CHEMICAL HERITAGE FOUNDATION

RUDOLPH A. MARCUS

Transcript of an Interview
Conducted by

James J. Bohning

in

Pasadena, California

on

20 June 1991

(With Subsequent Corrections and Additions)

THE CHEMICAL HERITAGE FOUNDATION
Oral History Program

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(Revised 17 March 1993)

Chemical Heritage Foundation
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Philadelphia, Pennsylvania 19106

RUDOLPH A. MARCUS

1923	Born in Montreal, Canada, on 21 July

Education

1943	B.Sc., chemistry, McGill University
1946	Ph.D., chemistry, McGill University

Professional Experience

1944-1946	Research Staff Member, RDX Project
1946-1949	Junior Research Officer in Photochemistry, National Research Council of Canada
1949-1951	Postdoctoral Research Associate in Theoretical Chemistry, University of North Carolina
	Polytechnic Institute of New York
1951-1954	Assistant Professor of Physical Chemistry
1954-1958	Associate Professor of Physical Chemistry
1958-1964	Professor of Physical Chemistry
	University of Illinois
1964-1978	Professor of Physical Chemistry
	California Institute of Technology
1978-present	Arthur Amos Noyes Professor of Chemistry

Honors

1943	Anne Molson Prize, McGill University
1972	Senior Fulbright-Hayes Scholar, Fulbright Program
1976	Senior U.S. Scientist Award, Alexander von Humboldt-Stiftung Foundation
1978	Irving Langmuir Award in Chemistry and Physics, American Chemical Society
1979	The Electrochemical Society Lecture Award
1982	Robinson Medal, Faraday Division of the Royal Society of Chemistry
1983	Chandler Medal, Columbia University

1983 D.Sc., honorary, University of Chicago
1985 Wolf Prize in Chemistry
1986 D.Sc., honorary, Polytechnic University
1987 D.Sc., honorary, University of Göteborg, Sweden
1988 Centenary Medal, Faraday Division of the Royal Society of Chemistry
1988 D.Sc., honorary, McGill University, Canada
1988 Peter Debye Award in Physical Chemistry, American Chemical Society
1988 Willard Gibbs Medal, Chicago Section, American Chemical Society
1989 National Medal of Science
1990 Evans Award, Ohio State University
1990 Theodore William Richards Medal, Northeastern Section, American Chemical Society
1991 Edgar Fahs Smith Award, Philadelphia Section, American Chemical Society
1991 Ira Remsen Memorial Award, Maryland Section, American Chemical Society
1991 Pauling Medal, Portland, Oregon and Puget Sound Section, American Chemical Society
1992 Nobel Prize in Chemistry
1993 Hirschfelder Prize in Theoretical Chemistry, University of Wisconsin
1993 D.Sc., honorary, University of New Brunswick, Canada
1993 D.Sc., honorary, Queen's University, Canada
1993 American Academy of Achievement Gold Plate Award
1994 Lavoisier Medal, Sociéte Française de Chimie
1995 D.Sc., honorary, University of Oxford, England
1996 D.Sc., honorary, University of North Carolina at Chapel Hill
1996 D.Sc., honorary, Yokohama National University, Japan
1996 Auburn-Kosolapoff Award, Auburn Section, American Chemical Society
1997 D.Sc., honorary, University of Illinois at Urbana-Champaign
1997 Award in Theoretical Chemistry, American Chemical Society
1997 Oesper Award, Cincinnati Section, American Chemical Society
1998 D.Sc., honorary, Technion-Israel Institute of Technology, Israel
1998 Top 75 Award, *Chemical and Engineering News*, American Chemical Society

ABSTRACT

Rudolph Marcus begins the interview with a discussion of his family background and early education. Though he spent some of his early years in Detroit, Michigan, he primarily grew up in a Jewish neighborhood in Montreal, Canada. Marcus was encouraged to continue his education by his parents and his uncles. He enrolled in the twelfth grade, the equivalent of the first year of college, to save money for the university. Marcus then attended McGill University, majoring in chemistry. He graduated with a B.Sc. in 1943; due to the war, he was able to take his fourth year in the course of a summer. Marcus went directly to graduate school, also at McGill, and studied physical chemistry with Carl Winkler. His research, RDX, was determined by war needs, and he received his Ph.D. in 1946. He spent an additional two and a half years on a National Research Council of Canada post-doc with Edward W. R. Steacie. In 1949, Marcus moved to the University of North Carolina, accepting a position with Oscar Rice, who had received an Office of Naval Research contract. It was there that Marcus began to focus on theory, particularly unimolecular and transition state theory. The result of this work was the development of the RRKM theory. In 1951, Marcus moved again, this time to Brooklyn Polytechnic University, where he became an assistant professor in the chemistry department. Marcus discusses his colleagues, including Herman Mark, Herbert Morawetz, and Charles Overberger, as well as the atmosphere of the institution. He became interested in electrostatics and polyelectrolytes. He also began some polymer research, and pursued work on electron transfer. In 1964, Marcus left Brooklyn Polytechnic for the University of Illinois. During his time there, he spent a few semesters at Oxford University as a visiting professor. In 1978, Marcus accepted a position at Caltech, where he began collaborating with Ahmed Zewail. His desire to pursue his research led him to decline administrative work. At Caltech, Marcus continued his electron transfer research. Marcus concludes with a discussion of his family, the challenges of research, and thoughts on his electron transfer work.

INTERVIEWER

James J. Bohning is currently Visiting Research Scientist at Lehigh University. He has served as Professor of Chemistry Emeritus at Wilkes University, where he was a faculty member from 1959 to 1990. He served there as chemistry department chair from 1970 to 1986 and environmental science department chair from 1987 to 1990. He was chair of the American Chemical Society's Division of the History of Chemistry in 1986, received the Division's outstanding paper award in 1989, and presented more than twenty-five papers before the Division at national meetings of the Society. He has written for the American Chemical Society News Service, and he has been on the advisory committee of the Society's National Historic Chemical Landmarks committee since its inception in 1992. He developed the oral history program of the Chemical Heritage Foundation beginning in 1985, and was the Foundation's Director of Oral History from 1990 to 1995.

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1. Robert Martin Caven and G. D. Lander, *Systematic Inorganic Chemistry from the Standpoint of the Periodic Law*, 6th edition (London: Blackie, 1939).

2. Otto Maass and Edward W. R. Steacie, *An Introduction to the Principles of Physical Chemistry*, 2nd edition (New York: John Wiley & Sons, 1939).

3. Henry Gilman, *Organic Chemistry, an advanced treatise*, 2nd edition (New York: Wiley, 1943).

4. Robert J. Hartman, *Colloid Chemistry* (Boston: Houghton Mifflin, 1939).

5. Leonard B. Loeb, *The Kinetic Theory of Gases* (New York: McGraw-Hill, 1934).

6. Cyril N. Hinshelwood, *The Kinetics of Chemical Change* (Oxford: Clarendon Press, 1940).

7. Louis Hammett, *Physical Organic Chemistry: reaction rates, equilibria, and mechanisms, 1st ed.* (New York & London: McGraw Hill, 1940).

8. R. A. Marcus, E. W. R. Steacie, and B. de B. Darwent, "The Mercury Photosensitized Reaction of Dimethyl Ether," *Journal of Chemical Physics*, 16 (1948): 987.

9. R. A. Marcus and E. W. R. Steacie, "Der sterische Faktor bei der Rekombination von Methyl-Radikalen," *Zeitschrift Naturforschung*, 4a (1949): 332.

10. Henry Eyring, "The Activated Complex in Chemical Reactions," *Journal of Chemical Physics*, 3 (1935): 107.

11. RRKM paper, presented at the "Symposium on Anomalies in Reaction Kinetics," American Chemical Society, Minneapolis, Minnesota, June 19-21, 1950, published later as reference 12.

12. R. A. Marcus and O. K. Rice, The Kinetics of the Recombination of Methyl Radicals and "Iodine Atoms," *Journal of Physical Colloid Chemistry*, 55 (1951): 894.

13. R. A. Marcus, "Unimolecular Dissociations and Free Radical Recombination Reactions," *Journal of Chemical Physics*, 20 (1952): 359.

14. R. A. Marcus, "Lifetimes of Active Molecules. I," *Journal of Chemical Physics*, 20 (1952): 352.

    R. A. Marcus, "Lifetimes of Active Molecules. II," *Journal of Chemical Physics*, 20 (1952): 355.

R. A. Marcus, “Recombination of Methyl Radicals and Atomic Cracking of Ethyl Radicals,” *Journal of Chemical Physics*, 20 (1952): 364.

15. Noel B. Slater, *Theory of Unimolecular Reactions*, (Ithaca, NY: Cornell University Press, 1959).

16. R. A. Marcus, “Titration of Polyelectrolytes at Higher Ionic Strengths,” *Journal of Physical Chemistry*, 58 (1954): 621.

17. R. A. Marcus, “Calculation of Thermodynamic Properties of Polyelectrolytes,” *Journal of Chemical Physics*, 23 (1955): 1057.

18. R. A. Marcus, “On the Theory of Oxidation-Reduction Reactions Involving Electron Transfer. I,” *Journal of Chemical Physics*, 24 (1956): 966.

R. A. Marcus, “Electrostatic Free Energy and Other properties of States Having Nonequilibrium Polarization. I,” *Journal of Chemical Physics*, 24 (1956): 979.

19. Ralph H. Page, Y. R. Shen and Y. T. Lee, “Local Modes of Benzene and Benzene Dimer, Studied by Infrared-Ultraviolet Double Resonance in a Supersonic Beam,” *Journal of Chemical Physics*, 88 (1988): 4621.

20. R. A. Marcus, H. P. Gregor and J. Belle, “Studies on Ion Exchange Resins. IX. Capacity and Specific Volumes of Quaternary Base Anion Exchange Resins,” *Journal of the American Chemical Society*, 76 (1954): 1984.

R. A. Marcus, H. P. Gregor and J. Belle, “Studies on Ion Exchange Resins. XIII. Selectivity Coefficients of Quaternary Base Anion-exchange Resins Toward Univalent Anions,” *Journal of the American Chemical Society*, 77 (1955): 2713.

21. R. A. Marcus and G. K. Oster, “Exploding Wire ad a Light Source in Flash Photolysis,” *Journal of Chemical Physics*, 27 (1957): 189.

R. A. Marcus and G. K. Oster, “Photochemical Studies in Flash Photolysis. I. Photolysis of Acetone,” *Journal of Chemical Physics*, 27 (1957): 472.

R. A. Marcus and N. Slagg, “Photochemical Studies in Flash Photolysis. II. Photolysis of Acetone with Filtered Light,” *Journal of Chemical Physics*, 34 (1961): 1013.

R. A. Marcus and A. Shilman, “Photochemical Studies in Flash Photolysis. IV. Intensity and Wavelength Effects,” *Bulletin des Sociétés Chimiques Belges*, 71 (1962): 653.

R. A. Marcus and A. Shilman, “Photochemical Studies in Flash Photolysis. III. Photolysis of Acetone in Different Wavelength Regions,” *Journal of Chemical Physics*, 39 (1963): 996.

22. R. A. Marcus, R. J. Ehrig and C. G. Overberger, “Ionic Polymerization. IX. The Effect of Water in the Cationic Polymerization of Styrene Catalyzed by Stannic Chloride,”

Journal of the American Chemical Society, 80 (1958): 2456.

23. R. A. Marcus and W. C. Kreye, "Highly Sensitive Low Temperature Fractionation Method for Separation and Measurement of Boron Hydrides," *Analytical Chemistry*, 34 (1962): 1665.

24. R. A. Marcus and W. C. Kreye, "Photolysis of Diborane at 1849 A," *Journal of Chemical Physics*, 37 (1962): 628.

R. A. Marcus and H. Brumberger, "Kinetic Study of the Reaction of Diborane with Phosphine," *Journal of Chemical Physics*, 24 (1956): 741.

25. R. A. Marcus, "Reorganization Free Energy for Electron Transfers at Liquid-Liquid and Dielectric Semiconductor-Liquid Interfaces," *Journal of Physical Chemistry*, 94 (1990): 1050.

R. A. Marcus, "On the Theory of Electron Transfer Rates Across Liquid-Liquid Interfaces," *Journal of Physical Chemistry*, 94 (1990): 4152; 7742; 99 (1995): 5742.

R. A. Marcus, "Theory of Electron Transfer Rates Across Liquid-Liquid Interfaces. II. Relationships and Applications," *Journal of Physical Chemistry*, 95 (1991): 2010; 99 (1995): 5742.

26. R. A. Marcus and S. J. Klippenstein, "Application of Unimolecular Reaction Rate Theory for Highly Flexible Transition States to the Dissociation of CH_2CO into CH_2 and CO," *Journal of Chemical Physics*, 91 (1989): 2280.

R. A. Marcus and D. M. Wardlaw, "RRKM Reaction Rate Theory for Transition States of Any Looseness," *Chemical Physics Letters*, 110 (1984): 230.

R. A. Marcus and D. M. Wardlaw, "Unimolecular Reaction Rate Theory for Transition States of Partial Looseness. II. Implementation and Analysis with Applications to NO_2 and C_2H_6 Dissociations," *Journal of Chemical Physics*, 83 (1985): 3462.

R. A. Marcus and D. M. Wardlaw, "Unimolecular Reaction Rate Theory for Transition States of Any Looseness. 3. Application to Methyl Radical Recombination," *Journal of Physical Chemistry*, 90 (1986): 5383.

R. A. Marcus and D. M. Wardlaw, "On the Statistical Theory of Unimolecular Processes," *Advances in Chemical Physics*, 70 Part 2 (1988): 231.

R. A. Marcus and S. J. Klippenstein, "Unimolecular Reaction Rate Theory for Highly Flexible Transition States. Use of Conventional Coordinates," *Journal of Physical Chemistry*, 92 (1988): 3105.

R. A. Marcus and S. J. Klippenstein, "Unimolecular Reaction Rate Theory for Highly Flexible Transition States. 2. Conventional Coordinate Formulas for the Various

Possible Fragment Combinations. Miscellaneous Topics," *Journal of Physical Chemistry*, 92 (1988): 5412.

R. A. Marcus, S. J. Klippenstein, L. R. Khundkar and A. H. Zewail, "Application of Unimolecular Reaction Rate Theory for Highly Flexible Transition States to the Dissociation of NCNO into NC and NO," *Journal of Chemical Physics*, 89 (1988): 4761.

27. R. A. Marcus, "Product Quantum State Distributions in Unimolecular Reactions Involving Highly Flexible Transition States," *Journal of Chemical Physics*, 85 (1986): 5035.

R. A. Marcus, "On the Theory of the State Distribution of the Reaction Products and Rates of Unimolecular Dissociations," *Chemical Physics Letters*, 144 (1988): 208.

R. A. Marcus, "Unimolecular Reactions, Rates and Quantum State Distribution of Products," *Philosophical Transactions of the Royal Society A*, 332 (1990): 283.

R. A. Marcus and S. J. Klippenstein, "Application of Unimolecular Reaction Rate Theory for Highly Flexible Transition States to the Dissociation of CH_2CO into CH_2 and CO. II. Photofragmentation Excitation Spectra for Vibrationally Excited Fragments," *Journal of Chemical Physics*, 93 (1990): 2418.

28. R. A. Marcus and Prabha Siddarth, "Comparison of Experimental and Theoretical Electronic Matrix Elements for Long-Range Electron Transfer," *Journal of Physical Chemistry*, 94 (1990): 2985.

R. A. Marcus and Prabha Siddarth, "Electron Transfer Reactions in Proteins: A Calculation of Electronic Coupling," *Journal of Physical Chemistry*, 94 (1990): 8430.

29. C. R. Leidner, P. Denisevich, K. W. Willman and Royce W. Murray, "Charge Trapping Reactions in Bilayer Electrodes," *Journal of Electroanalytical Chemistry*, 164 (1984): 63.

30. R. A. Marcus, "A Theory of Electron Transfer Processes at Electrodes," *Transactions of the Symposium on Electrode Processes*, E. Yeager, ed. (Wiley, 1961): 239.

R. A. Marcus, "Electron Transfers at Electrodes," *Encyclopedia of Electrochemistry*, C. A. Hampel, ed. (Reinhold, 1964): 529.

R. A. Marcus, "On the Theory of Electron-Transfer Reactions. VI. Unified Treatment of Homogenous and Electrode Reactions," *Journal of Chemical Physics*, 43 (1965): 679.

R. A. Marcus, "Electron Transfer at Electrodes and in Solution: Comparison of Theory and Experiment," *Electrochimica Acta*, 13 (1968): 356.

31. R. A. Marcus, "On the Theory of Oxidation-Reduction Reactions Involving Electron Transfer. I," *Journal of Chemical Physics*, 24 (1956): 966.

32. R. A. Marcus, “On the Theory of Oxidation-Reduction Reactions Involving Electron Transfer. II. Applications to Data on the Rates of Isotopic Exchange Reactions,” *Journal of Chemical Physics*, 26 (1957): 867.

R. A. Marcus, “On the Theory of Oxidation-Reduction Reactions Involving Electron Transfer. III. Applications to Data on the Rates of Organic Redox Reactions,” *Journal of Chemical Physics*, 26 (1957): 872.

33. R. A. Marcus, “On the Theory of Overvoltage for Electrode Processes Possessing Electron Transfer Mechanism. I.” (ONR Report No. 12, dated 1957). In *Special Topics in Electrochemistry*, P. A. Rock, ed. (Elsevier: New York, 1977), p. 181.

R. A. Marcus, “Electrostatic Free Energy and Other Properties of States Having Nonequilibrium Polarization. II. Electrode Systems.” (ONR Report No. 11, dated 1957). In *Special Topics in Electrochemistry*, P. A. Rock, ed. (Elsevier: New York, 1977), p. 210.

R. A. Marcus, “On the Theory of Electrochemical and Chemical Electron Transfer Processes,” *Canadian Journal of Chemistry*, 37 (1959): 155.

R. A. Marcus, “A Theory of Electron Transfer Processes at Electrodes,” In *Transactions of the Symposium on Electrode Processes*, E. Yeager, ed. (Wiley: New York, 1961), p. 239.

34. R. A. Marcus, “On the Theory of Electron-Transfer Reactions. VI. Unified Treatment of Homogeneous and Electrode Reactions,” *Journal of Chemical Physics*, 43 (1965): 679.

35. R. A Marcus, “Interactions in Polar Media. I. Interparticle Interaction Energy,” *Journal of Chemical Physics*, 38 (1963): 1335.

R. A. Marcus, “Free Energy of Nonequilibrium Polarization Systems. II. Homogeneous and Electrode Systems,” *Journal of Chemical Physics*, 38 (1963): 1858.

R. A. Marcus, “Interactions in Polar Media. II. Continua,” *Journal of Chemical Physics*, 39 (1963): 460.

R. A. Marcus, “Free Energy of Nonequilibrium Polarization Systems. III. Statistical Mechanics of Homogeneous and Electrode Systems,” *Journal of Chemical Physics*, 39 (1963): 1734.

36. R. A. Marcus, “Theory and Applications of Electron Transfers at Electrodes and in Solution,” In *Special Topics in Electrochemistry*, P. A. Rock, ed. (Elsevier: New York, 1977), p. 161.

37. Roger Parsons, “Equilibrium Properties of Electrified Phases,” In *Modern Aspects of Electrochemistry*, J. O’M. Bockris, ed. (London: Butterworths Scientific Publications,

1954).

38. C. A. Coulson, *Valence* (Oxford: Oxford University Press, 1952).

39. R. A. Marcus, "On the Analytical Mechanics of Chemical Reactions. Quantum Mechanics of Linear Collisions," *Journal of Chemical Physics*, 45 (1966): 4493.

R. A. Marcus, "On the Analytical Mechanics of Chemical Reactions. Classical Mechanics of Linear Collisions," *Journal of Chemical Physics*, 45 (1966): 4500.

R. A. Marcus, "Analytical Mechanics of Chemical Reactions. III. Natural Collision Coordinates," *Journal of Chemical Physics*, 49 (1968): 2610.

R. A. Marcus, "Analytical Mechanics of Chemical Reactions. IV. Classical Mechanics in Two Dimensions," *Journal of Chemical Physics*, 49 (1968): 2617.

R. A. Marcus and S.-F. Wu, "Analytical Mechanics of Chemical Reactions. V. Application to the Linear Reactive $H+H_2$ Systems," *Journal of Chemical Physics*, 53 (1970): 4026.

R. A. Marcus and S.-F. Wu, "Analytical Mechanics of Chemical Reactions. VI. Rotational and Vibrational Distributions of the $H+H_2$ Reaction in a Plane," *Journal of Chemical Physics*, 56 (1972): 3519.

39a. R. A. Marcus, "Generalization of Activated-Complex Theory. III. Vibrational Adiabaticity, Separation of Variables, and a Connection with Analytical Mechanics," *Journal of Chemical Physics*, 43 (1965): 1598.

40. H. C. Corben and P. Stehle, *Classical Mechanics* (New York: Wiley Press, 1950).

41. Robert G. Gilbert and Sean C. Smith, *Theory of Unimolecular and Recombinant Reactions* (Boston: Blackwell Scientific Publications, 1991).

42. R. A. Marcus, "Chemical and Electrochemical Electron-Transfer Theory," *Annual Review of Physical Chemistry*, 15 (1964): 155.

43. R. A. Marcus and N. Sutin, "Electron Transfers in Chemistry and Biology," *Biochim. Biophys. Acta*, 811 (1985): 265.

44. R. A. Marcus, D. W. Noid and M. L. Koszykowski, "Quasiperiodic and Stochastic Behavior in Molecules," *Annual Review of Physical Chemistry*, 32 (1981): 267.

45. P. J. Robinson and K. A. Holbrook, *Unimolecular Reactions* (New York: Wiley-Interscience, 1972).

W. Forst, *Theory of Unimolecular Reactions* (New York: Academic Press, 1973).

46. Rudolph A. Marcus, “Theory, Experiment, and Reaction Rates,” *Journal of Physical Chemistry*, Vol. 90, No. 16 (1986): 3460-3465.

47. R. A. Marcus, “Additivity of Heats of Combustion, LCAO Resonance Energies, and Bond Orders of Conformal Sets of Conjugated Compounds,” *Journal of Chemical Physics*, 43 (1965): 2643.

48. R. A. Marcus, “Theory of Electron-Transfer Reaction Rates of Solvated Electrons,” *Journal of Chemical Physics*, 43 (1965): 3477.

49. R. A. Marcus, “Theory of Oxidation-Reduction Reactions Involving Electron Transfer. IV. A Statistical-Mechanical Basis for Treating Contributions From Solvent, Ligands, and Inert Salt,” *Discussions of the Faraday Society*, 29 (1960): 21.

50. R. A. Marcus, R Haberkorn and M. E. Michel-Beyerle, “On Spin-Exchange and Electron-Transfer Rates in Bacterial Photosynthesis,” *Proceedings of the National Academy of Sciences*, 76 (1979): 4185.

R. A. Marcus and N. Sutin, “Electron Transfers in Chemistry and Biology,” *Biochim*
. *Biophys. Acta*, 811 (1985): 265.

R. A. Marcus, “An Internal Consistency Test and its Implications for the Initial Steps in Bacterial Photosynthesis,” *Chemical Physics Letters*, 146 (1988): 13.

R. A. Marcus, “Mechanisms of the Early Steps in Bacterial Photosynthesis and their Implications for Experiment,” *Israel Journal of Chemistry*, 28 (1988): 205.

51. R. A. Marcus and Prabha Siddarth, “Comparison of Experimental and Theoretical Electronic Matrix Elements for Long Range Electron transfer,” *Journal of Physical Chemistry*, 94 (1990): 2985.

52. R. A. Marcus and Prabha Siddarth, “Electron Transfer Reactions in Proteins: A Calculation of Electronic Coupling,” *Journal of Physical Chemistry*, 94 (1990): 8430.

53. R. A. Marcus, “Theories of Electrode Kinetics,” *Physicochemical Hydrodynamics (Pap. Conf.)*, 1 (1977): 473.

R. A. Marcus, “Similarities and Differences Between Electron and Proton Transfers at Electrodes and in Solution,” *Proceedings of the Third Symposium on Electrode Processes*, S. Bruckstein, J. D. E. McIntyre, B. Miller, E. Yeager, eds. (Electrochemical Society, Princeton, 1980): 1.

54. A. J. Appleby, J. O’M. Bockris, R. V. Sen and B. E. Conway, *MTP International Review of Science. Physical Chemistry Series*, 6 (1973): 1.

R. R. Dogonadze, A. M. Kuznetsov and V. G. Levich, *Electrochimica Acta*, 13 (1968): 1025.

55. R. A. Marcus, "Chemical-Reaction Cross-Sections, Quasi-equilibrium and Generalized Activated Complexes," *Journal of Chemical Physics*, 45 (1966): 2138.

R. A. Marcus, "On the Theory of Chemical-Reaction Cross Sections. I. Statistical-Dynamical Model," *Journal of Chemical Physics*, 45 (1966): 2630.

R. A. Marcus, "On the Theory of Chemical-Reaction Cross Sections. II. Application to the $H+H_2$ Reaction," *Journal of Chemical Physics*, 46 (1967): 959.

R. A. Marcus, "Relation Between State-Selected or State-Averaged Cross Sections of Endothermic Reactions and Rate Constants of Exothermic Reactions. Application of Bimolecular Microcanonical Activated Complex Theory," *Journal of Chemical Physics*, 53 (1970): 604.

R. A. Marcus, "On the Theory of Energy Distributions of Products of Molecular Beam Reactions Involving Transient Complexes," *Journal of Chemical Physics*, 62 (1975): 1372.

R. A. Marcus, "Energy Distributions in Unimolecular Reactions," *Berichte der Bunsen-Gesellschaft für physikadische Chemie*, 81 (1977): 190.

R. A. Marcus and G. Worry, "On the Theory of Translational Energy Distributions of Product Molecules of Molecular Beam Reactions Involving Transient Complexes. II," *Journal of Chemical Physics*, 67 (1977): 1636.

56. R. A. Marcus, "Treatment of Isotopic Exchange Reactions Having Complex Mechanisms," *Journal of Chemical Physics*, 23 (1955): 1107.

57. R. A. Marcus and W. K. Liu, "On the Theory of the Relaxation Matrix and Its Application to Microwave Transient Phenomena," *Journal of Chemical Physics*, 63 (1975): 272.

R. A. Marcus and W. K. Liu, "Theory of the Relaxation Matrix and Its Relation to Microwave Transient Phenomena. II. Semiclassical Calculations for Systems of OCS and Nonpolar Collision Partners," *Journal of Chemical Physics*, 63 (1975): 290.

58. R. A. Marcus, "On the Theory of Oxidation-Reduction Reactions Involving Electron Transfer. V. Comparison and Properties of Electrochemical and Chemical Rate Constants," *Journal of Physical Chemistry*, 67 (1963): 853, 2889.

59. R. A. Marcus, "On the Theory of Chemiluminescent Electron-Transfer Reactions," *Journal of Chemical Physics*, 43 (1965): 2654; 52 (1970): 2803.

60. R. A. Marcus, "Theoretical Relations Among Rate Constants, Barriers, and Brönsted Slopes of Chemical Reactions," *Journal of Physical Chemistry*, 72 (1968): 891.

R. A. Marcus and A. O. Cohen, "On the Slope of Free Energy Plots in Chemical Kinetics," *Journal of Physical Chemistry*, 72 (1968): 4249.

R. A. Marcus, "Unusual Slopes of Free Energy Plots in Kinetics," *Journal of the American Chemical Society*, 91 (1969): 7224.

61. R. A. Marcus and N. Sutin, "Electron-Transfer Reactions with Unusual Activation Parameters. A Treatment of Reactions Accompanied by Large Entropy Decreases," *Inorganic Chemistry*, 14 (1975): 213.

62. R. A. Marcus, "On the Theory of Shifts and Broadening of Electronic Spectra of Polar Solutes in Polar Media," *Journal of Chemical Physics*, 43 (1965): 1261.

63. R. A. Marcus and P. Siders, "Quantum Effects in Electron-Transfer Reactions," *Journal of the American Chemical Society*, 103 (1981): 741.

R. A. Marcus and P. Siders, "Quantum Effects for Electron-Transfer Reactions in the Inverted Region," *Journal of the American Chemical Society*, 103 (1981): 748.

64. R. A. Marcus and H. Sumi, "Dynamical Effects in Electron Transfer Reactions," *Journal of Chemical Physics*, 84 (1986): 4894.

R. A. Marcus and H. Sumi, "Dielectric Relaxation and Intramolecular Electron Transfers," *Journal of Chemical Physics*, 84 (1986): 4272.

R. A. Marcus and H. Sumi, "Solvent Dynamics and Vibrational Effects in Electron Transfer Reactions," *Journal of Electroanalytical Chemistry*, 204 (1986): 59.

R. A. Marcus and W. Nadler, "Dynamical Effects In Electron Transfer Reactions. II. Numerical Solution," *Journal of Chemical Physics*, 86 (1987): 3906.

65. R. A. Marcus and M. E. Coltrin, "A New Tunneling Path for Reactions such as $H+H_2 \prod H_2+H$," *Journal of Chemical Physics*, 67 (1977): 2609.

66. R. A. Marcus and V. K. Babamov, "Dynamics of Hydrogen Atom and Proton Transfer Reactions. Symmetric Case," *Journal of Chemical Physics*, 74 (1981): 1790.

R. A. Marcus, V. K. Babamov and V. Lopez, "Dynamics of Hydrogen Atom and Proton Transfer Reaction. Nearly Degenerate Asymmetric Case," *Journal of Chemical Physics*, 78 (1983): 5621.

R. A. Marcus, V. K. Babamov and V. Lopez, "Dynamics of Hydrogen Atom and Proton Transfer Reactions. Simplified Analytical Two-State Formulae," *Chemical Physics Letters*, 101 (1983): 507.

67. R. A. Marcus and A. O. Cohen, "Classical Mechanics of Rotational-Translational and Other Energy Transfer. I. A Hamilton-Jacobi (Action-Angle) Treatment," *Journal of Chemical Physics*, 49 (1968): 4509.

R. A. Marcus and A. O. Cohen, "Rotational-Translational Energy Transfer. II. Comparison of Action-Angle Solution in the Near-Static Approximation with Exact Results," *Journal of Chemical Physics*, 52 (1970): 3140.

68. R. A. Marcus, "Extension of the WKB Method to Wave Functions and Transition Probability Amplitudes (S-Matrix) for Inelastic or Reactive Collisions," *Chemical Physics Letters*, 7 (1970): 525.

R. A. Marcus, "Theory of Semiclassical Transition Probabilities (S Matrix) for Inelastic and Reactive Collisions," *Journal of Chemical Physics*, 54 (1971): 3965.

R. A. Marcus and J. N. L. Connor, "Theory of Semiclassical Transition Probabilities for Inelastic and Reactive Collisions. II. Asymptotic Evaluation of the S Matrix," *Journal of Chemical Physics*, 55 (1971): 5637.

R. A. Marcus, "Theory of Semiclassical Transition Probabilities (S Matrix) for Inelastic and Reactive Collisions. III. Uniformization Using Exact Trajectories," *Journal of Chemical Physics*, 56 (1972): 311.

R. A. Marcus and J. Stine, "Theory of Semiclassical Transition Probabilities for Inelastic and Reactive Collision. IV. Classically-Inaccessible Transitions Calculated by Integration Along Complex-Valued Trajectories," *Chemical Physics Letters*, 15 (1972): 536.

R. A. Marcus, "Theory of Semiclassical Transition Probabilities for Inelastic and Reactive Collisions. V. Uniform Approximation in Multidimensional Systems," *Journal of Chemical Physics*, 57 (1972): 4903.

R. A. Marcus, "Semiclassical S-Matrix Theory. VI. Integral Expression and Transformation of Conventional Coordinates," *Journal of Chemical Physics*, 59 (1973): 5145.

R. A. Marcus and J. R. Stine, "Semiclassical Transition Probabilities by an Asymptotic Evaluation of the S Matrix for Elastic and Inelastic Collisions. Bessel Uniform Approximation," *Journal of Chemical Physics*, 59 (1973): 5145.

R. A. Marcus and J. R. Stine, "Semiclassical S Matrix Theory for a Compound State Resonance in the Reactive Collinear $H+H_2$ Collision," *Chemical Physics Letters*, 29 (1974): 575.

R. A. Marcus, H. Kreek and R. L. Ellis, “Semiclassical Collision Theory. Application of Multidimensional Uniform Approximations to the Atom-Rigid-Rotor System,” *Journal of Chemical Physics*, 62 (1975): 913.

R. A. Marcus, “Semiclassical Wave Packets in the Angle Representation and Their Role in Molecular Dynamics,” *Chemical Physics Letters*, 152 (1988): 8.

69. R. A. Marcus and W. Eastes, “Compound State Resonances in the Collinear Collision of an Atom with a Diatomic Oscillator,” *Journal of Chemical Physics*, 59 (1973): 4757.

R. A. Marcus, “Semiclassical Theory for Collisions Involving Complexes (Compound State Resonances) and for Bound State Systems,” *Faraday Discussions of the Chemical Society*, 55 (1973): 34.

R. A. Marcus and W. Eastes, “Semiclassical Calculation of Bound States of a Multidimensional System,” *Journal of Chemical Physics*, 61 (1974): 4301.

70. R. A. Marcus, “Dissociation and Isomerization of Vibrationally Excited Species. III.,” *Journal of Chemical Physics*, 43 (1965): 2658; 52 (1970): 1018.

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