as was done by Wrinch and Irving Langmuir, in favor of a cyclol-type structure. In the paper with Pauling, not much is said about the stoichiometry of amino acids in proteins and one has the feeling that Niemann was no longer prepared to defend the thesis that his earlier hypothesis was a general one. Pauling and Niemann did point out that, if the number of the residues along the main chain in simple proteins turns out to be 288 ($2^5 \times 3^2$), the reason must be biochemical in origin rather than deriving from a physical factor providing special stability for 288 residues.

After two years at the Rockefeller Institute, Niemann accepted a position as assistant professor of organic chemistry at the California Institute of Technology but took a leave of absence to spend a year at University College Hospital Medical School in London as a Rockefeller Foundation Fellow. Then, in 1937, he and his wife moved to Pasadena, where he was to spend the rest of his life.

By the time Niemann came to Caltech, the Gates and Crellin Laboratories, under the leadership first of A. A. Noyes and then of Linus Pauling, had become world famous in physical and inorganic chemistry. Among the professors, besides Pauling, were William N. Lacey, Richard C. Tolman, Roscoe G. Dickinson, and Don M. Yost, and at Niemann's rank as assistant professor were also Arnold O. Beckman, Richard M. Badger, and Ernest H. Swift. Up to 1937, almost all of the teaching and research in organic chemistry was carried on by Howard J. Lucas, who was an excellent researcher and a leader in America in developing the new field of physical organic chemistry. Niemann's appointment was made possible by a special grant from the Rockefeller Foundation to provide more balance in the organic area and fitted in with Pauling's growing interest in molecular biology.

During his first few years at Caltech, Niemann carried a moderate teaching load—five one-term courses each year—and began a program of research on compounds related to thyroxine, the thyroid principle; on the structure of sphingosine, a prevalent component of nerve tissue; and on histamine action. The work in thyroxine and histamine action was aimed at discovering the structural requirements for biological activity.

Shortly after the United States entered World War II, Niemann was made an official investigator for the National Defense Research Council and in partnership with Ernest H. Swift carried on an extensive research program on analytical methods for chemical warfare agents. Particular emphasis was placed on procedures for rapid identification of new war gases which it was feared might be suddenly introduced on the battlefields or in cities by aerial attack. The work was carried on for Division 9 of the NDRC and was highly successful although, fortunately, its practical application in wartime work was primarily for identification of war gases manufactured by the Germans and uncovered by our invasion forces but not actually used in combat. The later stages of the NDRC work involved intensive field trials and Niemann spent much time at testing stations in Panama and Florida. Finally, in 1944 he served for several months as consultant to the General Headquarters Staff in the Southwest Pacific area. He was awarded a Presidential Certificate of Merit for his contributions to the war effort.

The postwar phase of Niemann's work was marked by the beginnings of his research on the action of the protolytic enzyme, α-chymotrypsin, one of the most fascinating, and as yet unsolved, problems of organic chemistry. The choice of this enzyme for study was not due to luck or a haphazard guess. Niemann recognized that α-chymotrypsin, although an extremely complex substance of unknown structure, was at least relatively stable and reproducible with a rather nonspecific mode of action. The relative nonspecificity of action meant that wholly artificial substances could be "digested" by the enzyme, and through measurements of the rates of these digestive-type processes, in relation to the structures of the substrates supplied, it was hoped to discover how the enzyme worked. The procedure was an essentially topological one and, in fact, something like trying to deduce the eating apparatus and habits of a creature living in a cave by throwing in variously shaped pieces of different kinds of foods and seeing which are consumed most readily, if at all.

The work in α-chymotrypsin led to more than ninety research publications in about fifteen years, one of the most important being a summary article published in *Science* in March 1964. Niemann's view of his achievements in the research on chymotrypsin was a characteristically modest one and was laid out in the conclusion of his article in *Science*:

"In 1906 Fischer described the approach to elucidation of the chemical synthesis of a protein in terms that might be applied today to elucidation of the mechanism of action of an enzyme. The approach, he said, is that of a pedestrian who 'seeks his way step by step with careful attentiveness and who must examine many roads until he has found the right one. On his long and troublesome travels, not only does he learn to recognize completely the geography and topography of the country, but also he becomes intimate with the tongue and culture of its inhabitants. When he finally has reached his goal, he is able to locate himself properly in every corner of the country and this will be possible for other people also if he writes a book about it.' As for elucidation of the mechanism of action of $\alpha$-chymotrypsin, the pedestrian has barely begun his journey, and this review is his first letter home."

The spirit in which Niemann's work on chymotrypsin-induced reactions was carried out was almost as important as the specific achievements. There was no striving for a quick, clever solution to the mechanistic problem but instead the approach was meticulously designed to give a broad spectrum of results with which theoretical approaches could be tested. The emphasis was on the determination of accurate values of experimental reaction-rate parameters characteristic of a variety of substrates and, particularly in the early stages, there was little attempt to discuss the mechanistic implications of the results.

The typical thoroughness of Niemann's work is illustrated by a statement from his first major paper with Huang on chymotrypsin in 1951:

"In this study, consideration was given to (a) the possibility of interaction of the enzyme with the buffer components, (b) the dependence of the activity of the enzyme on the pH of the reaction system, (c) the possibility of inhibition of the hydrolytic reaction by one or both of the hydrolysis products, (d) the development of suitable rate expressions and the determination of rate constants and (e) the possibility of the inhibition of the hydrolysis of the above substrates by their D-antipodes."

Later papers developed other important aspects of chymotrypsin methodology, including ways of analyzing the rate curves and the effects on the rates of salts, nonaqueous solvents, inhibitors, dimerization of the enzyme, and even adsorption of the enzyme on the walls of the containers. These studies were especially significant in showing the limitations which have to be placed on comparisons drawn between results collected under different experimental conditions.

Niemann had very clear ideas about the practice of laboratory work. Although several generations of students used essentially the same instruments and methods, he refused to set up standard procedures. It was his conviction that absence of standard procedure was some protection against determinate errors which otherwise might avoid detection. In addition, he would not hire technicians to do any of the work although some of the rate measurements seemed repetitive to his co-workers.

A considerable breakthrough came in 1960 with the discovery that the normal relative stereospecificity of chymotrypsin which markedly favors hydrolysis of L- over D-amino acid derivatives could be overturned by suitable substituent groups. The consequences of this discovery were developed in considerable detail by Niemann and Hein. Of particular importance was the concept of "wrong-way" binding which emphasizes that enzyme-substrate complexes may be combined at the active site in such a way as to be unproductive for the normal hydrolysis reaction.

The value of this hypothesis lies in its ability to explain why there has been no clear correlation between how firmly substrates of different structures are bound by the enzyme and the rates at which they hydrolyze. The hypothesis was further developed by assuming that relative affinities could be assigned to the substituent groups which are found in different substrates for various interaction sites in the enzyme—the aim being to permit prediction of the favored orientation of a substrate at the active site which, of course, might or might not be favorable for hydrolysis.

These ideas were not developed without opposition, and many of the Niemann papers either involved long battles with unsympathetic referees or contained detailed defenses of ideas attacked by critics. In these, Niemann was unfailingly courteous, but his command of language was such that a courteous reply could be incisively, if not stingingly, to the point.

The professional stature of a scientist can usually be established rather well from his published work provided reasonable account is taken of the mood of the times in which it was accomplished. Personal stature is often more ephemeral, having to be based on testimony deriving from recollections of close, or not so close, associates in the absence of soul-searching autobiographical material. Carl Niemann was not one who left a mass of heterogeneous memorabilia for posterity to use in constructing a personal image. Although he died wholly unexpectedly, just before he was to depart on a European vacation, his correspondence files were almost completely bare, it being his custom after answering a letter to consign both the letter and the carbon of his reply to the wastebasket. In striking contrast, he had very complete files of his reprints and manuscripts, often including early as well as final versions of his papers. There can be no clearer message of what the man himself regarded as important.

Carl Niemann in middle life was a good-looking man of somewhat more than medium height with an unostentatious, urbane appearance and an unusually pleasant and calm speaking voice. He was not a man who bustled or became outwardly excited and yet, in talking with him, one could sense a considerable inner tension and drive. He was a highly effective person. His less efficient colleagues never ceased to marvel at how he worked day after day (and many evenings) with his office door wide open. He always had a cheerful welcome for anyone wishing to consult with him, but as soon as the business at hand was over, one sensed he was, while remaining completely polite, beginning to think about the next phrase of the manuscript before him. He was a craftsman of scientific writing; each paper was written, rewritten, and rewritten again before he was satisfied. He usually worked on one thing at a time—in the midst of an important paper, letters went unanswered, forms remained uncompleted; only the business one could transact with him orally made much headway.

A picture of Niemann as a strongly independent, research-centered scientist would be quite incomplete. He was tenaciously independent, even if quietly so, but at the same time he believed that independence in an academic environment carried with it the obligation to be responsible, and in every commitment he took on he was always completely responsible. He disliked administrative work but he was a fine administrator, having for many years heavy responsibility as the Chairman of the Divisional Graduate Committee. It was administration on his own terms—he had independence of action in an important but limited area and, furthermore, the work was largely seasonal, leaving him with much free time for his research. In addition, he was in almost constant demand for service on Caltech committees and he was exceptionally effective in such work, not only because of his sensitivity to other people's ideas and difficulties, but also because of his rare sense of humor which was particularly useful for reducing arguments to their proper perspective.

Niemann was elected to the National Academy of Sciences in 1952 and was very interested in its affairs. He attended almost every annual meeting and served during the last two years before his death as Chairman of the Chemistry Section. For ten years he was a member of the Editorial Board of *Organic Reactions,* an annual collection of review chapters on important synthetic methods. It was a tedious job but was suited to his habits by virtue of being seasonal and was rewarding through association with the other editors, particularly Roger Adams of the University of Illinois, who founded the series in 1942.

Niemann had many interests outside of his scientific work. He read widely and had a detailed knowledge of the history of the Civil War. He loved the outdoors and enjoyed traveling with his wife and two daughters. Under the guidance of his good friend, Carl S. Marvel, Niemann became an ardent and expert birdwatcher, and at one time or another he sighted most of the important species of the land and water birds of the United States.

Carl Niemann was a scholar and a scientist of the first rank. He was devoted to the principles of both academic freedom and academic responsibility. His legacy is a corps of superbly trained and loyal students, a deeper understanding of the chemistry of life, and the many results of his efforts on behalf of the California Institute of Technology. He died very suddenly at the height of his career. His many friends will not soon forget the way in which he enriched their lives and the scientific profession.

## BIBLIOGRAPHY

*KEY TO ABBREVIATIONS*

Anal. Chem. = Analytical Chemistry
Arch. Biochem. = Archives of Biochemistry
Arch. Biochem. Biophys. = Archives of Biochemistry and Biophysics
Biochim. Biophys. Acta = Biochimica et Biophysica Acta
Cold Spring Harbor Symp. Quant. Biol. = Cold Spring Harbor Symposia on Quantitative Biology
J. Am. Chem. Soc. = Journal of the American Chemical Society
J. Biol. Chem. = Journal of Biological Chemistry
J. Ind. Eng. Chem., Anal. Ed. = Journal of Industrial and Engineering Chemistry, Analytical Edition
J. Nat. Cancer Inst. = Journal of the National Cancer Institute
J. Org. Chem. = Journal of Organic Chemistry
Proc. Nat. Acad. Sci. = Proceedings of the National Academy of Sciences
Proc. Soc. Exp. Biol. Med. = Proceedings of the Society for Experimental Biology and Medicine

1930

With K. P. Link. The action of weak mineral acids on uronic acids. J. Am. Chem. Soc., 52:2474-80.

1932

With K. P. Link. Synthesis of the hexuronic acids. I. The synthesis of DL-galacturonic acid from mucic acid. J. Biol. Chem., 95:203-11.

1933

With K. P. Link. Synthesis of the hexuronic acids. II. The synthesis of D-mannuronic acid from D-mannosaccharic acid. J. Biol. Chem., 100:407-13.

With E. Schoeffel and K. P. Link. Substituted hydrazine derivatives of the hexuronic acids. Phenylhydrazine and *p*-bromophenylhydrazine derivates of D-galacturonic acid and *p*-bromophenylhydrazine derivates of D-mannuronic acid. J. Biol. Chem., 101:337-58.

1934

With S. Karjala and K. P. Link. Synthesis of the hexuronic acids. III. The synthesis of DL-alluronic acid from allomucic acid. J. Biol. Chem., 104:189-94.

With K. P. Link. Synthesis of the hexuronic acids. IV. The synthesis of D-galacturonic acid from D-galactose. J. Biol. Chem., 104:195-204.

With K. P. Link. The composition of an aldobionic acid from flaxseed mucilage. J. Biol. Chem., 104:205-6.

With R. J. McCubbin and K. P. Link. Synthesis of the hexuronic acids. V. The synthesis of L-mannuronic acid from L-mannosaccharic acid. J. Biol. Chem., 104:737-41.

With K. P. Link. Synthesis of the hexuronic acids. VI. The synthesis of L-galacturonic acid from L-galactose. J. Biol. Chem., 104:743-46.

With K. P. Link. Synthesis of the hexuronic acids. VII. The synthesis of L-glucuronic acid and the resolution of DL-galacturonic acid. J. Biol. Chem., 106:773-81.

1935

With R. H. Roberts and K. P. Link. Isolation and determination of starch in plant tissue. Plant Physiology, 10:579-80.

With R. H. Roberts and K. P. Link. The isolation and characterization of a starch polysaccharide from the woody tissue of the apple tree *(Malus malus)*. J. Biol. Chem., 110:727-37.

1936

With M. Bergmann. On blood fibrin. A contribution to the problem of protein structure. J. Biol. Chem., 115:77-85.

With A. B. Anderson and K. P. Link. The isolation and characterization of a starch polysaccharide from the leaf tissue of the apple tree *(Malus malus)*. J. Biol. Chem., 116:447-55.

1937

With M. Bergmann. On the structure of proteins. Cattle hemoglobin, egg albumin, cattle fibrin, and gelatin. J. Biol. Chem., 118:301-14.

With M. Bergmann. On proteolytic enzymes. XIV. On the general nature of the enzymatic degradation of proteins. J. Biol. Chem., 118:781-87.

With M. Bergmann. Newer biological aspects of protein chemistry. Science, 86:187-90.

1938

With M. Bergmann. On the structure of silk fibroin. J. Biol. Chem., 122:577-96.

With W. H. Stein and M. Bergmann. The quantitative determination of amino acids. J. Am. Chem. Soc., 60:1703.

With M. Bergmann. The chemistry of amino acids and proteins. Annual Review of Biochemistry, 7:99-124.

The chemistry of protein structure. Cold Spring Harbor Symp. Quant. Biol., 6:58-66.

1939

The constitution of secretin. Proc. Nat. Acad. Sci., 25:267-69.

With L. Pauling. The structure of proteins. J. Am. Chem. Soc., 61: 1860-67.

1940

With J. English, Jr., and J. F. Mead. The synthesis of 3, 5-difluoro- and 3-fluoro-5-iodo-DL-tyrosine. J. Am. Chem. Soc., 62:350-54.

With C. E. Redemann. The diliturates (5-nitrobarbiturates) of some physiologically important bases. J. Am. Chem. Soc., 62: 590-93.

With V. Danford. Apparatus for semimicrodetermination of carbon and hydrogen. J. Ind. Eng. Chem., Anal. Ed., 12:563-66.

With J. T. Hays. The structure of N-acetyl-D-glucosylamine. J. Am. Chem. Soc., 62:2960-61.

1941

With J. F. Mead and A. A. Benson. The synthesis of 3′-fluoro-DL-thyronine and some of its iodinated derivatives. J. Am. Chem. Soc., 63:609-11.

With C. E. Redemann. The synthesis of DL-3, 5-diiodo-4(2′, 4′-diiodo-3′-hydroxyphenoxy)-phenylalanine, a physiologically inactive isomer of thyroxine. J. Am. Chem. Soc., 63:1549-52.

Isomerization of sphingosine sulfate. J. Am. Chem. Soc., 63:1763-64.

With A. A. Benson and J. F. Mead. The synthesis of 3′, 5′-difluoro-DL-thyronine and 3, 5-diiodo-3′, 5′-difluoro-DL-thyronine. J. Am. Chem. Soc., 63:2204-8.

With J. F. Mead. The synthesis of DL-3, 5-diiodo-4-(3′, 5′-diiodo-2′-hydroxyphenoxy)-phenylalanine, a physiologically active isomer of thyroxine. J. Am. Chem. Soc., 63:2685-87.

A new hydrolysis product derived from bovine cerebral and spinal tissue. J. Am. Chem. Soc., 63:3535.

1942

With P. L. Nichols, Jr. The synthesis of D-erythro- and D-threo-$\alpha$-amino-$\beta$,$\gamma$-dihydroxy-N-butyric acids. J. Biol. Chem., 143:191-202.

With C. D. Wagner. The synthesis of DL-1, 2-octadecanediol and several of its homologs. J. Org. Chem., 7:227-32.

With R. N. Lewis and J. T. Hays. The synthesis of the three isomeric DL-*beta*-pyridylalanines. J. Am. Chem. Soc., 64:1678-82.

With J. T. Hays. The relation between structure and histamine-like activity. J. Am. Chem. Soc., 64:2288-89.

With C. E. Redemann. 2, 3, 4, 6-tetraacetyl-$\alpha$-D-glucopyranosyl bromide (acetobromoglucose). Organic Syntheses, 22:1.

1943

With J. T. Hays. The synthesis of aldehydes from acylhydrazides. J. Am. Chem. Soc., 65:482-83.

With A. A. Benson and J. F. Mead. The contiguously substituted dihydroxyaminoalkanes. I. The synthesis of 1-amino-2, 3-dihydroxy-*n*-hexane and 1, 2-dihydroxy-3-amino-*n*-hexane. J. Org. Chem., 8:397-404.

1944

With G. E. McCasland. The synthesis of 2′, 6′-diiodo-DL-thyronine. J. Am. Chem. Soc., 66:1870-72.

With G. E. McCasland. 3, 5-Diiodo-4-(4′-hydroxyphenoxy)-hippuric acid and 3, 5-diiodo-4-(3′, 5′-diiodo-4′-hydroxyphenoxy)-hippuric acid. J. Am. Chem. Soc., 66:1984.

1945

With J. T. Hays. Studies on the N-acetyl-D-glucosylamine of Hockett and Chandler. J. Am. Chem. Soc., 67:1302-4.

1946

With M. M. Rapport. The toxicity of 3-fluoro-D(+)- and l(−)-tyrosine. J. Am. Chem. Soc., 68:1671.

With C. T. Redemann. The reduction of ethyl $\alpha$-benzylamino-*beta*-methoxy-*n*-caproate with sodium and butyl alcohol. J. Am. Chem. Soc., 68:1932-34.

With G. Holzman, E. Bennett, and D. Brown. A colorimetric method for the estimation of the activity of substances inhibiting the isoagglutination of blood group A cells. Arch. Biochem., 11:415-32.

1947

With J. W. Sease and E. H. Swift. The amperometric titration of thiodiglycol with electrolytically generated bromine. J. Ind. Eng. Chem., Anal. Ed., 19:197-200.

With C. Gould, Jr., and G. Holzman. Determination of the vapor pressure of liquids on a milligram scale. J. Ind. Eng. Chem., Anal. Ed., 19:204-6.

With P. A. Shaffer, Jr., and P. S. Farrington. Practical syringe microburet. J. Ind. Eng. Chem., Anal. Ed., 19:492-94.

With D. H. Brown and E. L. Bennett. The appearance of sheep cell lysins and human A cell agglutinins in a rabbit immunized with a partially purified blood group A-specific substance from hog gastric mucin. Journal of Immunology, 56:1-5.

With D. H. Brown, E. L. Bennett, and G. Holzman. A study of the isolation of blood group A-specific substance from commercial hog gastric mucin and some observations on the separation of A-substance from other natural sources. Arch. Biochem., 13: 421-36.

With H. K. Mitchell. The competitive inhibition of the metabolism of alpha-amino acids by their halogenated analogs. J. Am. Chem. Soc., 69:1232.

With E. L. Bennett, C. W. Gould, Jr., and E. H. Swift. Systematic qualitative tests for certain acidic elements in organic compounds. J. Ind. Eng. Chem., Anal. Ed., 19:1035-39.

With G. Holzman and R. V. MacAllister. The colorimetric determination of hexoses with carbazole. J. Biol. Chem., 171:27-35.

1948

With C. W. Gould, Jr., and G. Holzman. Distillation equipment suitable for centigram and decigram quantities. Anal. Chem., 20:361-63.

With J. W. Sease, T. Lee, G. Holzman, and E. H. Swift. Quantitative methods for certain organic sulfides. Anal. Chem., 20:431-34.

With G. Holzman. A spectrophotometric study of blood group A-specific substance isolated from hog gastric mucosa. J. Biol. Chem., 174:305-18.

With H. Rinderknecht. The esterification of acylated alpha-amino acids. J. Am. Chem. Soc., 70:2605.

With D. W. Thomas. The preparation of L-leucine and its behavior in some non-aqueous solvents. J. Biol. Chem., 175:241-48.

With J. Peterson and K. M. Harmon. The dependence of the specific activity of urease upon the apparent absolute enzyme concentration. J. Biol. Chem., 176:1-7.

With E. L. Bennett. The enzymatic synthesis of N-carbobenzoxy-D-and L-o-fluorophenylalanylphenylhydrazides. J. Am. Chem. Soc., 70:2610.

With E. L. Bennett. The use of ion-exchange resins in the isolation of blood group A-specific substance from hog gastric mucin. J. Biol. Chem., 176:969-75.

1949

With K. M. Harmon. The competitive inhibition of the urease catalyzed hydrolysis of urea by phosphate. J. Biol. Chem., 177:601-5.

With R. V. MacAllister and K. M. Harmon. The hydrolysis of N-benzoyl-DL-tyrosylglycinamide, N-acetyl-L-tyrosylglycinamide and N-acetyl DL-tyrosylglycylamide by chymotrypsin. J. Biol. Chem., 177:767-74.

With G. H. Cleland. Some observations on the Dakin-West reaction. J. Am. Chem. Soc., 71:841-43.

With C. R. Lindegren. The apparent ionization constants of acethydrazide and glycylhydrazide. J. Am. Chem. Soc., 71:1504.

With K. M. Harmon. The hydrolysis of N-benzoyl-L-argininamide by crystalline trypsin. J. Biol. Chem., 178:743-50.

With P. S. Farrington and E. H. Swift. Determination of Carbon by wet combustion. Anal. Chem., 21:1423-24.

With E. L. Bennett. Systematic qualitative tests for certain acidic elements in organic compounds. Elimination of interference by cyanide. Anal. Chem., 21:1582.

With M. Ikawa. A spectrophotometric study of the behavior of carbohydrates in seventy-nine per cent sulfuric acid. J. Biol. Chem., 180:923-31.

With J. C. Nevenzel and W. E. Shelberg. The apparent ionization constants and ultraviolet spectra of *o*-, *m*-, and *p*-chloro- and *p*-sulfamyl-DL-phenylalanine. J. Am. Chem. Soc., 71:3024-26.

With R. V. MacAllister. The hydrolysis of nicotinyl-L-tyrosylhydrazide by chymotrypsin. J. Am. Chem. Soc., 71:3854.

1950

With B. M. Iselin. A procedure for the determination of protoeolytic activity. J. Biol. Chem., 182:821-28.

With H. T. Huang. The formation of diketopiperazines from dipeptide amides. J. Am. Chem. Soc., 72:921-22.

With B. M. Iselin, H. T. Huang, and R. V. MacAllister. A new series of substrates for the evaluation of chymotrypsin activity. J. Am. Chem. Soc., 72:1729-31.

With E. L. Bennett. The enzymatic synthesis of N-acyl-D- and L-phenylalanylphenylhydrazides. J. Am. Chem. Soc., 72:1798-1800.

With E. L. Bennett. The preparation and resolution of the three isomeric nuclear substituted monofluoro-DL-phenylalanines. J. Am. Chem. Soc., 72:1800-3.

With E. L. Bennett. Transacylation in the Erlenmeyer-Plöchl reaction. J. Am. Chem. Soc., 72:1803-4.

With E. L. Bennett. The apparent ionization constants and ultraviolet spectra of *o*-, *m*-, and *p*-fluoro-DL-phenylalanine. J. Am. Chem. Soc., 72:1804-5.

With E. L. Bennett. The synthesis of 2-fluoro-DL-tyrosine and 2-fluoro-4-methoxy-DL-phenylalanine. J. Am. Chem. Soc., 72:1806-7.

With B. M. Iselin and H. T. Huang. A colorimetric method foı the determination of chymotrypsin activity. J. Biol. Chem., 183:403-7.

With G. Holzman. The isolation of blood group A-substance from hog gastric mucin by ethanol fractionation and electrodecantation. J. Am. Chem. Soc., 72:2044-48.

With G. Holzman. The isolation of two forms of blood group A-substance from hog gastric mucin. J. Am. Chem. Soc., 72: 2048-52.

With H. Rinderknecht. The synthesis of 5-fluoro-DL-tryptophan. J. Am. Chem. Soc., 72:2296.

Thyroxine and related compounds. Fortschritte der Chemie organischer Naturstoffe, 7:167-91.

With R. J. Foster and F. G. Rosicky. The monoacetylation of 2, 4-diamino-6-nitrotoluene. J. Am. Chem. Soc., 72:3959-60.

With H. T. Huang. The inertness of crystalline ovalbumin in systems containing alpha-chymotrypsin and hydrolyzable substrates. J. Am. Chem. Soc., 72:4286.

With M. Ikawa. The nature of certain impurities present in blood group A substance preparations derived from hog gastric mucosa. Biochemistry, 27:441-48.

With J. L. O'Brien. The acid catalyzed cyclization of alpha-acylamino acids. J. Am. Chem. Soc., 72:5348.

1951

With H. T. Huang. The enzymatic resolution of DL-phenylalanine. J. Am. Chem. Soc., 73:475.

With H. T. Huang. The kinetics of the alpha-chymotrypsin catalyzed hydrolysis of acetyl- and nicotinyl-L-tryptophanamide in aqueous solutions at 25° and pH 7.9. J. Am. Chem. Soc., 73: 1541-48.

With D. W. Thomas and R. V. MacAllister. The kinetics of the alpha-chymotrypsin catalyzed hydrolysis of acetyl-L-tryosinamide in aqueous solutions at 25° and pH 7.8-8.0. J. Am. Chem. Soc., 73:1548-52.

With R. J. Foster. The kinetics of the alpha-chymotrypsin catalyzed competitive hydrolysis of acetyl-L-tryptophanimide and acetyl-L-tyrosinamide in aqueous solutions at 25° and pH 7.9. J. Am. Chem. Soc., 73:1552-54.

With H. T. Huang. The enzyme-inhibitor dissociation constants of alpha-chymotrypsin and several competitive inhibitors of the unnatural or D-configuration. J. Am. Chem. Soc., 73:1555-58.

With W. H. Schuller. The papain catalyzed synthesis of acyl-D- and L-phenylalanylphenylhydrazides from a series of enantiomorphic pairs of acylated phenylalanines. J. Am. Chem. Soc., 73:1644-46.

With G. D. Fasman. A reinvestigation of the kinetics of the urease-catalyzed hydrolysis of urea. I. The activity of urease in the presence of sodium and potassium phosphate. J. Am. Chem. Soc., 73:1646-50.

With M. Ikawa. Further observations on the behavior of carbohydrates in seventy-nine per cent sulfuric acid. Arch. Biochem. Biophys., 31:62-71.

The proteolytic enzymes. Record of Chemical Progress, 12:107-15.

With H. T. Huang. The enzyme-inhibitor dissociation constants of alpha-chymotrypsin and three enantiomorphic pairs of competitive inhibitors. J. Am. Chem. Soc., 73:3223-27.

With H. T. Huang. The valuation of the enzyme-inhibitor dissociation constant of alpha-chymotrypsin and acetyl-D-tryptophan methyl ester. J. Am. Chem. Soc., 73:3228-31.

With H. T. Huang, R. V. MacAllister, and D. W. Thomas. The kinetics of the alpha-chymotrypsin catalyzed hydrolysis of nicotinyl-L-tyrosinamide in aqueous solutions at 25° and pH 7.9. J. Am. Chem. Soc., 73:3231-34.

With H. T. Huang. The reaction of chloramphenicol (chloromycetin) with alpha-chymotrypsin. J. Am. Chem. Soc., 73:4039.

With H. Rinderknecht. The synthesis of a cyclopropane derivative through exhaustive methylation. J. Am. Chem. Soc., 73:4259-60.

With R. T. Adams. The synthesis of D- and L-*threo*- and D- and L-*erythro*-alpha-amino-beta-hydroxy-*n*-caproic acid. J. Am. Chem. Soc., 73:4260-63.

With J. L. O'Brien. The ionization of amino acids in the solvent sulfuric acid. J. Am. Chem. Soc., 73:4264-67.

With H. T. Huang. The effect of competitive inhibitors on the milk clotting activity of alpha-chymotrypsin. J. Am. Chem. Soc., 73:4471.

1952

With H. J. Shine. The kinetics of the alpha-chymotrypsin-catalyzed hydrolysis of chloroacetyl- and trifluoroacetyl-L-tyrosinamide in aqueous solutions at 25°. J. Am. Chem. Soc., 74:97-101.

With H. T. Huang. The enzyme-inhibitor dissociation constants of alpha-chymotrypsin and three series of competitive inhibitors derived from D-tryptophan. J. Am. Chem. Soc., 74:101-5.

With H. T. Huang and R. J. Foster. The kinetics of the alpha-chymotrypsin catalyzed hydrolysis of acetyl- and nicotinyl-L-phenylalaninamide in aqueous solutions at 25° and pH 7.9. J. Am. Chem. Soc., 74:105-9.

With D. S. Hogness. The determination of the relative affinities of a series of specific substrates from their respective $K_s$ and $k_3$ values. J. Am. Chem. Soc., 74:3183.

With M. Ikawa, J. B. Koepfli, and S. G. Mudd. An agent from E. *coli* causing hemorrhage and regression of an experimental mouse tumor. I. Isolation and properties. J. Nat. Cancer Inst., 13:157-66.

With W. H. Schuller. The alpha-chymotrypsin catalyzed synthesis of the phenylhydrazides of certain acylated alpha-amino acids. J. Am. Chem. Soc., 74:4630-34.

With H. T. Huang. The kinetics of the alpha-chymotrypsin catalyzed hydrolysis of methyl hippurate in aqueous solutions at 25° and pH 7.9. J. Am. Chem. Soc., 74:4634-38.

With H. T. Huang. A redetermination of the kinetic constants for the system alpha-chymotrypsin-nicotinyl-L-tryptophanamide. J. Am. Chem. Soc., 74:4713.

With E. L. Bennett. The reaction of *cis*-1, 4-epoxycyclohexane with hydrochloric acid and with hydrobromic acid. J. Am. Chem. Soc., 74:5076-78.

With M. Ikawa, J. B. Koepfli, and S. G. Mudd. An agent from E. *coli* causing hemmorrhage and regression of an experimental mouse tumor. II. The component monosaccharides. J. Am. Chem. Soc., 74:5219-20.

With H. T. Huang. The enzyme-inhibitor dissociation constants of alpha-chymotrypsin and several series of bifunctional competitive inhibitors. J. Am. Chem. Soc., 74:5963-67.

1953

With D. S. Hogness. The kinetics of the alpha-chymotrypsin catalyzed hydrolysis of acetyl-L-tyrosinhydroxamide in aqueous solutions at 25° and pH 7.6. J. Am. Chem. Soc., 75:884-90.

With M. Ikawa, J. B. Koepfli, and S. G. Mudd. An agent from E. *coli* causing hemorrhage and regression of an experimental mouse tumor. III. The component fatty acids of the phospholipide moiety. J. Am. Chem. Soc., 75:1035-38.

With H. T. Huang. The inhibition of the alpha-chymotrypsin-catalyzed hydrolysis of nicotinyl-L-tryptophanamide and of methyl hippurate by indole. J. Am. Chem. Soc., 75:1395-1401.

With W. H. Schuller. The synthesis of substituted ureas. J. Am. Chem. Soc., 75:3425-28.

With M. Ikawa, J. B. Koepfli, and S. G. Mudd. An agent from E. *coli* causing hemorrhage and regression of an experimental mouse tumor. IV. Some nitrogenous components of the phospholipide moiety. J. Am. Chem. Soc., 75:3439-42.

With H. Rinderknecht and H. Koechlin. Oxindolylalanine. J. Org. Chem., 18:971-82.

With R. J. Foster. The estimation of the relative activities of a series of specific substrates. J. Am. Chem. Soc., 75:3590-91.

With R. J. Foster. Enzymes, specific substrates and competitive inhibitors as multifunctional entities. Proc. Nat. Acad. Sci., 39: 371-76.

With R. R. Jennings. The kinetics of the alpha-chymotrypsin catalyzed hydrolysis of acetyl-L-hexahydrophenylalaninamide in aqueous solutions at 25° and pH 7.9. J. Am. Chem. Soc., 75: 4687-92.

With R. J. Foster. The evaluation of the kinetic constants of enzyme catalyzed reactions. Proc. Nat. Acad. Sci., 39:999-1003.

With M. Ikawa. The synthesis of 4, 5-diamino-*n*-eicosane and of 2-methyl-3, 4-diamino-*n*-nonadecane. J. Am. Chem. Soc., 75: 6314-15.

With H. Rinderknecht. The synthesis of alpha, gamma-dihydroxy-beta-amino-*n*-butyric acid. J. Am. Chem. Soc., 75: 6322-23.

1954

With E. H. Swift. Semimicro system of qualitative and quantitative elementary analysis. Anal. Chem., 26:538-43.

With M. Ikawa, J. B. Koepfli, and S. G. Mudd. An agent from E. *coli* causing hemorrhage and regression of an experimental mouse tumor. V. Behavior of the agent in the presence of various reagents. J. Nat. Cancer Inst., 14:1195-1201.

With R. J. Foster and R. R. Jennings. The kinetics of the alpha-chymotrypsin catalyzed hydrolysis of L-tyrosinhydroxamide in aqueous solutions at 25° and pH 6.9. J. Am. Chem. Soc., 76: 3142-46.

With D. G. Crosby. Further studies on the synthesis of substituted ureas. J. Am. Chem. Soc., 76:4458-63.

1955

With R. A. Bernhard. Absence of wall effects in a typical alpha-chymotrypsin catalyzed hydrolysis. J. Am. Chem. Soc., 77:480.

With R. J. Foster. Re-evaluation of the kinetic constants of previously investigated specific substrates of alpha-chymotrypsin. J. Am. Chem. Soc., 77:1886-92.

With R. J. Foster and H. J. Shine. Re-evaluation of the inhibition constants of previously investigated competitive inhibitors of alpha-chymotrypsin. I. Hydrolysis products and enantiomorphs of previously investigated specific substrates. J. Am. Chem. Soc., 77:2378-83.

With R. Lutwack. The evaluation of enzyme-substrate dissociation constants. J. Am. Chem. Soc., 77:2648.

With R. J. Foster. The evaluation of the enzyme-inhibitor dissociation constants of alpha-chymotrypsin and several pairs of charged and uncharged competitive inhibitors at pH 7.9 and 6.9. J. Am. Chem. Soc., 77:3365-69.

With R. J. Foster. Re-evaluation of the inhibition constants of previously investigated competitive inhibitors of alpha-chymotrypsin. II. Mono-, bi- and trifunctional inhibitors evaluated under zone A conditions. J. Am. Chem. Soc., 77:3370-72.

With H. J. Shine. The effect of added sodium or potassium

chloride upon the alpha-chymotrypsin catalyzed hydrolysis of chloroacetyl-L-tyrosinamide at 25° and pH 7.75. J. Am. Chem. Soc., 77:4275-79.

With T. H. Applewhite. The evaluation of the kinetic constants of enzyme-catalyzed reactions by the method of Foster and Niemann. J. Am. Chem. Soc., 77:4923.

With R. R. Jennings. The evaluation of the kinetic constants of enzyme-catalyzed reactions by procedures based upon integrated rate equations. J. Am. Chem. Soc., 77:5432-33.

With K. A. Booman. The evaluation of the kinetic constants of enzyme-catalyzed reactions by procedures based upon integrated rate equations. II. J. Am. Chem. Soc., 77:5733-35.

With W. E. M. Lands. The evaluation of the initial velocities of enzyme-catalyzed reactions that are competitively inhibited by their reaction products. J. Am. Chem. Soc., 77:6508-10.

1956

With H. J. Shine. The effect of added sucrose upon the alpha-chymotrypsin catalyzed hydrolysis of chloroacetyl-L-tyrosinamide in aqueous solutions at 25° and pH 7.75. J. Am. Chem. Soc., 78:1872-74.

With K. A. Booman. The empirical evaluation of the initial velocities of enzyme catalyzed reactions. J. Am. Chem. Soc., 78:3642-46.

1957

With J. L. O'Brien. The formation and reactions of certain oxazolonium ions. J. Am. Chem. Soc., 79:80-85.

With J. L. O'Brien. The behavior of several nitrogenous compounds in sulfuric acid. J. Am. Chem. Soc., 79:1386-89.

With P. E. Peterson. Some reactions of alpha-phthalimidonitriles including those leading to the synthesis of alpha-amino amidoximes and alpha-amino thioamides. J. Am. Chem. Soc., 79:1389-95.

With R. Lutwack and H. F. Mower. The alpha-chymotrypsin-catalyzed hydrolysis of a series of hydrazides. I. Determination of pH optima and their dependence upon temperature. J. Am. Chem. Soc., 79:2179-84.

With R. A. Bernhard. Further studies on the kinetics of the alpha-chymotrypsin catalyzed hydrolysis of acetyl-L-tyrosinamide and

of acetyl-L-tryptophanamide in aqueous solutions at 25° and pH 7.9 ± 0.1. J. Am. Chem. Soc., 79:4085-91.

With R. A. Bernhard. The dependence of the enzyme-inhibitor dissociation constants of several bifunctional anionic competitive inhibitors of alpha-chymotrypsin upon added potassium phosphate. J. Am. Chem. Soc., 79:4091-96.

With H. F. Mower. The inertness of the ammonium salt of N-acetyl-L-cysteic acid carboxamide in systems containing alpha-chymotrypsin. Biochim. Biophys. Acta, 25:420-22.

With R. B. Martin. The effect of sodium chloride on the alpha-chymotrypsin catalyzed hydrolysis of methyl hippurate. J. Am. Chem. Soc., 79:4814.

With R. Lutwack and H. F. Mower. The alpha chymotrypsin-catalyzed hydrolysis of a series of hydrazides. II. Evaluation of the kinetic constants for aqueous systems at 25° and at the optimum pH for each specific substrate. J. Am. Chem. Soc., 79: 5690-93.

With R. B. Martin. The calcium chloride and hydroxyl ion catalyzed hydrolysis of several acylated alpha-amino acid esters. J. Am. Chem. Soc., 79:5828.

With K. A. Booman. The association of alpha-chymotrypsin and its influence upon the kinetics of a reaction catalyzed by this enzyme. Biochim. Biophys. Acta, 26:439-41.

With R. B. Martin. The nature of the enzyme blank observed with crystalline alpha-chymotrypsin. Biochim. Biophys. Acta., 26:634-35.

With T. H. Applewhite. Mixed anhydrides of *S*-phenylthiocarbonic acid and carboxylic acids. J. Org. Chem., 23:143.

With H. F. Mower. Alpha-*N*-trichloroacetyl-L-tyrosinamide. J. Org. Chem., 23:144.

With T. H. Applewhite and R. B. Martin. The alpha-chymotrypsin-catalyzed hydrolysis of methyl hippurate in aqueous solutions at 25° and pH 7.9, its inhibition by indole and its dependence upon added non-aqueous solvents. J. Am. Chem. Soc., 80:1457-64.

With T. H. Applewhite and H. Waite. The alpha-chymotrypsin-catalyzed hydrolysis of acetyl-, chloroacetyl- and benzoyl-L-valine methyl ester. J. Am. Chem. Soc., 80:1465-69.

With R. J. Kerr. The dependence of the alpha-chymotrypsin-catalyzed hydrolysis of alpha-N-nicotinyl-L-tyrosinhydrazide upon the concentration of the buffer. J. Am. Chem. Soc., 80: 1469-73.

With R. B. Martin. The catalytic activity of dimeric alpha-chymotrypsin. J. Am. Chem. Soc., 80:1473-77.

With D. T. Manning. The kinetics of the alpha-chymotrypsin-catalyzed hydrolysis of alpha-N-carbethoxy-L-tyrosinamide and its inhibition by alpha-N-carbethoxy-D-tyrosinamide. J. Am. Chem. Soc., 80:1478-81.

With P. E. Peterson and J. P. Wolf III. The decarbonylation of 3-indoleglyoxalyl chloride. J. Org. Chem., 23:303-4.

With R. J. Kerr. Glycolamide esters of acylated alpha-amino acids. J. Org. Chem., 23:304.

With R. B. Martin. The effect of various salts on the alpha-chymotrypsin-catalyzed hydrolysis of two acylated alpha-amino acid esters. J. Am. Chem. Soc., 80:1481-86.

With R. R. Jennings and R. J. Kerr. The effect of calcium chloride on several alpha-chymotrypsin-catalyzed hydrolyses. Biochim. Biophys. Acta, 28:144-47.

With R. L. Bixler. The synthesis of beta-(4-pyridyl)-DL-alanine and of beta-(4-pyridyl-1-oxide)-DL-, D- and L-alanine. J. Org. Chem., 23:575-84.

With R. L. Bixler. The synthesis and rate of acetolysis of 1-bicyclo[2.2.1] heptylmethyl tosylate. J. Org. Chem., 23:742-44.

With R. L. Bixler. The alpha-chymotrypsin-catalyzed hydrolysis of alpha-N-benzoyl-beta-(4-pyridyl-1-oxide)-L-alanine methyl ester and of alpha-N-(nicotinyl-loxide)-L-phenylalanine methyl ester. J. Am. Chem. Soc., 80:2716-19.

With R. J. Kerr. Some observations on the preparation of salicylamide esters of acylated alpha-amino acids. J. Org. Chem., 23:893-96.

With G. Fraenkel. The mode of protonation of amides. Proc. Nat. Acad. Sci., 44:688-91.

1959

With R. L. Bixler. Surface effects in alpha-chymotrypsin catalyzed hydrolyses. J. Am. Chem. Soc., 81:1412-17.

With D. T. Manning. The interaction of alpha-chymotrypsin with alpha-N-carbethoxy-D- and L-tyrosinmethylamide. J. Am. Chem. Soc., 81:747-49.

With W. E. M. Lands. The interaction of alpha-chymotrypsin with a series of alpha-N-acylated-L-tyrosinmethylamides. J. Am. Chem. Soc., 81:2204-8.

With T. H. Applewhite. The interaction of alpha-chymotrypsin with a series of alpha-N-acetyl-alpha-amino acid methylamides. J. Am. Chem. Soc., 81:2208-14.

With J. T. Braunholtz and R. J. Kerr. Re-examination of the alpha-chymotrypsin catalyzed hydrolysis of alpha-N-acetyl-L-tyrosinhydrazide. J. Am. Chem. Soc., 81:2852-56.

With H. Rinderknecht. Toxic protein degradation products. Proc. Soc. Exp. Biol. Med., 100:35-40.

With H. R. Almond, Jr., and R. J. Kerr. The apparent ionization constants of a series of phenylalanine derivatives. J. Am. Chem. Soc., 81:2856-60.

With J. P. Wolf III. Activation of an enzyme catalyzed reaction by excess substrates. J. Am. Chem. Soc., 81:1012.

1960

With G. E. Hein and R. B. McGriff. An inversion of the usual antipodal specificity observed in alpha-chymotrypsin catalyzed reactions. J. Am. Chem. Soc., 82:1830-31.

With H. R. Almond, Jr. The consequences of systematic error in enzyme kinetics. Biochim. Biophys. Acta, 44:143-50.

With N. S. Isaacs. The asymmetric acetylation of (±)-butan-2-ol by *p*-nitro-phenyl acetate and alpha-chymotrypsin. Biochim. Biophys. Acta, 44:196-97.

With J. T. Braunholtz. The kinetics of the alpha-chymotrypsin-catalyzed hydrolysis of alpha-N-(acetylglycyl)-L-tyrosinhydrazide. Biochim. Biophys. Acta, 45:375-77.

With H. I. Abrash and A. N. Kurtz. The calculation of kinetic constants of enzyme-catalyzed reactions using digital computers. Biochim. Biophys. Acta, 45:378-79.

1961

With P. E. Peterson. The interaction of alpha-chymotrypsin with alpha-N-acetyl-L-phenylalaninamidoxime. Biochim. Biophys. Acta, 48:331-34.

With A. N. Kurtz. The synthesis and properties of ethyl 1-acetyl-2-benzyl carbazate, an analog of acetyl-D and L-phenylalanine ethyl ester. J. Org. Chem., 26:1842-46.

With A. N. Kurtz. The interaction of ethyl 1-acetyl-2-benzylcarbazate with alpha-chymotrypsin. J. Am. Chem. Soc., 83:1879-82.

With A. N. Kurtz. Nitrogen analogs of representative substrates and inhibitors of alpha-chymotrypsin. Biochim. Biophys. Acta, 50:520-26.

With A. N. Kurtz. The interaction of alpha-chymotrypsin with 1-acyl-2-(alpha-aminoacyl) hydrazines. Biochim. Biophys. Acta, 53:324-31.

With G. E. Hein. An interpretation of the kinetic behavior of model substrates of alpha-chymotrypsin. Proc. Nat. Acad. Sci., 47:1341-55.

With A. N. Kurtz. Rearrangement of alpha-N-acetyl-L-tyrosinhydrazide to 1-acetyl-2-(L-tyrosyl)hydrazine. J. Am. Chem. Soc., 83:3309-14.

1962

With H. R. Almond, Jr. Transpeptidation and the alpha-chymotrypsin-catalyzed hydrolysis of alpha-amino acid esters, hydroxamides, amides, and hydrazides. Biochemistry, 1:12-18.

With A. N. Kurtz. Use of the pH-stat in kinetic studies of reactions whose products are capable of functioning as buffers. Biochemistry, 1:238-42.

With H. R. Almond, Jr., and D. T. Manning. Interaction of alpha-chymotrypsin with several alpha-methyl-alpha-acylamino acid methyl esters. Biochemistry, 1:243-49.

With H. R. Waite. The alpha-chymotrypsin-catalyzed hydrolysis of a series of acylated-L-valine esters. Biochemistry, 1:250-53.

With G. E. Hein. Steric course and specificity of alpha-chymotrypsin-catalyzed reactions. I. J. Am. Chem. Soc., 84:4487-94.

With G. E. Hein. Steric course and specificity of alpha-chymotrypsin-catalyzed reactions. II. J. Am. Chem. Soc., 84:4495-4503.

With J. B. Jones. The alpha-chymotrypsin-catalyzed hydrolysis of several esters of acetyl-L-norvaline. Biochemistry, 1:1093-96.

With G. E. Hein and J. B. Jones. The kinetics of the alpha-chymotrypsin catalyzed hydrolysis of acetyl-L-leucine methyl ester. Biochim. Biophys. Acta, 65:353-55.

1963

With J. P. Wolf III. The alpha-chymotrypsin catalyzed hydrolysis of a series of acylated glycine methyl esters. Biochemistry, 2:82-90.

With R. A. Wallace and A. N. Kurtz. The interaction of aromatic compounds with alpha-chymotrypsin. Biochemistry, 2: 824-36.

With J. P. Wolf III. The alpha-chymotrypsin catalyzed hydrolysis of a series of analogs of acetylglycine methyl ester. Biochemistry, 2:493-97.

With J. B. Jones. A further comparison of the behavior of analogous aromatic and hydroaromatic substrates of alpha-chymotrypsin. Biochemistry, 2:498-500.

With R. L. Peterson and K. W. Hubele. The alpha-chymotrypsin catalyzed hydrolysis of alpha-N- and O-alkyl derivatives of alpha-N-acetyl-L-tyrosine methyl ester. Biochemistry, 2:942-46.

With H. I. Abrash. Steric hindrance in alpha-chymotrypsin catalyzed reactions. Biochemistry, 2:947-53.

With J. R. Rapp. A further example of inversion of the usual antipodal specificity of alpha-chymotrypsin. J. Am. Chem. Soc., 85:1896.

With A. Platt. Variation of the conformation of the active site of alpha-chymotrypsin with hydrogen ion concentration. Proc. Nat. Acad. Sci., 50:817-21.

1964

With W. A. Mukatis. Variation of the conformation of the active site of alpha-chymotrypsin with hydrogen ion concentration. II. Proc. Nat. Acad. Sci., 51:397-402.

With J. P. Wolf III, R. A. Wallace, and R. L. Peterson. The alpha-chymotrypsin-catalyzed hydrolysis of a series of acylated glycine methyl esters. II. Behavior at low and high substrate concentrations. Biochemistry, 3:940-44.

Alpha-chymotrypsin and the nature of enzyme catalysis. The problem of enzyme catalysis is considered in terms of the behavior of a single hydrolytic enzyme. Science, 143:1287-96.

With H. I. Abrash. Interaction of aromatic compounds with alpha-chymotrypsin. II. Combination of the isomeric indole carboxamides and carboxylate ions with the active site. Biochemistry, 4:99-104.

With R. A. Bernhard. A dilatometric investigation of the alpha-chymotrypsin catalyzed hydrolysis of nicotinyl-L-tryptophanamide. Arch. Biochem. Biophys., 110:195-99.

With J. B. Jones and G. E. Hein. The primary specificity of alpha-chymotrypsin: interaction with acylated derivatives of D-valine methyl ester and D-norvaline methyl ester. Biochemistry, 4:1735.

1965

With J. B. Jones, T. Kunitake, and G. E. Hein. The primary specificity of alpha-chymotrypsin. Acylated amino acid esters with normal alkyl side chains. J. Am. Chem. Soc., 87:1777.

1966

With G. L. Neil and G. E. Hein. Structural specificity of $\alpha$-chymotrypsin: polypeptide substrates. Nature, 210:903-7.

With C. L. Hamilton and G. S. Hammond. A quantitative analysis of the binding of N-acyl derivatives of $\alpha$-aminoamides by $\alpha$-chymotrypsin. Proc. Nat. Acad. Sci., 55:664-69.