

THE BECKMAN CENTER FOR THE HISTORY OF CHEMISTRY

FRANK H. WESTHEIMER

Transcript of an Interview
Conducted by

Leon Gortler

at

Harvard University

on

4 and 5 January 1979

This interview has been designated as **Free Access**.

One may view, quote from, cite, or reproduce the oral history with the permission of CHF.

Please note: Users citing this interview for purposes of publication are obliged under the terms of the Chemical Heritage Foundation Oral History Program to credit CHF using the format below:

Frank H. Westheimer, interview by Leon Gortler at Harvard University, 4 and 5 January 1979 (Philadelphia: Chemical Heritage Foundation, Oral History Transcript # 0046).



Chemical Heritage Foundation
Oral History Program
315 Chestnut Street
Philadelphia, Pennsylvania 19106



FRANK HENRY WESTHEIMER

1912 Born in Baltimore, Maryland on 15 January

Education

1932 A.B., chemistry, Dartmouth College
1933 M.A., chemistry, Harvard University
1935 Ph.D., chemistry, Harvard University
(Mentors: James B. Conant; Elmer P. Kohler)

Professional Experience

1935-1936 National Research Fellow, Columbia University
(with Louis Hammett)
University of Chicago
1936-1941 Instructor
1941-1946 Assistant Professor
1946-1948 Associate Professor
1948-1954 Professor
1953-1954 Visiting Professor, Harvard University
Harvard University
1954-1960 Professor
1959-1962 Department Chairman
1960-1982 Loeb Professor of Chemistry
1982-1983 Senior Professor
1983- Loeb Professor of Chemistry Emeritus

1944-1945 Research Supervisor, Explosives Research Laboratory,
National Defense Research Committee
1964-1965 Chairman, National Academy of Science Committee to
Survey Chemistry (Westheimer Report)
1967-1970 Member, President's Science Advisory Committee

Awards

1954 Elected Member, National Academy of Sciences
1970 Willard Gibbs Medal, Chicago Section, American
Chemical Society
1970 James Flack Norris Award in Physical Organic
Chemistry, Northeastern Section, American
Chemical Society
1976 Theodore William Richards Medal, Northeastern
Section, American Chemical Society
1980 Richard Kokes Award, National Academy of Sciences
1980 Charles Frederick Chandler Award
1981 Lewis C. Rosenstiel Award, Rosenstiel Basic Medical
Sciences Research Center
1982 Robert A. Welch Award, The Robert A. Welch
Foundation

1982 Arthur C. Cope Award, American Chemical Society
1982 William H. Nichols Medal, New York Section, American
Chemical Society
1983 Christopher Ingold Medal, The Chemical Society of
London
1988 Priestley Medal, American Chemical Society

ABSTRACT

In this interview, Frank Westheimer begins with his family, his childhood and early education in Baltimore, his undergraduate days at Dartmouth, his decision to go into chemistry, and his choice of Harvard for his graduate work. Next he covers his years as a graduate student at Harvard and talks about his research with James Conant and Elmer Kohler, the faculty at Harvard and the courses they taught, and his summer work with Alsoph Corwin at Johns Hopkins. He also talks at length about his early interest in biochemistry, his view of theoretical organic chemistry in the mid-1930s and the opportunities for research open to him, the development of theoretical organic chemistry in the early part of the twentieth century, and the publications of some of the early scientists. This is followed by a description of his year as a National Research Fellow at Columbia, his research, his colleagues, and more on the development of his interest in biochemical problems. Westheimer continues with the offer of a position at the University of Chicago from Morris Kharasch, and includes an extensive discussion of the university, his research, and his collaboration with John Kirkwood, Joe Mayer and Birgit Vennesland. In the next part of the interview he comments on his selection and training of students and discusses a number of former students who have been successful in research careers. The interview concludes with more discussion of physical organic chemistry, past, present and future; a review of his work on the hydrolysis of phosphate esters and pseudorotation; comments on the future of organic chemistry; and a review of the Westheimer Report, the analysis of American chemistry by the National Academy of Sciences.

INTERVIEWER

Leon Gortler is professor of chemistry at Brooklyn College of the City University of New York. He holds A.B. and M.S. degrees from the University of Chicago and a Ph.D. from Harvard University. He has long been interested in the history of chemistry, and helped establish the Beckman Center's oral history program. He has conducted over forty oral and videotaped interviews with major American scientists.

TABLE OF CONTENTS

- 1 Childhood, Family and Early Education
Father's background and abilities. Father's influence. Family values of hard work and integrity. Mother's background and her role. Early schooling. Problems with spelling and writing. English lessons from James Senior at the University of Chicago. Learning trigonometry on his own. Lesson learned. Jobs as a teenager. Early reading.

- 7 Undergraduate Education at Dartmouth
Selecting a college. Entered Dartmouth, 1928. Experiences at Dartmouth. Intelligence testing. Decision to become a chemist. Parents' reaction. View of being a chemist. Decision to enter Harvard and work with James Conant. Chemistry courses at Dartmouth. State of the chemistry laboratories. Undergraduate research and current opinion of its value. Nonscience courses at Dartmouth.

- 16 Graduate Study at Harvard
Courses. Picking a research mentor. First research project. Research with Elmer Kohler. Friends and associates at Harvard. Development of interest in biochemistry. Research with Alsoph Corwin. Thoughts on theoretical organic chemistry as a graduate student. Awarded National Research Fellowship. Important conversation with James Conant. Courses with George Kistiakowsky, Elmer Kohler, Louis Fieser and Paul Bartlett. Thoughts on the development of organic chemistry. Reading in organic chemistry--comments on the work of Louis Hammett, Arthur Lapworth, Max Bodenstein, Robert Robinson, Christopher Ingold. First meeting with George Wheland.

- 32 Research at Columbia University
More on development of interest in biochemistry. Selection by Morris Kharasch for Chicago position. Anti-Semitism in chemistry. Graduate students and faculty at Columbia.

- 41 University of Chicago
First research papers from Chicago. Teaching physical organic chemistry for the first time. Collaboration with John Kirkwood. Robert Hutchins' view of science. Morris Kharasch and other Chicago faculty. Chicago's emphasis on physical organic chemistry. Important criterion for choosing a research problem. Chromic acid oxidation. Meeting with Jan Rocek in London. Research facilities at Chicago. Postwar atmosphere in chemistry at Chicago--great scientists, exciting problems. Reason for leaving Chicago. Courses taught and textbooks used.

- 63 Research Projects and Philosophy
Reading the literature. Research productivity and the size of research groups. Project on optically active biphenyls with Joe Mayer. Nitration of aromatic compounds. Work at Bruceton, the Explosives Research Laboratory. Kinetic analysis. Decarboxylation research. Nicotinamide adenine dinucleotide (NAD) research--enzymatic oxidation-reduction. Paper of A. G. Ogston on asymmetric decarboxylation. The use of kinetic isotope effects in mechanistic studies. Optically active deuterioethanol. Simultaneous publication with Andrew Streitwieser.
- 83 Graduate Students and Postdoctoral Fellows
Selection of graduate students and postdoctoral fellows. The training of graduate students. Former graduate students and postdocs who have been successful.
- 87 Physical Organic Chemistry
The community in 1935 and 1940. Self-recognition as a community. The community in 1946. Knowledge of Lewis bonding theory as an undergraduate. Delay in the beginning of physical organic chemistry. The effect of successful empirical organic chemistry. Current status of physical organic chemistry.
- 97 The Hydrolysis of Phosphate Esters. Pseudorotation.
- 102 The Future of Chemistry. The Use of Enzymes.
- 104 The Westheimer Report
- 111 Notes
- 117 Index

NOTES

1. Paul H. DeKruif, Microbe Hunters (New York: Harcourt, Brace and Co., 1926).
2. Wendell M. Latimer and Joel H. Hildebrand, Reference Book of Inorganic Chemistry (New York: Macmillan Co., 1929).
3. August Bernthsen, Kurzes Lehrbuch der organischen Chemie, 14th ed. (Braunschweig: Friederick Viewerg & Sohn, 1919); revised edition by J. J. Sudborough, A Textbook of Organic Chemistry (New York: D. Van Nostrand Co., 1929).
4. Leo A. Flexser and Louis P. Hammett, "The Base Strengths and Absorption Spectra of p-Methylacetophenone and p-Bromoacetophenone," Journal of the American Chemical Society, 60 (1938): 885-888.
5. Frank H. Westheimer, "Semicarbazone Formation in Sixty Percent Methyl Cellosolve," Journal of the American Chemical Society, 56 (1934): 1962-1965.
6. Elmer P. Kohler, Frank H. Westheimer, and Max Tishler, "Hydroxyfurans. I. β -Hydroxytriphenylfuran," Journal of the American Chemical Society, 58 (1936): 266-267.
7. Paul Karrer, Lehrbuch der organischen Chemie (Leipzig: George Thieme, 1928).
8. Walter Hückel, Theoretische Grundlagen der organischen Chemie, 2nd ed. (Leipzig: Akademische Verlagsgesellschaft, 1934).
9. Frank H. Westheimer and Herzl Cohen, "The Amine Catalysis of the Dealdolization of Diacetone Alcohol," The Journal of the American Chemical Society, 60 (1938): 90-94.
10. Gilbert Newton Lewis and Merle Randall, Thermodynamics (New York: McGraw Hill Book Co., 1923).
11. Louis Frederick Fieser, The Chemistry of Natural Products Related to Phenanthrene (New York: Reinhold Publishing Corporation, 1936).
12. Louis P. Hammett and Alden J. Deyrup, "A Series of Simple Basic Indicators. I. The Acidity Functions of Mixtures of Sulfuric and Perchloric Acids with Water," Journal of the American Chemical Society, 54 (1932): 2721-2739; Hammett and Deyrup, "A Series of Simple Basic Indicators. II. Some Applications to Solutions in Formic Acid," Journal of the American Chemical Society, 54 (1932): 4239-4247.
13. Louis P. Hammett, "The Theory of Acidity," Journal of the American Chemical Society, 50 (1928): 2660-2673.

14. Arthur Lapworth, "The Action of Halogens on Compounds Containing the Carbonyl Group," Journal of the Chemical Society, (1904): 30-42.
15. Max Bodenstein, "Über die Zersetzung des Jodwasserstoffgases in der Hitze," Zeitschrift für physikalische Chemie, 13 (1894): 56-127; Bodenstein, "Zersetzung und Bildung von Jodwasserstoff," Zeitschrift für physikalische Chemie, 22 (1897): 1-22; Bodenstein, "Die Zersetzung des Jodwasserstoffgases im Licht," Zeitschrift für physikalische Chemie, 22 (1897): 23-33; Bodenstein, "Gasreaktionen in der chemischen Kinetik. II. Einfluss der Temperatur auf Bildung und Zersetzung von Jodwasserstoff," Zeitschrift für physikalische Chemie, 29 (1899): 295-314.
16. Robert Robinson, "Synthesis of Tropinone," Journal of the Chemical Society, 111 (1917): 762-768.
17. Wendell M. Stanley, "Isolation of a Crystalline Protein Possessing the Properties of Tobacco Mosaic Virus," Science, 81 (1935): 664-665.
18. Ernest Baldwin, Dynamic Aspects of Biochemistry (New York: Macmillan Company, 1947).
19. O. Meyerhof, "Intermediate Stages in the Biological Breakdown of Carbohydrate," Ergebnisse der Enzymforschung, 4 (1935): 208-229.
20. Arthur Harden, Alcoholic Fermentation, 4th ed. (London: Longmans, Green & Company, 1932).
21. Meyer Bodansky, Introduction to Physiological Chemistry, 3rd ed. revised (New York: John Wiley and Sons, Inc., 1934).
22. Mabel Foy and Morris Kharasch, "Peroxide Effect in the Cannizzaro Reaction," Journal of the American Chemical Society, 57 (1935): 1510; see also note 27.
23. Chemistry: Opportunities and Needs (Washington, DC: National Academy of Sciences, National Research Council, 1965).
24. George E. Kimball and Irving Roberts, "The Halogenation of Ethylenes," Journal of the American Chemical Society, 59 (1937): 247-248.
25. Frank H. Westheimer, "Amino Acid Catalysis of the Mutarotation of Glucose," Journal of Organic Chemistry, 2 (1937): 431-441.

26. C. Gardner Swain and John F. Brown, Jr., "Concerted Displacement Reactions. VIII. Polyfunctional Catalysis," Journal of the American Chemical Society, 74 (1952): 2538-2543.
27. Frank H. Westheimer, "Kinetics of the Benzilic Acid Rearrangement," Journal of the American Chemical Society, 58 (1936): 2209-2214; footnote 14, p. 2213.
28. Frank H. Westheimer, "Kinetics of Some Amine Catalyzed Reactions," Annals of the New York Academy of Sciences, 39 (1940): 401-407.
29. Christopher K. Ingold, "Remarks on the Electrical and Mechanical Conditions in the Neighbourhood of a Dissolved Ion," Journal of the Chemical Society, (1931): 2179-2190.
30. John G. Kirkwood, "Theory of Solutions of Molecules Containing Widely Separated Charges with Special Application to Amphoteric Ions," Journal of Chemical Physics, 2 (1934): 351-361.
31. Niels Bjerrum, "Dissoziationskonstanten von mehrbasischen Säuren und ihre Anwendung zur Berechnung molekularer Dimensionen," Zeitschrift für physikalische Chemie, 106 (1923): 219-242.
32. A. Eucken, "Gesetzmässigkeiten für die Veränderlich in der Affinitätskonstanten substituierter organischer Säuren," Angewandte Chemie, 45 (1932): 203-208.
33. (a.) John G. Kirkwood and Frank H. Westheimer, "The Electrostatic Influence of Substituents on the Dissociation Constants of Organic Acids. I.," Journal of Chemical Physics, 6 (1938): 506-512; (b.) Kirkwood and Westheimer, "The Electrostatic Influence of Substituents on the Dissociation Constants of Organic Acids. II.," Journal of Chemical Physics, 6 (1938): 513-517.
34. S. E. Ehrenson, "Transmission of Substituent Effects. Generalization of the Ellipsoidal Cavity Field Effect Model," Journal of the American Chemical Society, 98 (1976): 7510-7514.
35. J. T. Edward, P. G. Farrel and J. L. Job, "Re-examination of the Kirkwood-Westheimer Theory of Electrostatic Effects. I. Calculation of the 'Effective' Dielectric Constant," Journal of Chemical Physics, 57 (1972): 5251-5256.
36. John G. Kirkwood and Frank H. Westheimer, "Errata: The Electrostatic Influences of Substituents on the Dissociation Constants of Organic Acids. I and II.," Journal of Chemical Physics, 7 (1939): 437.

37. James N. Sarmousakis, "The Effect of Substituents on the Dissociation Constants of Carboxylic Acids," Journal of Chemical Physics, 12 (1966): 277-288.
38. George W. Wheland, Advanced Organic Chemistry (New York: John Wiley & Sons, Inc., 1949; second edition 1954).
39. Peter Debye, Polar Molecules (New York: The Chemical Catalogue Co., Inc., 1929).
40. F. Malsch, "Über die Messung der Dielektrizitätskonstanten von Flüssigkeiten bei hohen elektrischen Feldstärken nach einer neuen Methode," Annalen der Physik, 84 (1927): 841-879.
41. Frank H. Westheimer and Aaron Novick, "The Kinetics of the Oxidation of Isopropyl Alcohol by Chromic Acid," Journal of Chemical Physics, 11 (1943): 506-512.
42. Frank H. Westheimer, "Amino Acid Catalysis of the Mutarotation of Glucose," Journal of Organic Chemistry, 2 (1937): 431-441.
43. Morris S. Kharasch and Frank R. Mayo, "The Peroxide Effect in the Addition of Reagents to Unsaturated Compounds. I. The Addition of Hydrogen Bromide to Allyl Bromide," Journal of the American Chemical Society, 55 (1933): 2468-2496.
44. Morris Kharasch and Otto Reinmuth, Grignard Reaction of Non-Metallic Substances (New York: Prentice Hall, 1954).
45. Frank H. Westheimer and Joseph E. Mayer, "The Theory of Racemization of Optically Active Derivatives of Diphenyl," Journal of Chemical Physics, 14 (1946): 733-738; Westheimer, "A Calculation of the Energy of Activation for the Racemization of 2,2'-Dibromo-4,4'-Dicarboxydiphenyl," Journal of Chemical Physics, 15 (1947): 252-260.
46. Frank H. Westheimer and M. S. Kharasch, "The Kinetics of Nitration of Aromatic Nitro Compounds in Sulphuric Acid," Journal of the American Chemical Society, 68 (1946): 1871-1876.
47. Frank H. Westheimer and Warren Watanabe, "The Kinetics of the Chromic Acid Oxidation of Isopropyl Alcohol: The Induced Oxidation of Manganous Ion," Journal of Chemical Physics, 17 (1949): 61-70.
48. Rudolph Steinberger and Frank H. Westheimer, "The Metal Ion Catalyzed Decarboxylation of Dimethylaloacetic Acid," Journal of the American Chemical Society, 71 (1949): 4158-4159; Steinberger and Westheimer, "Metal Ion Catalyzed Decarboxylation: A Model for an Enzyme System," Journal of the American Chemical Society, 73 (1951): 429-435.

49. Frank H. Westheimer and William A. Jones, "The Effect of Solvent on Some Reaction Rates," Journal of the American Chemical Society, 63 (1941): 3283-3286.
50. Kai J. Pedersen, "Decomposition of α -Nitro Carboxylic Acids. Decomposition of β -Keto Carboxylic Acids," Journal of Physical Chemistry, 38 (1934): 559-571.
51. F. H. Westheimer, H. F. Fisher, E. E. Conn, and B. Vennesland, "The Enzymatic Transfer of Hydrogen from Alcohol to DPN," Journal of the American Chemical Society, 73 (1951): 2403. Subsequent papers appeared in the 1953 Journal of Biological Chemistry.
52. T. A. Geissman, "A Theory of the Mechanism of Enzyme Action," Quarterly Review of Biology, 24 (1949): 309-327.
53. Frank A. Loewus, Frank H. Westheimer and Birgit Vennesland, "Enzymatic Synthesis of the Enantiomorphs of Ethanol-1-d," Journal of the American Chemical Society, 75 (1953): 5018-5023.
54. A. G. Ogston, "Interpretation of Experiments on Metabolic Processes Using Isotopic Tracer Elements," Nature, 162 (1948): 963.
55. Frank H. Westheimer and Nicholas Nicolaides, "The Kinetics of the Oxidation of 2-Deuteropropanol-2 by Chromic Acid," Journal of the American Chemical Society, 71 (1949): 25-28.
56. Lars Melander, "On the Mechanism of Electrophilic Aromatic Substitution: An Investigation by Means of the Effect of Isotopic Mass on Reaction Velocity," Arkiv för Kemi, 2 (1950): 211-295.
57. Andrew Streitwieser, Jr., "Stereochemistry of the Primary Carbon. I. Optically Active n-Butanol-1-d," Journal of the American Chemical Society, 75 (1953): 5014-5018.
58. Louis P. Hammett, Physical Organic Chemistry (New York: McGraw-Hill Book Company, 1940).
59. Walter Hückel, Theoretische Grundlagen der organischen Chemie (Leipzig: Akademische Verlagsgesellschaft MBH, 1931).
60. Frank H. Westheimer and William W. Butcher, "The Lanthanum Hydroxide Gel Promoted Hydrolysis of Phosphate Esters," Journal of the American Chemical Society, 77 (1955): 2420-2424.
61. R. Stephen Berry, "Correlation of Rates of Intramolecular Tunneling Processes, with Application to Some Group V Compounds," Journal of Chemical Physics, 32 (1960): 933-938.

62. E. L. Muetterties, W. Mahler, and R. Schmutzler, "Stereochemistry of Phosphorus (V) Fluorides," Inorganic Chemistry, 2 (1963): 613-618; Muetterties, Mahler, K. J. Packer, and Schmutzler, "Five-Coordinate Stereochemistry," Inorganic Chemistry, 3 (1964): 1298-1303.
63. Paul C. Haake and F. H. Westheimer, "Hydrolysis and Exchange in Esters of Phosphoric Acid," Journal of the American Chemical Society, 83 (1961): 1102-1109.
64. Frank H. Westheimer and Edward A. Dennis, "The Rates of Hydrolysis of Esters of Cyclic Phosphinic Acids," Journal of the American Chemical Society, 88 (1966): 3431-3432; Westheimer and Dennis, "The Geometry of the Transition State in the Hydrolysis of Phosphate Esters," Journal of the American Chemical Society, 88 (1966): 3432-3433; Westheimer, "Pseudorotation in the Hydrolysis of Phosphate Esters," Accounts of Chemical Research, 1 (1968): 70-78.

INDEX

A

Abeles, Robert, 85
Abnormal addition of hydrogen bromide to allyl bromide, 52
Acetaldehyde, 79
Acetic acid, 22
Acetoacetate decarboxylase, 100
Acetone, 72
Acetophenone, 13
Acetylmesitylene, 77
Acid chromate-dichromate equilibrium, 72
Acidity, 13
Acidity function, 69, 70
Acidity studies, 20
Acid-base catalysis, 40
Activation energy, 29, 66
Activity coefficients of proteins, 44
Adams, Roger, 10, 24, 55
Addition of bromine to double bonds, 37
Aerobacter, 103
Aflatoxin, 20
Alcoholic fermentation, 32, 33
Alexander, Elliot, 91
American Chemical Society, 105
Amine catalysis of the dealdolization of diacetone, 41
Amino acids, 27, 41
Annals of the New York Academy of Sciences, 41
Anti-Semitism, 2, 36, 62
Arigoni, Duilio, 102
Aston, Jack, 41
Asymmetric center, 81

B

Baldwin, Ernest, 31
Baltimore, Maryland, 1, 9
Balzac, Honore de, 6
Barium ethylene phosphate, 100
Bartlett, Paul D., 7, 23, 27, 30, 32, 38, 41, 47, 54, 87, 89, 90, 91
Battersby, Alan, 102
Beckman DU, 58, 59
Beilstein's Handbuch der organischen Chemie, 12
Bender, Myron, 59, 85
Benner, Stephen, 85, 86, 102
Benzaldehyde, 34
Benzenoid compounds, 46
Benzilic acid rearrangement, 24, 34, 35
Benzoic acid, 13
Bergmann hypothesis, 49
Bernthsen, August, 12
Berry, Stephen, 98, 99
Bimolecular exchange, 29
Binet IQ test, 8, 9
Biographies of chemists (in Fieser's organic text), 61

Biology course (Dartmouth College), 16
Bioorganic chemistry, 85, 86
Biosynthesis of steroids, 60
Biphenyls, 66, 68
Bjerrum, Niels, 44, 47, 72
Bloch, Konrad, 60
Bodansky, Meyer, 32, 33
Bodenstein, Max, 29, 96
Bogert, Marston T., 24, 35, 39
Bohr, Niels, 26
Bolser, Charles, 12
Boron, 54
Breslow, Ronald C. D., 109
Bromination of acetone, 29, 30
Bromine, 29
Bromonium ion intermediates, 37
Brookhaven National Laboratory, 86
Brown, Bancroft, 10
Brown, H. C., 42
Brown, John F., 40
Brown University, 85
Brown, Weldon, 54, 81, 91
Brønsted, Johannes, 72, 88, 92
Bruceton, Pennsylvania, 37, 70, 83
Bunton, C. A., 97
Burg, Anton, 54
Butcher, Walter, 97

C

Calorimetry, 103
California Institute of Technology (Caltech), 86
California, University of, Berkeley, 54, 88
California, University of, Los Angeles, 89
Calvin, Melvin, 88
Cambridge, Massachusetts, 60
Cancer Institute (Philadelphia), 77
Cannizzaro, Stanislao, 35
Cannizzaro reaction, 34
Carbohydrates, 27
Carbon dating, 60
Carbonium ion, 108
Carcinogens, 20
Catalysis, 40
Charge-charge interaction, 44
Chemical Abstracts, 63
Chicago, University of, 4, 8, 9, 28, 30, 31, 34-36, 41-43, 45, 49, 50, 51, 55, 58-61, 63, 64, 70, 71, 81, 83-86, 97, 98, 108
Child Study organization (Baltimore), 3
Chloracetic acid, 44
Chow, Bacon, 19
Chowdhry, Vinay, 86
Chromatography, 13
Chromic acid, 49, 55, 65
Chromic acid oxidation, 55, 56, 65, 72, 76

Chromium
 hexavalent, 72
 pentavalent, 72
 tetravalent, 72
Cincinnati, Ohio, 1
Citric acid, 80, 81
Civil War, 1
Cleveland, William Wallace, 101
Cohen, Herzl, 62
Cohn, Edwin, 34, 44
Cohn, Mildred, 38, 101
Coleman, Roberta, 86
College Board Examinations, 5, 7
Columbia University, 32-35, 37, 39, 41, 50, 60, 65, 68, 72
Combustion train, 78
Committee on Science and Public Policy (National Academy of Sciences), 105
Computational methods, 96
Conant, James B., 10, 11, 13, 14, 16, 17, 20-26, 28, 30, 38, 41, 69, 71, 83, 87
Condensation reactions, 17, 24, 76
Conference on Organic Reaction Mechanisms, Notre Dame University (1946), 89
Conflict between teaching and research, 63
Conrad, Joseph, 6
Conway, Hertsell, 62
Cooperman, Barry, 86
Copper oxide, 78
Cornell University, 35, 36, 43
Cornforth, Sir John, 102
Corwin, Alsoph, 22, 23, 31
Coulson, Charles A., 109
Cram, Donald J., 89, 108
Criegee, R., 87
Crystallization
 of enzymes, 33
 of urease, 33
Cyanohydrin formation, 28
Cyclic phosphate, 99

D

Dartmouth College, 1, 7-11, 14-16, 18, 19, 26, 72, 92
Davidson, Norman, 42
Dawson, --, 92
De Kruif, Paul H., 6
Dealdolization, 73
Debye, Peter, 9, 48
Debye curve, 48
Debye-Hückel activity coefficient, 34
Decarboxylation, 71, 73-77, 88
Decarboxylation of oxaloacetate, 74
Delaware, University of, 86
Dennis, Edward, 86, 99
Depression, The Great, 2, 10, 11, 26, 36, 51
Determinant, solving N by N, 68

Deuterium, 78, 79, 110
Deuterium isotope effect, 81, 82
Deyrup, Alden J., 28, 43
Diazotization, 91
Dibasic acids, 44
Dichromate ion, 72
Dickens, Charles, 6
Dideuteroethanol, 78, 80
Dielectric constant, 44, 74
Dietz, Emma, 19
Dilatometer, 59
Dimethyl phosphate, 103
Dimethylacetoacetic acid, 73
Dimethylsulfoxide, 108
Diphosphopyridine nucleotide, 78
Dipole-charge interaction, 44
Dipyrrolmethanes, 22, 23
Dipyrrolmethines, 22
Distilling columns, 13
Doering, W. von Eggers, 68
Doisy, Edward A., 21
DPN, 33, 78
DPND, 79, 80
DPNH, 78
Du Pont de Nemours & Co., E. I., Inc., 86, 99
Dumas, Alexandre, 6
Dynamic Aspects of Biochemistry, 31

E

Eckstein, Fritz, 101
Edward, J. T., 46
Ehrenson, S. E., 46
Electrical saturation, 44, 48
Electricity and magnetism course (University of Chicago), 28, 41, 44
Electrochemical measurements of acidity, 13
Electron conduit, 77
Electrostatic equations, 63
Electrostatic equations for a sphere, 45
Electrostatic theory, 44
Emulsifying agent, 34
Enantiotopic and diastereotopic atoms, 80
Enantiotopic deuterium compounds, 81
ENIAC, 67
Enolization, 75, 81
Enolpyruvate, 77
Enzyme models, 73
Enzymes, 54, 97
 as proteins, 33, 40
Enzymic
 columns, 102
 decarboxylation, 74
 hydrolysis, 77
 oxidation-reduction, 77
 reactions at phosphorous, 101

Enzymology, 103
Equations for the oblate ellipsoid of revolution, 46
Ester hydrolysis, 55
Ethanol, 79
Ethyl acetate, 48
Ethyl acetoacetate, 22
Ethyl ether, 48
Ethylene phosphate, 99, 100, 103
Eucken, A., 44, 47
Explosives Research Laboratory (NDRC), Bruceton, Pennsylvania,
37, 58, 70
Explosives work, 70, 104
Eyring, Henry, 90, 96
Eyring absolute rate theory, 96

F

Farrel, P. G., 46
Fermentation, 33
Fermi, Enrico, 59
Ferric complexes, 77
Fieser, Louis F., 13, 16, 17, 20, 27, 61, 62, 89
Fieser's course on steroids, 27
Fischer, Emil, 13, 27
Fischer, Hans, 23
Fisher, Harvey, 78, 85
Flexser, Leo A., 13, 28
Florida, University of, 73
Fourier series and spherical harmonics, 45
Four-membered cyclic transition state, 29
Franck, James, 9
Free radical reaction, 29
Frey, Perry, 85, 101
Friday afternoon physical organic seminars (Harvard University),
32
Fridovich, Irwin, 85
Fructose-1,6-diphosphate, 32
Furanol, 18
Fuson, Reynold C., 77

G

Geissman, T. A. (Ted), 77, 79
Genetic code, 64
Gerlt, John, 86, 103
Gershinowitz, Harold, 19
Glycolysis, 33
in muscle, 32
Gordon Conference on Enzymology, 85, 87
Gorenstein, David, 86
Goucher College, 3
Greenberg, Daniel, 63
Greenspan, Joseph, 37
Grignard reaction, 20, 77
Grigsby, William, 77
Guthrie, Peter, 86

H

- Haake, Paul, 85, 99, 100
Halogenation of acetone, 28
Hamilton, Gordon, 85
Hammett, Louis P., 13, 24, 28, 36-39, 42, 43, 60, 70, 87, 89
Harden, Arthur, 33
Harden-Young ester, 32
Harkins, William, 54, 83
Hartshorn, E. B., 12
Harvard University, 10, 11, 13, 14, 16, 17, 21-23, 27, 28, 34, 35, 38, 43, 61, 83, 84, 87
Harvard Business School, 7
Harvard Medical School, 44
Hauser, Charles, 76, 90
Heats of hydrolysis of cyclic and acyclic phosphates, 103
Heilbronner, Edgar, 109
Hercules, Inc., 104
Heterocyclic chemistry, 23
History (as taught at Dartmouth College), 15
History of metallurgy, 93
History of science, 64, 66
Hoffmann, Roald, 108
Hogness, Thorfin Rusten, 54
Hooke's Law, 67
Hückel, Eric, 90
Hückel, Walter, 90
Hückel's Theoretische Grundlagen der organischen Chemie, 21
Hutchins, Robert Maynard, 50, 59, 65
Hydrogen bonding, 48
Hydrogen bromide, 76
Hydrogen peroxide, 102
Hydrogen transfer, 78
Hydrogen-bonded liquids, 47
Hydrogen-deuterium exchange, 110
Hydrogen-deuterium ratio, 79
Hydrolysis
 of carboxylic acid esters and amides, 98
 of nitriles, 102
 of phosphate esters, 97, 99, 103
 of nucleotide diesters, 103

I

- Immobilized enzymes, 102
Indiana University, 83
Infrared (IR) instrumentation, 13, 58
Ingold, Sir Christopher, 30, 43, 44, 48, 69, 87, 88, 108
Ingraham, L. L., 109
Intelligence tests, 8
Intermediary metabolism, 98, 101
Iodination of tyrosine, 49
Ionization, 13
Isopropyl alcohol, 72
Isotope effect, 82
Isotope ratio mass spectrometers, 59
Isotope ratios of carbon and oxygen in carbonate, 59

Isotope separation, 38

J

Job, J. L., 46
John Harvard Fellowships, 26
Johns Hopkins University, 22
Johnson, Lyndon, 104
Jones, William, 73
Journal of Biological Chemistry, 75
Journal of Chemical Physics, 75, 76
Journal of the American Chemical Society, 21, 76, 94, 96

K

Kaiser, E. T., 85
Kaplan, Nate, 66
Karplus, Martin, 97
Karrer, Paul, 21
Katchalski, Emphraim, 102
Kennelly, Arthur Edwin, 19
Kennelly, Reginald, 19
Kenyon, George, 86
Kharasch, Morris, 5, 34-36, 43, 51-55, 60, 68, 69, 80, 87, 91, 108
Khorana, Har Gobind, 64, 102
Kimball, George E., 37, 90
Kinetic isotope effect, 81
Kirkwood, John G., 34, 43-45, 47, 48, 68, 75, 76, 97
Kistiakowsky, George B., 11, 17, 19, 26, 29
Klotz, Irving, 42
Kluger, Ronald, 86
Knorr pyrrole synthesis, 22
Knowles, Jeremy, 101
Kohler, Elmer P., 11, 16-18, 20, 23, 26, 30, 84
Kornblum, Nathan, 91
Koshland, Daniel, 59, 85
Krebs cycle, 33, 80
Kurzes Lehrbuch der organischen Chemie,

L

La Jolla, California, 66, 86
LaMer, Victor K., 37, 72
Lapworth, Arthur, 13, 28-30, 52, 72, 81, 87, 92-94, 96
Lasso mechanisms, 62
Leermakers Symposium, 94, 96
Legendre functions, 45
Lehrbuch der organischen Chemie, 21
Lerman, Charles E., 86
Lewis, Gilbert N., 92
Lewis and Randall, Thermodynamics, 26
Lewis octet, 92
Libby, Willard F., 54, 59, 60
Lipscomb, William, 96
Lithium aluminum hydride, 54, 91
London, England, 57
Long, Franklin A., 83, 105, 106

Longuet-Higgins, H. C., 109
Lowry, Martin, 92
Lucas, Howard, 87, 88

M

Malsch, F., 48
Marberg, Carl M., 50
Marvel, Carl S., 24, 55
Massachusetts Institute of Technology (MIT), 34, 44, 82, 102
Massachusetts, University of, 20
Mass spectrometers, 59
Mauzerall, David, 85
Maximum-minimum problems, 1
May, Ernest, 43
Mayer, Joseph, 54, 59, 65, 67, 68, 75, 77
Mayer, Maria, 60, 65
Mayo, Frank R., 34, 52, 54, 91, 108
McEwen, William, 20
McKenna, Charles, 86
Mechanism
 of enolization, 81
 of enzyme action, 40
Mechanistic approach to organic chemistry, 30
Mechanistic organic chemistry, 13
Meerwein, H., 87, 94
Melander, Lars, 82
Metabolic pathway of glycolysis and of fermentation, 32
Metal enolates, 75
Metal-ion decarboxylation, 74
Methyl cellosolve, 17
Methyl ethylene phosphate, 99, 100
Methyl phosphonate, 101
Methylcholanthrene, 20
Methylene group, 75
Methyl ethylene phosphate, 99
Methyl trimethylene phosphonate, 99
Methyl tetramethylene phosphinate, 99
Methylene, singlet and triplet states, 94
Meyerhof, O., 32
Microbe Hunters, 6
Miller, William, 35
Molecular mechanics, 65
 application to proteins, 97
Monomeric metaphosphate, 97
Mooney, Rose C. L., 49
Morton, Thomas, 85
Muettterties, E. L., 99
Mulliken, Robert, 109
Mutarotation, 40

N

National Academy of Sciences, 90, 104, 105
National Defense Research Committee (NDRC), 37
National Research Council (NRC), 34, 37
National Research Council Fellow, 35

National Science Foundation (NSF), 105
Nature, 80
Nelson, J. M. "Pop", 38
Neuberg ester, 32
New Orleans, Louisiana, 49
Newman, Melvin, 19, 20
Nicolaides, Nicholas, 81, 82
Nictotinamide adenine dinucleotide, 78
Nitration, 69
 of benzene, 82
Nitration reactions, 69
Nitric acid, 69
Nitrilase, 102
Nitriles, 102
Non-hydrogen-bonding liquids, 48
Northrop, John H., 33
Notre Dame University, 92
Novick, Aaron, 49, 71, 72, 76, 86
Nucleic acids, 27
Nucleotides, 64, 98
Nucleus, structure of, 60
Number series, 9

O

Oblate ellipsoid of revolution, 46
Oceans, ancient, temperature of, 59, 60
Ogg, Richard, 19
Ogston, A. G., 80, 81
Ohio State University, 85
O'Leary, Marion, 86
Optically active biphenyls, 68
Optically active deuterobutanol, 82
Optically active deuterioethanol, 82
Organic chemistry course (University of Chicago), 61, 64
Organic chemistry course (Harvard University), 11, 26
Organic chemistry course (Dartmouth College), 11, 12
Organic chemistry course, teaching of, 65
Organic structure determination, 92
Organofluorine compounds, 35
Oxaloacetate, 81
Oxygen-18 exchange, 99
Oxygen-18 water, 100
Oxy-nitration process, 70
OZ books, 6

P

Park School (Baltimore), 4, 5
Paul, Martin, 28, 37, 41
Pauling, Linus, 30, 87, 89, 108, 109
Pederson, Kai, 73, 75, 76, 88
Pennsylvania State University, 41
Pennsylvania, University of, 7, 86
Pepsin, 33
Peroxide effect, 34, 35
Perrin, Charles, 86

Phi Beta Kappa, 64
Philadelphia, Pennsylvania, 42
Philosophy of science, 64
Phosphate esters, 32, 98
Phosphoenolpyruvate, 77
Phosphorous atom, 98
Phosphorylation of glucose, 32
Photographic UV, 13
Physical chemistry course (Dartmouth College), 11
Physical chemistry course (Harvard University), 26
Physical chemistry of solutions, 47
Physical organic chemistry, 17, 28, 31, 38, 41, 42, 52, 78, 83, 86,
87, 89, 91, 92, 94, 96-98, 102
Physical organic chemists, 89, 91
Physical organic chemistry course (Harvard University), 61
Planets, origin of, 60
Porphyrin syntheses, 20-22
Preparative synthetic chemistry, 22
Price, Charles C., 88-92
Prolate ellipsoid of revolution, 45
Proteins, 27, 40
Protonations, 70
Pseudorotation, 98, 101
Pseudorotation in phosphorous compounds, 98
Pseudorotation mechanism, 99
Puck, Ted, 42
Purines, 11, 27
Putnam, Frank, 83
Pyrex glass, 13
alpha-Pyridone, 40
Pyridoxal phosphate, 94
Pyrimidine base, 99
Pyrimidines, 11, 27
Pyrrole, 22, 23
Pyruvate, 81

Q

Quadrangle Club, 30
Qualifying examinations (Harvard University), 11
Quantum mechanical calculations, 94, 96
Quantum theory, 26
Quarterly Review of Biology, 79
Quattlebaum, Merrit, 19, 20
Quinones, 13

R

Racemization of optically active biphenyls, 66
Raman spectra, 69
Randall, Merle, 26
Reaction between hydrogen and iodine, 29
Reaction kinetics, 29, 31, 37, 59, 72
Reaction mechanisms, 23, 38
Reinmuth, Otto, 53
Retroaldol condensation, 21, 32
Ribonuclease, 99

Richards, T. W., 13
Roberts, John D., 37, 90, 91, 108
Roberts, Irving, 37
Robinson, Sir Robert, 30, 52, 87
Rocek, Jan, 56, 86
Rockefeller University, 86
Rocket propellants, 104
Roosevelt, Franklin D., 58
Rose, Ernie, 77

S

Samuel, David, 86
San Francisco, California, 86
Sanger, Frederick, 64
Sarmousakis, James N., 46
Scheraga, Harold, 97
Schiff base, 41
Schiff base mechanism, 73
Schlesinger, Hermann, 36, 49, 50, 51, 53, 54
Schmutzler, R., 99
Schrödinger equation, 26
Science, 63
Science Advisory Committee, 104
Seitz, Fred, 108
Selenium electrode, 17
Seligman, Arnold, 20
Seltzer, Stanley, 86
Semicarbazone formation, 17, 24, 41
Senior, James, 4, 16, 43
Shull, Harrison, 105
Sigal, Irving, 86
Sigman, David, 85
Silk fibroin, 49
Singlet and triplet states of methylene, 94
Skell, Philip, 94
Smith, Cyril, 93
Sodium benzoate, 34
Sodium hydride, 54
Sodium hydroxide, 103
Sodium nitrite, 22
Solvent effects, 97
Solvent effects on acids and bases, 17
Solvolytic, 43, 55
Sophie Newcomb College, 49
Spatial perception, 9
Sprague Institute, 50
Stanley, Wendell, 31, 40
Steigman, Joseph, 37
Steinberger, Rudolph, 73, 75-77
Stereochemical inversion, 79
Stereochemical inversion at phosphorous, 101
Stereochemistry, 81
Stereospecific transfer of hydrogen, 71
Steric hindrance, 77
Steroids, 27

Stieglitz, Julius, 36, 53
Stock Market crash, 11
Streitwieser, Andrew, 82, 90, 91, 109
Structure of the nucleus, 60
Sturtevant, Julian, 103
St. Joseph, Missouri, 1
Successive approximations, 67
Sudborough, J. J., 12
Sugarman, Nathan, 42
Sugars, 27
Sumner, James B., 33
Superacidity, 43
Surface chemistry, 54
Swain, C. Gardner, 40, 91
Synthesis, mixed chemical-enzymic, 102
Synthetic organic chemistry, 64

T

Tagaki, Wachiro, 100
Tarbell, D. Stanley, 90
Teaching of elementary organic chemistry, 65
Teller, Edward, 59
Temperatures of the ancient oceans, 59, 60
Tertiary butyl group, 76
Tetramethylglucose, 40
The Chemistry of Natural Products Related to Phenanthrene, 27
The Mikado, 53
Theoretical organic chemistry, 10, 23, 55, 62
Theoretische Grundlagen der organischen Chemie, 21
Theory of organic chemistry, 93
Thermodynamics (Lewis and Randall), 26
Thiamin, 109, 110
Thiazole, 110
Thornton, Edward, 86, 96
Three-point attachment, 81
Thurstone, Louis Leon, 8
Tishler, Max, 18, 19, 20
Titration, 59
Tobacco mosaic virus, 31, 40
Todd, Sir Alexander R., 99
Toepler pump, 79
TPN, 33
Transition state, 74
Transitory enols, 77
Treffers, (Henry) Peter, 37
2,4,6-Trimethylacetophenone, 77
Trinucleotides, 64
Triphenylcarbinol series, 70
Triphenylmethane indicators, 69, 70
Tritium, 82
Tritium isotope effect, 82
Tropinone alkaloids, 30
Trypsin, 33
Tuck School (Dartmouth College), 7, 9
Two-electron bond, 92

U

Ultraviolet (UV) spectra, 13, 77
University of California Medical School, 86
University of Chicago Nursery School, 3
University of Chicago schools, 6
Unstable free-radicals, 60
Unsymmetrical ester, 76
Urey, Harold C., 38, 54, 59, 60, 65, 66, 79
Usher, David, 101
U.S. Rubber Company, 104

V

Van der Waals repulsion, 67
Vennesland, Birgit, 71, 77, 78, 82
Vitamin K structure and synthesis, 21
Volstead Act, 1, 2, 3

W

Walling, Cheves, 91, 108
War projects, 68
War work, 71
Watanabe, Warren, 71, 72, 76
Weak acids and bases, 13
Weinhaus, Sid, 80
Wesleyan University, 94
Western Ontario, University of, 86
Westheimer, Ellen (daughter), 3
Westheimer, Ferdinand (grandfather), 1
Westheimer, Frank H.
 associate professor, 66
 biology course, 16
 brokerage business, 9
 brothers, 3
 children, 4
 family business, 2
 interest in biochemistry, 31
 John Harvard Fellowship, 25
 mother, 2, 3
 mother-in-law, 64
 NRC Fellowship, 24
 parents, 9, 11
 undergraduate research, 14
Westheimer function, 69
Westheimer, Henry (father), 1, 2, 10, 11
 brokerage business, 5, 7
 friends, 6
Westheimer, Jeanne (wife), 3, 31, 39, 41, 42, 57
Westheimer Report, 37, 104
Westheimer, Ruth (daughter), 3
Wharton School (University of Pennsylvania), 7
Wheland, George W., 9, 10, 30, 31, 47, 54, 55, 81, 87, 89, 108, 109
Wheland's Advanced Organic Chemistry, 47
Whitesides, George, 102

Whitmore, Frank C., 87, 108
Wiberg, Kenneth B., 56-58, 72, 90, 91, 109
Wieland, Heinrich, 27
Wilson, Christopher, 88
Windaus, Adolph, 27
Winstein, Saul, 23, 83, 87, 88, 108
Wisconsin, University of, 101
Wolfenden, Richard, 103
Woodward, Robert B., 60, 64, 85, 93, 102
Woodward-Hoffmann rules, 97
World War I, 3
World War II, 58, 65-67, 69, 83
Wright, George, 19

X

X-ray crystallography, 27

Y

Yale University, 86, 103
Young, Thomas F., 54
Young, William, 88

Z

Zerner, Burt, 85
Zinc, 22, 78, 79
Zwitterion, 34, 74