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A UNITED STATES DEPARTMENT OF COMMERCE PUBLICATION

PUB

NBS SPECIAL PUBLICATION 349

Heavy-Atom Kinetic Isotope Effects

An Indexed Bibliography

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards

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Heavy-Atom Kinetic Isotope Effects

An Indexed Bibliography

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National Bureau of Standards Special Publication 349

Nat. Bur. Stand. (U.S.), Spec. Publ. 349, 39 pages (June 1972)

CODEN: XNBSAV

Issued June 1972

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (Order by SD Catalog No. C 13.10:349) Price 45 cents
Stock number 0303-0844

Library of Congress Catalog Card Number: 70-611342

Foreword

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David R. Lide, Jr., *Chief*
Office of Standard Reference Data

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Heavy-Atom Kinetic Isotope Effects An Indexed Bibliography*

Marvin J. Stern and Max Wolfsberg*****

A bibliography of heavy-atom kinetic isotope effects has been compiled covering the complete literature from the earliest entry found (1911) through 1965. Review articles and theoretical papers are listed through 1968. The bibliography is divided into a list of the references, an author index and a subject index. The subject index has been annotated to describe, in brief, the type of reaction being observed. The following areas have been excluded: geochemistry (except for specific laboratory reactions), living systems, mass spectrometry and electron impact, electrochemistry, diffusion-controlled processes, hot-atom chemistry, photochemistry involving selective excitation of isotopes, and processes involving no chemical change.

Key words: Author index; bibliography; heavy-atom isotope effects; isotope effects; kinetic isotope effects; reaction kinetics; subject index.

Introduction

Background

The authors at first considered writing a critical review monograph on kinetic isotope effects. The literature embraced by this field was believed to be sufficiently large to be divisible into two parts: (1) isotope effects due to the substitution of hydrogen by deuterium or tritium; (2) isotope effects due to heavy-atom substitutions. To make the project manageable, only the latter aspect of the subject was chosen for the critical review.

However, after a bibliography containing approximately 500 references had been assembled, it was found that usually each experimental system was sufficiently different from the others to warrant separate analysis. In addition, the early papers contained many contradictory data which appeared to make critical analysis very difficult. As a consequence, the authors decided to reduce the scope of their effort and prepare an annotated index to the literature in the field. This endeavor has involved a thorough reading of the selected papers, and classification and indexing of the pertinent information. It is hoped that researchers engaged in kinetic isotope effect studies or others wanting to make use of such studies will find this indexed bibliography useful.

Description and Classification Scheme

The main, but by no means only, sources of pertinent references for the bibliography were Chemical Abstracts and Nuclear Science Abstracts through the year 1965. The search was extended through the year 1968, but only for review articles and theoretical papers. One review article published in 1969 is also included. The bibliography was checked against reprints in the files of the authors; references within the articles collected for the bibliography were checked for appropriateness of inclusion; and other appropriate bibliographies or partial bibliographies of the field were checked. Many of the authors' colleagues helped by submitting reprints of their articles. The papers finally included were generally restricted to those appearing in formally published literature (journal articles, chapters in books, proceedings of symposia, etc.). Thus, works such as doctoral theses, technical reports, and abstracts of talks presented at scientific meetings were, with rare exceptions, omitted. It is the belief of the authors that, for the period covered and topics considered (vide infra), the bibliography is better than 98 percent complete (except, perhaps, for Chinese literature). Articles that might have been missed probably fall into one of three categories: (1) papers published prior to 1966 but not appearing in the abstract journals until a later date; (2) reviews of reaction mechanisms containing very limited discussions of isotope effect studies; (3) papers on isotopic tracer studies which note only in passing the observation of kinetic isotope effects.

The study of the effect of isotopic substitution on a rate constant (kinetic isotope effect) serves to elucidate the reaction mechanism. There is strong interplay between experiment and theory in this area, and the experimental data are often interpreted by applying transition state theory (absolute reaction rate theory). The area of interest has been defined to include only in vitro reactions of well-defined reactants which are in thermal equilibrium. Isotope effects in the following areas have been specifically excluded: (1) geochemistry (unless the work involves specific labo-

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ratory reactions); (2) living systems; (3) mass spectrometry and electron impact; (4) electrochemistry; (5) diffusion-controlled processes; (6) processes not involving chemical change (with a few exceptions); (7) hot-atom chemistry; (8) photochemistry involving selective excitation of isotopes. General theoretical papers which have direct application to kinetic isotope effects have been included whether they deal specifically with heavy-atom effects or not. Some hydrogen isotope effect papers, which demonstrate points in kinetic isotope effect theory that have not been well-demonstrated by means of heavy-atom effects (e.g., unimolecular gas-phase reactions), have also been included.

The bibliography consists of three sections:

I. Listing of Papers
II. Author Index
III. Subject Index

The Listing of Papers contains the names of the authors, the titles of the papers, and the literature references. The reference abbreviations conform to the 1969 edition of ACCESS (Chemical Abstracts Service, American Chemical Society). The entries are arranged and numbered chronologically by years, and alphabetically according to authors' names within each year. The first entry is a paper by F. Soddy published in 1911. The listing numbers (total of 527) are used as references in the Author Index and Subject Index. The user can best acquaint himself with the Subject Index by skimming through it. Where appropriate, indexing is carried out by:

(1) isotope effect type, e.g., *Carbon-13 kinetic isotope effects;*

(2) common name of isotopically substituted reactant and reaction undergone, e.g., *Acetophenone (carbonyl-^{14}C) reaction with semicarbazide* [The *less-abundant* isotope in parentheses following the chemical name indicates the actual label or isotopic substitution considered. In the case of salts and esters, when the isotopic position is in the second part of the name (anion or acid moiety), the entry is repeated with the reactant name inverted; e.g., *Ethyl propionate (2-^{14}C)* . . . also appears as *Propionic acid (2-^{14}C), ethyl ester,* . . .];

(3) reaction type, e.g., *Decarboxylation reactions;*

(4) reaction name, e.g., *Diels—Alder reactions;*

(5) theoretical concepts, e.g., *Activation-energy effects* (The word "effects" without specification refers to effects on reaction kinetic isotope effects.);

(6) method employed, e.g., *Computer calculations of isotope effects.*

Purely theoretical articles and review articles are usually entered only once, under Theory or Reviews. On the average, there are five index entries per article. With relatively few exceptions, each paper was read for index entries by both of the authors. In general, under-listing was more feared than over-listing. If there was doubt about including a given entry in the index, it was usually included. Since the reading was carried out over a period of several years, some inconsistencies were introduced in the manner in which the papers were indexed. Although the authors have attempted to remove these inconsistencies in the final tabulation, some of them have undoubtedly been retained.

Inspection of the Subject Index makes for many interesting observations. For example, one sees that, among the heavy-atom kinetic isotope effects, carbon-13 and carbon-14 effects have been studied more than any of the others; among reaction types, decarboxylations have been the most studied.

The authors urge that the bibliography be updated at periodic intervals. Such a task will be easier than the present undertaking due to the fact that the indexing of isotope effects in Chemical Abstracts has been markedly improved during the past decade.

The authors wish to thank the Library staffs of the Belfer Graduate School of Science, Yeshiva University, and Brookhaven National Laboratory for their help and cooperation in the collection of articles appropriate for inclusion in the bibliography, as well as their many colleagues who sent them reprints of papers. Although the list of scientists who contributed in one way or another to the completion of this work is too long to present here, special acknowledgments are due Professor Takanobu Ishida for translating into English several Japanese articles, and Professors Irving J. Borowitz and Martin Pomerantz for answering scores of questions about organic chemistry, as well as for inspecting the final Subject Index for ambiguities. We are grateful to Dr. Marilyn L. Wolfsberg for help in reading proof. Finally, the authors wish to thank Professor Jacob Bigeleisen for suggesting that they undertake this project, and for his encouragement during the course of its development.

I. Listing of Papers

(1) *Soddy, F.*, The chemistry of mesothorium, J. Chem. Soc. **99**, 72–83 (1911).
(2) *Paneth, F.*, On the chemical reactions of the radioelements, Jahrb. Radioaktiv. Elektron. **11**, 451–470 (1914).
(3) *Schmidt, H.*, The isotopes, Umschau **19**, 385–388 (1915).
(4) *Richards, T. W.*, and *Hall, N. F.*, Attempt to separate the isotopic forms of lead by fractional crystallization, J. Amer. Chem. Soc. **39**, 531–541 (1917).
(5) *Soddy, F.*, The separation of isotopes: A comment on the paper by T. W. Richards and N. F. Hall, J. Amer. Chem. Soc. **39**, 1614–1615 (1917).
(6) *Lindemann, F. A.*, and *Aston, F. W.*, The possibility of separating isotopes, Phil. Mag. **37**, 523–534 (1919).
(7) *Fleck, A.*, The separation of isotopes, Nature (London) **104**, 565 (1920).
(8) *Thomson, J. J.*, *Aston, F. W.*, *Soddy, F.*, *Merton, T. R.*, and *Lindemann, F. A.*, Discussion on isotopes, Proc. Roy. Soc. **99A**, 87–104 (1921).
(9) *Dillon, T.*, *Clarke, R.*, and *Hinchy, V. M.*, Preliminary experiments on a chemical method of separating the isotopes of lead, Sci. Proc. Roy. Dublin Soc. **17**, 53–57 (1922).
(10) *Ludlam, E. B.*, An attempt to separate the isotopes of chlorine, Proc. Cambridge Phil. Soc. **21II**, 45–51 (1922).
(11) *Kendall, J.*, The separation of isotopes, Phys. Rev., **21**, 389–390 (1923).
(12) *Robinson P. L.*, and *Briscoe, H. V. A.*, A redetermination of the atomic weight of bromine. The inseparability of the isotopes by fractional crystallization, J. Chem. Soc. **127**, 138–150 (1925).
(13) *Richards, T. W.*, *King, H. S.*, and *Hall, L. P.*, Attempts to fractionate mixed isotopes of lead, and the atomic weight of this metal, J. Amer. Chem. Soc. **48**, 1530–1543 (1926).
(14) *Cremer, E.*, and *Polanyi, M.*, A test of "tunnel theory" of heterogeneous catalysis in the hydrogenation of styrene, Z. Phys. Chem. **19B**, 443–450 (1932).
(15) *Wigner, E.*, On the crossing of potential thresholds in chemical reactions, Z. Phys. Chem. **19B**, 203–216 (1932).
(16) *Eyring, H.*, The zero point energy and the separation of isotopes, Proc. Nat. Acad. Sci. U.S. **19**, 78–81 (1933).
(17) *Urey, H. C.*, and *Rittenberg, D.*, Some thermodynamic properties of the H^1H^2, H^2H^2 molecules and compounds containing the H^2 atom, J. Chem. Phys. **1**, 137–143 (1933).
(18) *Bawn, C. E. H.*, and *Ogden, G.*, Wave mechanical effects and the reactivity of the hydrogen isotopes, Trans. Faraday Soc. **30**, 432–443 (1934).
(19) *Farkas, A.*, and *Farkas, L.*, Experiments on heavy hydrogen.—Part 1, Proc. Roy. Soc. **144A**, 467–480 (1934).
(20) *Polanyi, M.*, Discussion on heavy hydrogen, Proc. Roy. Soc. **144A**, 14–16 (1934).
(21) *Polanyi, M.*, Reaction rates of the hydrogen isotopes, Nature (London) **133**, 26–27 (1934).
(22) *Taylor, H. S.*, and *Gould, A. J.*, Oxygen isotope separation by chemical reaction, J. Amer. Chem. Soc. **56**, 1823 (1934).
(23) *Bell, R. P.*, Quantum mechanical effects in reactions involving hydrogen, Proc. Roy. Soc. **148A**, 241–250 (1935).
(24) *Eyring, H.*, The activated complex in chemical reactions, J. Chem. Phys. **3**, 107–115 (1935).
(25) *Urey, H. C.*, and *Greiff, L. J.*, Isotopic exchange equpilibria, J. Amer. Chem. Soc. **57**, 321–327 (1935).
(26) *Urey, H. C.*, and *Teal, G. K.*, The hydrogen isotope of atomic weight two, Rev. Mod. Phys. **7**, 34–94 (1935).
(27) *Bradley, R. S.*, A small chemical separation of the chlorine isotopes, Nature (London) **137**, 403–404 (1936).
(28) *Daniels, F.*, Calculation for separation, from chapter 10 (Isotopic tracers), Chemical Kinetics, pp. 248–252 (Cornell University Press, Ithaca, N.Y., 1938).
(29) *Wigner, E.*, The transition state method, Trans. Faraday Soc. **34**, 29–41 (1938).
(30) *Hirschfelder, J. O.*, and *Wigner, E.*, Some quantum-mechanical considerations in the theory of reactions involving an activation energy, J. Chem. Phys. **7**, 616–628 (1939).
(31) *Taylor, T. I.*, Do the isotopes of an element have identical chemical properties?, Science **89**, 176–177 (1939).
(31a) *Glasstone, S.*, *Laidler, K. J.*, and *Eyring, H.*, The Theory of Rate Processes (McGraw-Hill Book Company, Inc., New York, 1941).
(32) *Teis, R. V.*, and *Florensky, K. P.*, Distribution of isotopes of hydrogen and oxygen during the freezing of water, C. R. (Dokl.) Acad. Sci. l'URSS **32**, 199–202 (1941).
(33) *Waldmann, L.*, The theory of isotope separation by exchange reactions, Naturwissenschaften **31**, 205–206 (1943).
(34) *Bigeleisen, J.*, and *Mayer, M. G.*, Calculation of equilibrium constants for isotopic exchange reactions, J. Chem. Phys. **15**, 261–267 (1947).
(35) *Schaefer, K.*, The physical-chemical differences of isotopes, Angew. Chem. **59A**, 42–48 (1947).
(36) *Urey, H. C.*, The thermodynamic properties of isotopic substances, J. Chem. Soc. **1947**, 562–581.
(37) *Bigeleisen, J.*, Theory of isotope effects in chemical reaction rates, Brookhaven Conference Report, "Isotopic Exchange Reactions and Chemical Kinetics," Chem. Conf. **No. 2**, 53–75 (1948).
(38) *Myerson, A. L.*, and *Daniels, F.*, Relative rates of hydrolysis of urea containing C^{12} and C^{14}, Science **108**, 676 (1948).
(39) *Slater, N. B.*, Aspects of a theory of unimolecular reaction rates, Proc. Roy. Soc. **194A**, 112–131 (1948).
(40) *Stevenson, D. P.*, *Wagner, C. D.*, *Beeck, O.*, and *Otvos, J. W.*, Isotope effect in the thermal cracking of propane-1-C^{13}, J. Chem. Phys. **16**, 993–994 (1948).
(41) *Yankwich, P. E.*, Isotopic effects in some simple chemical processes, Brookhaven Conference Report, "Isotopic Exchange Reactions and Chemical Kinetics," Chem. Conf. **No. 2**, 44–52 (1948).
(42) *Bigeleisen, J.*, The validity of the use of tracers to follow chemical reactions, Science **110**, 14–16, 149 (1949).
(43) *Bigeleisen, J.*, Isotope effect in the rupture of carbon—carbon bonds in propane-1-C^{13}, J. Chem. Phys. **17**, 344–345 (1949).
(44) *Bigeleisen, J.*, Isotope effect in the decarboxylation of labelled malonic acids, J. Chem. Phys. **17**, 425–426 (1949).
(45) *Bigeleisen, J.*, The relative reaction velocities of isotopic molecules, J. Chem. Phys. **17**, 675–678 (1949).
(46) *Bigeleisen, J., and Friedman, L.*, C^{13} Isotope effect in the decarboxylation of malonic acid, J. Chem. Phys. **17**, 998–999 (1949).
(47) *Lindsay, J. G.*, *McElcheran, D. E.*, and *Thode, H. G.*, The isotope effect in the decomposition of oxalic acid, J. Chem. Phys. **17**, 589 (1949).
(48) *Pitzer, K. S.*, Carbon isotope effect on reaction rates, J. Chem. Phys. **17**, 1341–1342 (1949).
(49) *Slater, N. B.*, The motion of point-masses in terms of their mutual distances, Proc. Leeds Phil. Lit. Soc. Sci. Sect. **5**, 75–80 (1949).
(50) *Stevens, W. H.*, and *Attree, R. W.*, The effect on reaction rates caused by the substitution of C^{14} for C^{12}. I. The alkaline hydrolysis of carboxyl-labeled ethyl benzoate, Can. J. Res. **27B**, 807–812 (1949).
(51) *Yankwich, P. E.*, Radioactive isotopes as tracers, Anal. Chem. **21**, 318–321 (1949).
(52) *Yankwich, P. E.*, and *Calvin, M.*, An effect of isotopic mass on the rate of a reaction involving the carbon—carbon bond, J. Chem. Phys. **17**, 109–110 (1949).

(53) *Armstrong, W. D., Singer, L., Zbarsky, S. H.,* and *Dunshee, B.,* Errors of combustion of compounds for C^{14} analysis, Science **112**, 531–533 (1950).

(54) *Bothner-By, A. A., Friedman, L.,* and *Bigeleisen, J.,* Isotope effects in the decarboxylation of dibasic acids, Brookhaven Conference Report, "Use of Tracers in Inorganic Reaction Mechanism Studies," Chem. Conf. **No. 4**, 39–48 (1950).

(55) *Calvin, M.,* and *Yankwich, P. E.,* Chemical method for concentrating isotopes of carbon, U.S. Patent 2,511,667 (1950).

(56) *Daniels,* F., Chemical kinetics, Annu. Rev. Phys. Chem. **1**, 233–270 (1950).

(57) *Friedman, L., and Bigeleisen, J.,* Oxygen and nitrogen isotope effects in the decomposition of ammonium nitrate, J. Chem. Phys. **18**, 1325–1331 (1950).

(58) *McCrea, J. M.,* On the isotopic chemistry of carbonates and a paleotemperature scale, J. Chem. Phys. **18**, 849–857 (1950).

(59) *Melander, L.,* On the mechanism of electrophilic aromatic substitution. An investigation by means of the effect of isotopic mass on reaction velocity, Ark. Kemi **2**, 211–292 (1950).

(60) *Stevens, W. H.,* and *Attree, R. W.,* The effect on reaction rates caused by the substitution of C^{14} for C^{12}, J. Chem. Phys. **18**, 574 (1950).

(61) *Tudge, A. P.,* and *Thode, H. G.,* Thermodynamic properties of isotopic compounds of sulphur, Can. J. Res. **28B**, 567–578 (1950).

(62) *Bigeleisen, J.,* and *Allen, T. L.,* Fractionation of the carbon isotopes in decarboxylation reactions. IV. The relative rates of decomposition of 1-C^{12} and 1-C^{13} trichloracetate ions, J. Chem. Phys. **19**, 760–764 (1951).

(63) *Bothner-By, A. A.,* and *Bigeleisen, J.,* Fractionation of the carbon isotopes in decarboxylation reactions. III. The relative rates of decomposition of carboxyl-C^{12} and -C^{13} mesitoic acids, J. Chem. Phys. **19**, 755–759 (1951).

(64) *Evans, E. A.,* and *Huston, J. L.,* Isotope effect in the oxidation of carboxyl-C^{14} acetic acid, J. Chem. Phys. **19**, 1214 (1951).

(65) *Harris, G. M.,* Limitations of the tracer method in scientific research I. Physical aspects, Proc. Conf. Appl. Isotop. Sci. Res., Melbourne, 1950 (Univ. of Melbourne), 65–76 (1951).

(66) *Harris, G. M.,* Kinetics of isotopic exchange reactions, Trans. Faraday Soc. **47**, 716–721 (1951).

(67) *Lindsay, J. G., Bourns, A. N.,* and *Thode, H. G.,* C^{13} isotope effect in the decarboxylation of normal malonic acid, Can. J. Chem. **29**, 192–200 (1951).

(68) *Roe, A.,* and *Hellmann, M.,* Determination of an isotope effect in the decarboxylation of malonic-1-C^{14} acid, J. Chem. Phys. **19**, 660 (1951).

(69) *Ropp, G. A.,* and *Neville, O. K.,* A review of the uses of isotopic carbon in organic chemical research, Nucleonics **9**, 22–37, 70 (1951).

(70) *Ropp, G. A., Weinberger, A. J.,* and *Neville, O. K.,* The determination of the isotope effect and its variation with temperature in the dehydration of formic-C^{14} acid, J. Amer. Chem. Soc. **73**, 5573–5575 (1951).

(71) *Stewart, D. W.,* Isotopes, Annu. Rev. Phys. Chem. **2**, 67–82 (1951).

(72) *Baertschi, P.,* The fractionation of the isotopes of carbon during the absorption of carbon dioxide, Helv. Chim. Acta **35**, 1030–1036 (1952).

(73) *Becker, E. W.,* and *Beyrich, W.,* Effect of isotopic substitution on the collision properties of the carbon dioxide molecule, J. Phys. Chem. **56**, 911–913 (1952).

(74) *Bell, J.,* and *Reed, R. I.,* Isotopic tracer studies of pyrolytic ractions. Part I. The formation of acetaldehyde, J. Chem. Soc. **1952**, 1383–1389.

(75) *Bernstein, R. B.,* Enrichment of isotopes by difference in rates for irreversible isotopic reactions, J. Phys. Chem. **56**, 893–896 (1952).

(76) *Bigeleisen, J.,* Isotopes, Annu. Rev. Phys. Chem. **3**, 39–56 (1952); Annu. Rev. Nucl. Sci. **2**, 221–238 (1953).

(77) *Bigeleisen, J.,* A theoretical evaluation of the nitrogen isotope effect in the thermal deammonation of phthalamide, Can. J. Chem. **30**, 443–447 (1952).

(78) *Bigeleisen, J.,* The effects of isotopic substitution on the rates of chemical reactions, J. Phys. Chem. **56**, 823–828 (1952).

(79) *Brown, F.,* and *Holland, D. A.,* Isotope effects: Reaction at the carbonyl group, Can. J. Chem. **30**, 438–442 (1952).

(80) *Bunton, C. A.,* and *Llewellyn, D. R.,* Decomposition of hydrogen peroxide in water enriched in heavy oxygen, Research (London) **5**, 142–143 (1952).

(81) *Bunton, C. A.,* and *Llewellyn, D. R.,* Isotope effects in the oxidation of oxalic acid, Research (London) **5**, 443 (1952).

(82) *Cahill, A. E.,* and *Taube, H.,* The use of heavy oxygen in the study of reactions of hydrogen peroxide, J. Amer. Chem. Soc. **74**, 2312–2318 (1952).

(83) *Dole, M.,* The chemistry of the isotopes of oxygen, Chem. Rev. **51**, 263–300 (1952).

(84) *Dole, M., Rudd, D. P., Muchow, G. R.,* and *Comte, C.,* Isotopic composition of oxygen in the catalytic decomposition of hydrogen peroxide, J. Chem. Phys. **20**, 961–968 (1952).

(85) *Downes, A. M.,* Isotope effect in the reaction of ^{14}C-formaldehyde with dimedone, Australian J. Sci. Res. **5A**, 521–529 (1952).

(86) *Downes, A. M.,* and *Harris, G. M.,* Isotope effect in the Cannizzaro reaction of carbon-14-labeled formaldehyde, J. Chem. Phys. **20**, 196–197 (1952).

(87) *Edwards, R. R.,* Isotopic tracers in chemical systems, Annu. Rev. Nucl. Sci. **1**, 301–342 (1952).

(88) *Eyring, H.,* and *Cagle, F. W., Jr.,* The significance of isotopic reactions in rate theory, J. Phys. Chem. **56**, 889–892 (1952).

(89) *Fry, A.,* and *Calvin, M.,* The isotope effect in the decomposition of oxalic acid, J. Phys. Chem. **56**, 897–901 (1952).

(90) *Fry, A.,* and *Calvin, M.,* The C^{14} isotope effect in the decarboxylation of α-naphthyl- and phenylmalonic acids, J. Phys. Chem. **56**, 901–905 (1952).

(91) *Harris, G. M.,* Chemical applications of radiocarbon, Rev. Pure Appl. Chem. **2**, 57–64, (1952).

(92) *Hunt, J. P.,* and *Taube, H.,* The photochemical decomposition of hydrogen peroxide. Quantum yields, tracer and fractionation effects, J. Amer. Chem. Soc. **74**, 5999–6002 (1952).

(93) *Lindsay, J. G., Bourns, A. N.,* and *Thode, H. G.,* Influence of temperature on the intermolecular C^{13} isotope effect in the decarboxylation of normal malonic acid, Can. J. Chem. **30**, 163–165 (1952).

(94) *Roe, A.,* and *Albenesius, E. O.,* The isotope effect. III. The reaction of acetone-1-C^{14} with alkaline hypoiodite, J. Amer. Chem. Soc. **74**, 2402–2403 (1952).

(95) *Roe, A.,* and *Finlay, J. B.,* The isotope effect. II. Pyrolysis of lithium acetate-1-C^{14}, J. Amer. Chem. Soc. **74**, 2442–2443 (1952).

(96) *Ropp, G. A.,* Effect of isotope substitution on organic reaction rates, Nucleonics **10**, 22–27 (1952).

(97) *Ropp, G. A.,* and *Raaen, V. F.,* Effect of nuclear substituents on the C^{14} isotope effect in the saponification of carboxyl-labeled ethyl benzoates at 25°C, J. Chem. Phys. **20**, 1823 (1952).

(98) *Ropp, G. A., and Raaen, V. F.,* A comparison of the magnitudes of the isotope intermolecular effects in the decarboxylations of malonic-1-C^{14} acid and malonic-2-C^{14} acid at 154°, J. Amer. Chem. Soc. **74**, 4992–4994 (1952).

(99) *Schmitt, J. A., Myerson, A. L.,* and *Daniels, F.,* Relative rates of hydrolysis of urea containing C^{14}, C^{13} and C^{12}, J. Phys. Chem. **56**, 917–920 (1952).

(100) *Stacey, F. W., Lindsay, J. G.,* and *Bourns, A. N.,* Isotope effects in the thermal deammonation of phthalamide, Can. J. Chem. **30**, 135–145 (1952).

(101) *Stevens, W. H., Pepper, J. M.,* and *Lounsbury, M.,* Relative isotope effects of C^{13} and C^{14}, J. Chem. Phys. **20,** 192 (1952).

(102) *Stevens, W. H., Pepper, J. M.,* and *Lounsbury, M.,* The decarboxylation of anthranilic acid, Can. J. Chem. **30,** 529–540 (1952).

(103) *Stranks, D. R.,* and *Harris, G. M.,* Isotope effect in some reactions of carbon-14-labeled carbonatotetrammine cobaltic complex ion, J. Phys. Chem. **56,** 906–910 (1952).

(104) *Yankwich, P. E.,* and *McNamara, J. E.,* Isotope effects in the exchange reaction between uncomplexed carbonate—bicarbonate ions and carbonate-*bis*-ethylenediamine-cobalt(III), J. Chem. Phys. **20,** 1325 (1952).

(105) *Yankwich, P. E., Stivers, E. C.,* and *Nystrom, R. F.,* Intramolecular isotope effects in the decarboxylation of malonic acid, J. Chem. Phys. **20,** 344 (1952).

(106) *Bigeleisen, J.,* The effect of isotopic substitution on the entropy, enthalpy, and heat capacity of ideal gases. I. Systems in thermal equilibrium. II. Chemically reacting systems, J. Chem. Phys. **21,** 1333–1339 (1953).

(107) *Bigeleisen, J., Bothner-By, A. A.,* and *Friedman, L.,* Fractionation of the carbon isotopes in decarboxylation reactions. V. The mechanism of the pyrolysis of barium adipate, J. Amer. Chem. Soc. **75,** 2908–2910 (1953).

(108) *Bigeleisen, J.,* and *Wolfsberg, M.,* Temperature independent factor in the relative rates of isotopic three center reactions, J. Chem. Phys. **21,** 1972–1974 (1953); **22,** 1264 (1954).

(109) *Bigeleisen, J.,* and *Wolfsberg, M.,* Fractionation of the carbon isotopes in decarboxylation reactions. VI. Comparison of the intermolecular isotope effects of a pair of isotopic isomers, J. Chem. Phys. **21,** 2120–2121 (1953).

(110) *Bonner, W. A.,* and *Collins, C. J.,* An isotope effect in the oxidation of a secondary carbinol, J. Amer. Chem. Soc. **75,** 2308–2311 (1953).

(111) *Bonner, W. A.,* and *Collins, C. J.,* An isotope effect during ozonization, J. Amer. Chem. Soc. **75,** 3693–3694 (1953).

(112) *Bonner, W. A.,* and *Collins, C. J.,* Isotope effects during catalytic hyrogenations, J. Amer. Chem. Soc. **75,** 4516–4518 (1953).

(113) *Burr, J. G., Jr.,* The addition of water to diphenylacetylene-1,2-$C^{14}{}_1$, J. Amer. Chem. Soc. **75,** 1990–1991 (1953).

(114) *Pitzer, K. S.,* and *Gelles, E.,* Magnetic catalysis of a decarboxylation reaction, J. Amer. Chem. Soc. **75,** 5132–5133 (1953).

(115) *Raaen, V. F.,* and *Ropp, G. A.,* Intramolecular isotope effects in the reactions of benzoic-α-C^{14} anhydride, J. Chem. Phys. **21,** 1902–1903 (1953).

(116) *Ropp, G. A., Raaen, V. F.,* and *Weinberger, A. J.,* Studies of some carbon-14 isotope effects in organic chemistry, J. Amer. Chem. Soc. **75,** 3694–3697 (1953).

(117) *Schmitt, J. A.,* and *Daniels, F.,* The carbon isotope effect in the acid hydrolysis of urea, J. Amer. Chem. Soc. **75,** 3564–3566 (1953).

(118) *Slater, N. B.,* Gaseous unimolecular reactions: Theory of the effects of pressure and of vibrational degeneracy, Phil. Trans. Roy. Soc. London **246A,** 57–80 (1953).

(119) *Thode, H. G.,* Isotopes, Annu. Rev. Phys. Chem. **4,** 95–118 (1953).

(120) *Yankwich, P. E.,* Isotope effects in chemical reactions, Annu. Rev. Nucl. Sci. **3,** 235–248 (1953).

(121) *Yankwich, P. E.,* and *Belford, R. L.,* Intermolecular carbon isotope effect in the decarboxylation of normal malonic acid in quinoline solution, J. Amer. Chem. Soc. **75,** 4178–4182 (1953).

(122) *Yankwich, P. E., Belford, R. L.,* and *Fraenkel, G.,* Temperature coefficient of the intermolecular carbon isotope effect in the decarboxylation of normal malonic acid, J. Amer. Chem. Soc. **75,** 832–835 (1953).

(123) *Yankwich, P. E.,* and *Promislow, A. L.,* Carbon isotope constitution of some acetic acids, J. Amer. Chem. Soc. **75,** 4881 (1953).

(124) *Yankwich, P. E.,* and *Stivers, E. C.,* Intramolecular carbon isotope effects in the decarboxylation of malonic acid and bromomalonic acid, J. Chem. Phys. **21,** 61–66 (1953).

(125) *Attree, R. W., Brown, F., Dunn, G. E.,* and *Lounsbury, M.,* Isotope effects in the combustion of carbon monoxide, Can. J. Chem. **32,** 921–930 (1954).

(126) *Bartholomew, R. M., Brown, F.,* and *Lounsbury, M.,* Chlorine isotope effect, Nature (London) **174,** 133 (1954).

(127) *Bartholomew, R. M., Brown, F.,* and *Lounsbury, M.,* Chlorine isotope effect in reactions of *tert*-butyl chloride, Can. J. Chem. **32,** 979–983 (1954).

(128) *Bernstein, R. B.,* Carbon-13 isotope effect in the thermodecomposition of nickel carbonyl, J. Chem. Phys. **22,** 710–713 (1954).

(129) *Dole, M.,* Calculation of isotopic exchange equilibrium constants, Chapt. 11, Sect. 2, Introduction to Statistical Thermodynamics, pp. 163–170 (Prentice-Hall, Inc., Englewood Cliffs, N.J., 1954).

(130) *Dole, M.,* and *Lane, G. A.,* Fractionation of oxygen isotopes during the formation of metal oxide films, J. Chem. Phys. **22,** 949-950 (1954).

(131) *Fraenkel, G., Belford, R. L.,* and *Yankwich, P. E.,* Decarboxylation of malonic acid in quinoline and related media, J. Amer. Chem. Soc. **76,** 15–18 (1954).

(132) *Heyns, K.,* and *Brockmann, R.,* On the thermal decomposition of Leuchs' compound to polyglycine, Z. Naturforsch. **9B,** 21–26 (1954).

(133) *Jones, W. M.,* Isotopes, Annu. Rev. Phys. Chem. **5,** 91–118 (1954).

(134) *Lee, C. C.,* and *Spinks, J. W. T.,* The isotope effect in the synthesis of 3,3′-methylene-C^{14}-*bis*(4-hydroxycoumarin), Can. J. Chem. **32,** 327–330 (1954).

(135) *Melander, L.,* Note on the kinetics of exchange of isotopes with appreciable isotope effect, Ark. Kemi **7,** 287–289 (1954).

(136) *Ropp, G. A., Bonner, W. A., Clark, M. T.,* and *Raaen, V. F.,* Examination of the iodoform and Schmidt reactions of acetone-1-C^{14} for isotope effects, J. Amer. Chem. Soc. **76,** 1710–1711 (1954).

(137) *Ropp, G. A.,* and *Raaen, V. F.,* The effect of ring substituents on the isotope effects in reactions of carbonyl-C^{14} esters and ketones, J. Chem. Phys. **22,** 1223–1227 (1954).

(138) *Ropp, G. A.,* and *Raaen, V. F.,* Examination of a Meerwein reaction for an intramolecular isotope effect with carbon-14, J. Amer. Chem. Soc. **76,** 4484 (1954).

(139) *Sheppard, W. A., Bader, R. F. W.,* and *Bourns, A. N.,* Sulphur isotope effects in the bisulphite addition reaction of aldehydes and ketones II. Bond-formation effect, Can. J. Chem. **32,** 345–350 (1954).

(140) *Stevens, W. H.,* and *Crowder, D. A.,* The C^{14} isotope effect in the condensation of benzoylbenzoic acid-carboxyl-C^{14} to anthraquinone-9-C^{14}, Can. J. Chem. **32,** 792–801 (1954).

(141) *Wagner, G., Pelz, A.,* and *Higatsberger, M. J.,* An experimental contribution to the problem of isotopic separation by chemical means, Monatsb. Chem. **85,** 464–466 (1954).

(142) *Wiberg, K. B.,* The deuterium isotope effect of some ionic reactions of benzaldehyde, J. Amer. Chem. Soc. **76,** 5371–5375 (1954).

(143) *Yankwich, P. E.,* and *Belford, R. L.,* Intramolecular carbon isotope effect in the decarboxylation of normal malonic acid in quinoline solution, J. Amer. Chem. Soc. **76,** 3067–3070 (1954).

(144) *Yankwich, P. E.,* and *Promislow, A. L.,* Intramolecular carbon isotope effect in the decarboxylation of

liquid malonic acid near the melting point, J. Amer. Chem. Soc. **76**, 4648–4651 (1954).

(145) *Yankwich, P. E., Promislow, A. L.*, and *Nystrom, R. F.*, C^{14} and C^{13} intramolecular isotope effects in the decarboxylation of liquid malonic acid at 140.5°, J. Amer. Chem. Soc. **76**, 5893 (1954).

(146) *Bernstein, R. B.*, Oxygen-18 isotope effect in the reaction of oxygen with copper, J. Chem. Phys. **23**, 1797–1802 (1955).

(147) *Bernstein, R. B.*, and *Pars, H. G.*, Tracer study of the oxygen in precipiated HgO and Ag_2O; O^{18} isotope effect in the reaction of OH^- with Hg^{++} and Ag^+, J. Amer. Chem. Soc. **77**, 4433 (1955).

(148) *Bigeleisen, J.*, Statistical mechanics of isotopic systems with small quantum corrections. I. General considerations and the rule of the geometric mean, J. Chem. Phys. **23**, 2264–2267 (1955).

(149) *Bunton, C. A., Craig, D. P.*, and *Halevi, E. A.*, The kinetics of isotopic exchange reactions, Trans. Faraday Soc. **51**, 196–204 (1955).

(150) *Carrick, W. L.*, and *Fry, A.*, A carbon-14 isotope effect study of the Dieckmann condensation of diethyl phenylenediacetate, J. Amer. Chem. Soc. **77**, 4381–4387 (1955).

(151) *Collins, C. J.*, and *Ropp, G. A.*, A study of the accuracy obtained in Van Slyke combustion and radioassay of carbon-14 compounds, J. Amer. Chem. Soc. **77**, 4160–4161 (1955).

(152) *Craig, H.*, and *Boato, G.*, Isotops, Annu. Rev. Phys. Chem. **6**, 403–432 (1955).

(153) *Friedman, H. L., Bernstein, R. B.*, and *Gunning, H. E.*, C^{13} isotope effect in the thermodecomposition of ethyl bromide, J. Chem. Phys. **23**, 109–112, 1722–1723 (1955).

(154) *Gelles, E.*, and *Pitzer, K. S.*, Magnetic catalysis of decarboxylation and other reactions, J. Amer. Chem. Soc. **77**, 1974–1978 (1955).

(155) *Gelles, E.*, and *Reed, R. I.*, Carbon-13 isotope effects in the decarboxylation of some oxaloacetates, Nature (London) **176**, 1262 (1955).

(156) *Gold, V.*, and *Satchell, D. P. N.*, The principles of hydrogen isotope exchange reactions in solution, Quart. Rev. Chem. Soc. **9**, 51–72 (1955).

(157) *Jenkins, F. E.*, and *Harris, G. M.*, An unusual isotope fractionation effect, J. Amer. Chem. Soc. **77**, 4439 (1955).

(158) *Maccoll, A.*, and *Thomas, P. J.*, Mechanism of the pyrolysis of ethyl bromide. A note on a paper by Friedman, Bernstein, and Gunning, J. Chem. Phys. **23**, 1722 (1955).

(159) *Marcus, R. A.*, Treatment of isotopic exchange reactions having complex mechanisms, J. Chem. Phys. **23**, 1107–1112 (1955).

(160) *Melander, L. C. S.*, The use of nuclides in the determination of organic reaction mechanisms. Isotopes and the theory of absolute reaction rates, Peter C. Reilly Lect. Chem. (Univ. Notre Dame) **11**, 34–48 (1955).

(161) *Ott, D. G., and Smith, G. G.*, A carbon-14 tracer study of the alkaline rearrangement of chlorophenanthraquinones, J. Amer. Chem. Soc. **77**, 2325–2329 (1955).

(162) *Polanyi, J. C.*, Rates of isotopic reactions between methyl and hydrogen, J. Chem. Phys. **23**, 1505–1513 (1955); **24**, 493 (1956).

(163) *Ropp, G. A.*, Examination of the isotope effect in the condensation of *o*-benzoylbenzoic acid-carboxyl-C^{14} to anthraquinone-9-C^{14}, J. Chem. Phys. **23**, 2196 (1955).

(164) *Stranks, D. R.*, ^{14}C isotope effects. Part 1. The bicarbonate ion—carbonatocobaltic complex exchange systems, Trans. Faraday Soc. **51**, 492–499 (1955).

(165) *Stranks, D. R.*, ^{14}C isotope effects. Part 2. The carbon monoxide/phosgene exchange, Trans. Faraday Soc. **51**, 499–504 (1955).

(166) *Stranks, D. R.*, Kinetics of isotopic exchange reactions. Part 5. The photochemical carbon monoxide+phosgene system, Trans. Faraday Soc. **51** 514–524 (1955).

(167) *Stranks, D. R.*, Kinetics of isotopic exchange reactions. Part 6. The thermal carbon monoxide+phosgene system, Trans. Faraday Soc. **51**, 524–527 (1955).

(168) *Wagner, G.*, and *Pelz, A.*, An experimental contribution to the problem of isotopic separation by chemical means. II., Monatsh. Chem. **86**, 414–418 (1955).

(169) *Wang, J. H.*, On the role of diffusion in catalysis, J. Phys. Chem. **59**, 1115–1116 (1955).

(170) *Wang, J. H.*, On the detailed mechanism of a new type of catalase-like action, J. Amer. Chem. Soc. **77**, 4715–4719 (1955).

(171) *Wiberg, K. B.*, The deuterium isotope effect, Chem. Rev. **55**, 713–743 (1955).

(172) *Yankwich, P. E.*, and *Weber, H. S.*, Intermolecular carbon isotope effect in the decarboxylation of the mono-anion of malonic acid in quinoline solution, J. Amer. Chem. Soc. **77**, 4513–4516 (1955).

(173) *Brodsky, A. I.*, Calculation of the kinetic isotope effect from experimental data, Ukr. Khim. Zh. **22**, 417–419 (1956).

(174) *D'Hont, M.*, and *DeLattre, A.*, Note on the isotopic effect in the fractional decomposition of potassium fluoborate, Nucl. Phys. **2**, 736 (1956/57).

(175) *Frey, H. M., Danby, C. J.*, and *Hinshelwood, C.*, The intramolecular isotope effect in the pyrolysis of 1-^{14}C propane. Proc. Roy. Soc. **234A**, 301–305 (1956).

(176) *Grigg, E. C. M.*, C^{14}-intramolecular isotope effects of malonic and bromomalonic acids, Aust. J. Chem. **9**, 252–257 (1956).

(177) *Grovenstein, E., Jr.*, and *Ropp, G. A.*, Carbon-13 isotope fractionation as a criterion of the mechanism of bromodecarboxylation of 3,5-dibromo-4-hydroxybenzoic acid, J. Amer. Chem. Soc. **78**, 2560–2562 (1956).

(178) *Halevi, E. A.*, and *Nussim, M.*, Electron release from carbon—hydrogen and carbon—deuterium bonds, Bull. Res. Counc. Isr. **5A**, 263–264 (1956).

(179) *Ogata, Y.*, and *Tabuse, I.*, Application of isotopes in organic chemistry; supplementary, Kagaku No Ryoiki **10**, 932–939 (1956).

(180) *Rabinowitz, J. L., Sall, T., Bierly, J. N., Jr.*, and *Oleksyshyn, O.*, Carbon isotope effects in enzyme systems. I. Biochemical studies with urease, Arch. Biochem. Biophys. **63**, 437–445 (1956).

(181) *Roberts, J. D., Semenow, D. A., Simmons, H. E., Jr.*, and *Carlsmith, L. A.*, The mechanism of aminations of halobenzenes, J. Amer. Chem. Soc. **78**, 601–611 (1956).

(182) *Roginskv, S. Z.*, Theoretical Principles of Isotope Methods for Investigating Chemical Reactions, (Academy of Sciences USSR Press, Moscow, 1956); AEC-tr-2873.

(183) *Ropp, G. A.*, and *Hodnett, E. M.*, Isotope fractionation studies of reactions with cleavage of a carbon-14 to hydrogen bond in the rate-determining step, J. Chem. Phys. **25**, 587–588 (1956).

(184) *Semenow, D. A.*, and *Roberts, J. D.*, Uses of isotopes in organic chemistry, J. Chem. Educ. **33**, 2–14 (1956).

(185) *Shiuttse, V.*, An investigation of the isotopic constitution of boron, Sov. Phys. JETP **2**, 402–405 (1956).

(186) *Silverman, J.*, and *Cohen, K.*, Isotopes, Annu. Rev. Phys. Chem. **7**, 335–358 (1956).

(187) *Taube, H.*, Applications of oxygen isotopes in chemical studies, Annu. Rev. Nucl. Sci. **6**, 277–302 (1956).

(188) *Yankwich, P. E.*, and *Weber, H. S.*, Intramolecular carbon isotope effect in the decarboxylation of the mono-anion of malonic acid in quinoline solution, J. Amer. Chem. Soc. **78**, 564–567 (1956).

(189) *Zlotowski, I.*, Applications of isotopes in chemistry and chemical technology, Zeszyty Problemowe "Kosmosu" **6**, 55–82 (1956).

(190) *Alberty, R. A.*, and *Miller, W. G.*, Integrated rate equations for isotopic exchange in simple reversible reactions, J. Chem. Phys. **26**, 1231–1237 (1957).

(191) *Bender, M. L.*, and *Hoeg, D. F.*, Carbon-14 kinetic isotope effect in the nucleophilic displacement reaction of [^{14}C]-methyl iodide and triethylamine, Chem. Ind. (London) **1957**, 463–464.

(192) *Bender, M. L.*, and *Hoeg, D. F.*, Carbon-14 kinetic isotope effects in nucleophilic substitution reactions, J. Amer. Chem. Soc. **79**, 5649–5654 (1957).

(193) *Bernstein, R. B.*, Simple laboratory method for producing enriched carbon-13, Science **126**, 119–120 (1957).

(194) *Bernstein, R. B.*, *Pars, H. G.*, and *Blumenthal, D. C.*, O^{18} study of the reaction of hydroxide with mercury(II) nitrate. Characterization of basic nitrates of mercury(II), J. Amer. Chem. Soc. **79**, 1579–1584 (1957).

(195) *Brodsky, A. I.*, Chemistry of Isotopes, (Academy of Sciences USSR Press, Moscow, 1957).

(196) *Brodsky, A. I.*, Connection between kinetic isotope effect and change in isotope content in the process of reaction, Probl. Kinet. Katal. **9**, 360–362 (1957).

(197) *Brown, J. B.*, *Dole, M.*, *and Lane, G. A.*, Fractionation of oxygen isotopes in the formation of oxide films on copper, J. Chem. Phys. **27**, 251–258 (1957).

(198) *Duncan, J. F.*, and *Lynn, K. R.*, The mechanism of the pinacol—pinacone rearrangement. V. Carbon isotope effects, Aust. J. Chem. **10**, 7–25 (1957).

(199) *Halevi, E. A.*, Secondary hydrogen isotope effects as a criterion of mechanism, Tetrahedron **1**, 174–175 (1957).

(200) *Harrison, A. G.*, and *Thode, H. G.*, The kinetic isotope effect in the chemical reduction of sulphate, Trans. Faraday Soc. **53**, 1648–1651 (1957).

(201) *Hoering, T.*, The isotopic composition of the ammonia and the nitrate ion in rain, Geochim. Cosmochim. Acta **12**, 97–102 (1957).

(202) *Jenkins, F. E.*, and *Harris, G. M.*, Isotopic fractionation in the system iodine cyanide/cyanide by a combined equilibration—precipitation process, J. Amer. Chem. Soc. **79**, 276–277 (1957).

(203) *Johnston, H. S.*, *Bonner, W. A.*, and *Wilson, D. J.*, Carbon isotope effect during oxidation of carbon monoxide with nitrogen dioxide, J. Chem. Phys. **26**, 1002–1006 (1957).

(204) *King, E. L.*, Kinetics of reactions in solution, Annu. Rev. Phys. Chem. **8**, 273–298 (1957).

(205) *Magee, E. M.*, and *Daniels, F.*, The kinetics and carbon-13 isotope effect in the decomposition of substituted ureas, J. Amer. Chem. Soc. **79**, 829–832 (1957).

(206) *Murmann, R. K.*, *Taube, H.*, and *Posey, F. A.*, Mechanisms of electron transfer in aquo cations—The reaction of RH_2O^{+++} with Cr^{++}, J. Amer. Chem. Soc. **79**, 262–265 (1957).

(207) *Posey, F. A.*, and *Taube, H.*, The mechanisms of substitution reactions of octahedral complexes: The induced aquation of the halogenopentamminecobaltic ions by metal cations, J. Amer. Chem. Soc. **79**, 255–262 (1957).

(208) *Roberts, J. D.*, *Hammond, G. S.*, and *Cram, D. J.*, Organic reaction mechanisms, Annu. Rev. Phys. Chem. **8**, 299–330 (1957).

(209) *Ropp, G. A.*, Errors in quantitative tracer studies. Examples resulting from isotopic dilution after synthesis, J. Chem. Educ. **34**, 60–63 (1957).

(210) *Ropp, G. A.*, *Danby, C. J.*, and *Dominey, D. A.*, Studies involving isotopically labelled formic acid and its derivatives. II. Relation of the absolute reaction rates to the magnitudes of the isotope effects in the oxidation of formic-C^{13} acid by halogen atoms, J. Amer. Chem. Soc. **79**, 4944–4948 (1957).

(211) *Saunders, W. H., Jr.*, and *Asperger, S.*, Mechanisms of elimination reactions. Sulfur isotope effects in the decomposition of some sulfonium salts, J. Amer. Chem. Soc. **79**, 1612–1615 (1957).

(212) *Stockmayer, W. H.*, Isotope effects on thermodynamic functions of hindered rotators, J. Chem. Phys. **27**, 321–322 (1957).

(213) *Stranks, D. R.*, and *Wilkins, R. G.*, Isotopic tracer investigations of mechanism and structure in inorganic chemistry, Chem. Rev. **57**, 743–866 (1957).

(214) *Tong, J. Y.*, and *Yankwich, P. E.*, Calculation of experimental isotope effects for pseudo first-order irreversible reactions, J. Phys. Chem. **61**, 540–543 (1957).

(215) *Varshavsky, Y. M.*, The influence of the thermodynamic isotope effect on the kinetics of exchange reactions, Probl. Kinet. Katal. **9**, 363–368 (1957).

(216) *Weston, R. E., Jr.*, Effect of pressure on the isotope effect in a unimolecular gaseous reaction: Tritium and carbon-13 effects in the isomerization of cyclopropane, J. Chem. Phys. **26**, 975–983 (1957).

(217) *Weygand, F.*, Isotopes in organic chemistry, Naturwissenschaften **44**, 169–176 (1957).

(218) *Yankwich, P. E.*, and *Copeland, J. L.*, The pyrolysis of lead oxalate; isotope effects and product composition, J. Amer. Chem. Soc. **79**, 2081–2086 (1957).

(219) *Bender, M. L.*, and *Buist, G. J.*, Carbon-14 kinetic isotope effects III. The hydrolysis of 2-chloro-2-methylpropane-2-C^{14}, J. Amer. Chem. Soc. **80**, 4304–4307 (1958).

(220) *Bernstein, R. B.*, Enrichment of isotopes by the difference in rates of isotopic reactions, Proc. Int. Symp. Isotope Separ., 1st, Amsterdam, 1957 (North-Holland Publ. Co.), 313–315 (1958).

(221) *Bigeleisen, J.*, The significance of the product and sum rules to isotope fractionation processes, Proc. Int. Symp. Isotope Separ., 1st, Amsterdam, 1957 (North-Holland Publ. Co.), 121–157 (1958).

(222) *Bigeleisen, J.*, Second-order sum rule for the vibrations of isotopic molecules and the second rule of the mean, J. Chem. Phys. **28**, 694–699 (1958).

(223) *Bigeleisen, J.*, and *Wolfsberg, M.*, Theoretical and experimental aspects of isotope effects in chemical kinetics, Advan. Chem. Phys. **1**, 15–76 (1958).

(224) *Bonner, W. A.*, and *Tanner, D. D.*, The deamination of 2-amino-3-phenylbutane-1-C^{14} with nitrous acid, J. Amer. Chem. Soc. **80**, 1447–1451 (1958).

(225) *Buist, G. J.*, and *Bender, M. L.*, Carbon-14 kinetic isotope effects IV. The effect of activation energy on some carbon-14 kinetic isotope effects, J. Amer. Chem. Soc. **80**, 4308–4311 (1958).

(226) *Fava, A.*, Reaction kinetics in solution, Annu. Rev. Phys. Chem. **9**, 221–244 (1958).

(227) *Heyns, K.*, and *Schultze, H.*, The mechanism of the polymerization of amino acid-N-carboxyanhydrides. Investigations of the isotope effect III., Justus Liebigs Ann. Chem. **611**, 40–57 (1958).

(228) *Heyns, K.*, *Schultze, H.*, and *Brockmann, R.*, The mechanism of the polymerization of amino acid-N-carboxyanhydrides. Investigations of the isotope effect II., Justus Liebigs Ann. Chem. **611**, 33–39, (1958).

(229) *Iwasaki, I.*, *and Fukutomi, H.*, Fractionation of sulfur during oxidation, Proc. Jap. Conf. Radioisotop., 2nd (Dai-2-kai Nippon Isotope Kaigi Hôbunshû), Tokyo, 1958 (Japan Atomic Industrial Forum, Inc.), 161–164 (1958); AEC-tr-4482, pp. 439–446.

(230) *Iwasaki, I.*, *Fukutomi, H.*, and *Shimojima, H.*, Fractionation of sulfur isotopes during oxidation, Bull. Chem. Soc. Japan **31**, 495–496 (1958).

(231) *Iwasaki, I.*, *Shimojima, H.*, and *Fukutomi, H.*, Fractionation of sulfur isotopes during reduction, Bull. Chem. Soc. Japan **31**, 496 (1958).

(232) *Korshunov, I. A.*, and *Novotorov, N. F.*, Isotope effects on the kinetics of hydrolysis reaction of several carboxylic acid esters, Tr. Khim. Khim. Tekhnol. **1**, 221–224 (1958).

(233) *Matsuura, T.*, and *Okuno, H.*, Isotope effect of boron in the thermal decomposition of the boron trifluoride—calcium fluoride compound, Bull. Chem. Soc. Japan **31**, 999–1001 (1958).

(234) *Nakane, R.*, Fractionation of nitrogen isotopes by oxidation of ammonium ion, Rika Gaku Kenkyusho Hokoku **34**, 203–205 (1958).

(235) *Raaen, V. F.*, and *Collins, C. J.* The carbon isotope effect in the pinacol—pinacolone rearrangement: A reinvestigation, J. Amer. Chem. Soc. **80**, 4432 (1958).

(236) *Rabinowitz, J. L., Lafair, J. S., Strauss, H. D.*, and *Allen, H. C., Jr.*, Carbon-isotope effects in enzyme systems II. Studies with formic acid dehydrogenase, Biochim. Biophys. Acta **27**, 544–548 (1958).

(237) *Ropp, G. A.*, Isotopic evidence for the mechanisms of decarbonylation of three carboxylic acids in sulfuric acid, J. Amer. Chem. Soc. **80**, 6691 (1958).

(238) *Spinner, E.*, Causes of secondary hydrogen isotope effects, Chem. Ind. (London) **1958**, 827.

(239) *Streitwieser, A., Jr., Jagow, R. H., Fahey, R. C.*, and *Suzuki, S.*, Kinetic isotope effects in the acetolyses of deuterated cyclopentyl tosylates, J. Amer. Chem. Soc. **80**, 2326-2332 (1958).

(240) *Swain, C. G., Stivers, E. C., Reuwer, J. F., Jr.*, and *Schaad, L. J.*, Use of hydrogen isotope effects to identify the attacking nucleophile in the enolization of ketones catalyzed by acetic acid, J. Amer. Chem. Soc. **80**, 5885–5893 (1958).

(241) *Varshavsky, Y. M.*, and *Vaisberg, S. E.*, Limits of applicability of the first-order kinetic equation for isotope exchange, Zh. Fiz. Khim. **32**, 454–459 (1958).

(242) *Yankwich, P. E.*, and *Veazie, A. E.*, Temperature dependence of the carbon isotope effect in the acid hydrolysis of urea, J. Amer. Chem. Soc. **80**, 1835–1838 (1958).

(243) *Zollinger, H.*, Kinetic isotope effects and their application to the investigation of azo couplings, Angew. Chem. **70**, 204–210 (1958).

(244) *Banholzer, K.*, and *Schmid, H.*, The mechanism of thermal decarbonylation of oxaloacetic esters, Helv. Chim. Acta **42**, 2584–2597 (1959).

(245) *Bell, R. P.*, The tunnel effect correction for parabolic potential barriers, Trans. Faraday Soc. **55**, 1–4 (1959).

(246) *Bigeleisen, J.*, Temperature independent isotope effects in chemical exchange equilibria involving linear molecules, Proc. U.N. Int. Conf. Peaceful Uses At. Energy, 2nd, Geneva, 1958 (Pergamon Press) **4**, 480–484 (1959).

(247) *Boreskov, G. K.*, The relationship between the kinetic and thermodynamic isotope effects and the molecularity of a reaction, Dokl. Akad. Nauk SSSR **129**, 607–609 (1959).

(248) *Brodsky, A. M., Kalinenko, R. A.*, and *Lavrovsky, K. P.*, On the kinetic isotope effect in cracking, Int. J. Appl. Radiat. Isotop. **7**, 118–122 (1959).

(249) *Brodsky, A. M., Kalinenko, R. A.*, and *Lavrovsky, K. P.*, The isotope effect in the cracking of ethane, Dokl. Akad. Nauk SSSR **124**, 340–341 (1959).

(250) *Brodsky, A. M., Kalinenko, R. A.*, and *Lavrovsky, K. P.*, Relations between kinetic isotope effects in rupture of the bonds C^{12}—C^{14} and C^{14}—C^{14}, Dokl. Akad. Nauk SSSR **126**, 1293–1295 (1959).

(251) *Collins, C. J.*, and *Lietzke, M. H.*, The isotope effect and its relation to the validity of isotopic tracer experiments, J. Amer. Chem. Soc. **81**, 5379–5383 (1959).

(252) *Feldman, D. E., Yost, H. T., Jr.*, and *Benson, B. B.*, Oxygen isotope fractionation in reactions catalyzed by enzymes, Science **129**, 146–147 (1959).

(253) *Gold, V.*, Physical organic chemistry, Annu. Rev. Phys. Chem. **10**, 169–190 (1959).

(255) *Halevi, E. A.*, and *Nussim, M.*, Secondary hydrogen isotope effects and vibrational frequency shifts, Tetrahedron **5**, 352–353 (1959).

(256) *Hodnett, E. M., and Feldman, C. F., Jr.*, Kinetics of the Friedel—Crafts ethylation of benzene with ethylene and with ethylene-C^{14}, J. Amer. Chem. Soc. **81**, 1638–1640 (1959).

(257) *Lewis, E. S.*, Isotope effects and hyperconjugation, Tetrahedron **5**, 143–148 (1959).

(258) *Lietzke, M. H.*, and *Collins, C. J.*, Tables of isotope effect functions for homocompetitive first-order reactions, Oak Ridge National Laboratory Report No. 2678 (May 11, 1959); and Supplement (July 15, 1959).

(259) *Olsen, S. R., and Watanabe, F. S.*, Behavior of P32 in tracer studies, Soil Sci. **88**, 256–259 (1959).

(260) *Riesz, P., and Bigeleisen, J.*, Solvent effect on a primary carbon isotope effect—Decarboxylation of trinitrobenzoate ion in water and ethanol—water mixture, J. Amer. Chem. Soc. **81**, 6187–6189 (1959).

(261) *Roginsky, S. Z.*, Application of isotopes in studies of chemical process mechanisms, Khim. Nauka Prom. **4**, 479–486 (1959).

(262) *Ropp, G. A.*, Curves for computation of kinetic isotope effects, U.S. Atomic Energy Commission Report CF-59-12-4 (December 8, 1959).

(263) *Russell, M. E.*, and *Bernstein, R. B.*, Kinetics of the thermal decomposition of dimethylmercury. II. Carbon-13 isotope effect, J. Chem. Phys. **30**, 613–617 (1959).

(264) *Seltzer, S., Hamilton, G. A.*, and *Westheimer, F. H.*, Isotope effects in the enzymatic decarboxylation of oxalacetic acid, J. Amer. Chem. Soc. **81**, 4018–4024 (1959).

(265) *Shiner, V. J., Jr.*, Deuterium isotope effects and hyperconjugation, Tetrahedron **5**, 243–252 (1959).

(266) *Simon, H.*, and *Palm, D.*, Comparison of the isotope effects of CH_2T and $^{14}CH_3$ groups, Chem. Ber. **92**, 2701–2706 (1959).

(267) *Smith, G. G.*, and *Fahey, D. M.*, The mechanism of base-catalyzed acylative decarboxylation, J. Amer. Chem. Soc. **81**, 3391–3397 (1959).

(268) *Weston, R. E., Jr.*, The magnitude of electronic isotope effects, Tetrahedron **6**, 31–35, (1959).

(269) *Weston, R. E., Jr.*, H_3 activated complex and the rate of reaction of hydrogen atoms with hydrogen molecules, J. Chem. Phys. **31**, 892–898 (1959).

(270) *Williams, C. M., Krise, G. M.*, and *Rabinowitz, J. L.*, Carbon isotope effects in enzyme systems III—Studies with creatine phosphokinase, Atompraxis **5**, 489–491 (1959).

(271) *Yankwich, P. E.*, and *Buddemeier, R. W.*, Large reverse carbon isotope effect, J. Chem. Phys. **30**, 861–862 (1959).

(272) *Yankwich, P. E., and Ikeda, R. M.*, Temperature independent factor in the rate constant ratio for isotopic reactions: Four center systems, J. Amer. Chem. Soc. **81**, 1532–1535 (1959).

(273) *Yankwich, P. E.*, and *Ikeda, R. M.*, Intermolecular carbon isotope effect in the decarboxylation of malonic acid in dioxane solution, J. Amer. Chem. Soc. **81**, 5054–5059 (1959).

(274) *Zlotowski, I.*, and *Zielinski, M.*, Isotope effect in the Van Slyke combustion of some carbon-14 aliphatic alcohols and acids, Nukleonika **4**, 5–12 (1959).

(275) *Zlotowski, I.*, and *Zielinski, M.*, Some relations between the mechanism of the reaction $CO_{(gas)} \xrightarrow{I_2O_5} CO_{2(gas)}$ and the kinetic isotope effect for ^{14}C, Nukleonika **4**, 599–610 (1959).

(276) *Bartell, L. S.*, Secondary isotope effects and mass-sensitive amplitudes of vibration, Tetrahedron Lett. **No. 6**, 13–16 (1960).

(277) *Begun, G. M.*, and *Fletcher, W. H.*, Partition function ratios for molecules containing nitrogen isotopes, J. Chem. Phys. **33**, 1083–1085 (1960).

(278) *Buncel, E.*, and *Bourns, A. N.*, The mechanism of the carbonyl elimination reaction of benzyl nitrate. Kinetic isotope effects and deuterium exchange, Can. J. Chem. **38**, 2457–2466 (1960).

(279) *Collins, C. J.*, Some aspects of deuterium isotope effects in mechanism studies, Ann. N.Y. Acad. Sci. **84**, 603–607 (1960).

(280) *Gutmann, J. R.*, Use of the isotope effect in the study of heterogeneous catalytic reactions, Int. J. Appl. Radiat. Isotop. **7**, 186–191 (1960).

(281) *Halevi, E. A.*, The secondary hydrogen isotope effect, Int. J. Appl. Radiat. Isotop. **7**, 192–197 (1960).

(282) *Hodnett, E. M.*, and *Jensen, A. W.*, Isotope effects in polymerizations of carbon-14-labeled styrenes, J. Polym. Sci. **43**, 183–191 (1960).

(283) *Hoering, T. C.*, The biogeochemistry of the stable isotopes of carbon. The carbon isotope effect on the rate of enzymatic decarboxylation of formic and glutamic acid, Carnegie Inst. Washington Pap. Geophys. Lab. **No. 1363**, 200–201 (1960/61).

(284) *Hoering, T. C.*, The pbysical chcmistry of isotopic substances. The effect of physical changes on isotope fractionation, Carnegie Inst. Washington Pap. Geophys. Lab. **No. 1363**, 201–204 (1960/61).

(285) *Hoering, T. C.*, The physical chemistry of isotopic substances. The carbon isotope effect in the synthesis of diamond, Carnegie Inst. Washington Pap. Geophys. Lab. **No. 1363**, 204 (1960/61).

(286) *Hoering, T. C.*, and *Ford, H. R.*, The isotope effect in the fixation of nitrogen by *azotobacter*, J. Amer. Chem. Soc. **82**, 376–378 (1960).

(287) *Hoffman, M. Z.*, and *Bernstein, R. B.*, Relative quenching cross sections in the reaction of $Hg(6^3P_1)$ atoms with isotopic N_2O molecules, J. Chem. Phys. **33**, 526–529 (1960).

(288) *Hoffman, M. Z.*, and *Bernstein, R. B.*, Isotope effects in $Hg(6^3P_1)$-photosensitized reactions: $H_2 + N_2O$ and $H_2 + NO$, J. Phys. Chem. **64**, 1753–1756 (1960).

(289) *Hoffman, M. Z.*, and *Bernstein, R. B.*, The $Hg(6^3P_1)$-photosensitized decomposition of nitric oxide, J. Phys. Chem. **64**, 1769–1771 (1960).

(290) *Johnston, H. S.*, Large tunnelling corrections in chemical reaction rates, Advan. Chem. Phys. **3**, 131–170 (1960).

(291) *Joy, H. W.*, and *Libby, W. F.*, Size effects among isotopic molecules, J. Chem. Phys. **33**, 1276 (1960).

(292) *Klemm, R. F.*, and *Bernstein, R. B.*, Kinetics of the reaction of methyl iodide with toluene, J. Amer. Chem. Soc. **82**, 5987–5990 (1960).

(293) *Krumbiegel, P.*, Consideration of isotope effects when working with stable isotopes in organic chemistry, Isotopentechnik **1**, 190–192 (1960/1961).

(294) *Lynn, K. R.*, and *Yankwich, P. E.*, Method for studying isotope fractionation in both atoms of a forming carbon—carbon bond, Chem. Ind. (London) **1960**, 117.

(295) *Mattern, J. A.*, Comparison of $^{18}O/^{16}O$ and $^{17}O/^{16}O$ isotope effects in some reactions of hydrogen peroxide, J. Inorg. Nucl. Chem. **15**, 388–389 (1960).

(296) *Melander, L.*, Isotope Effects on Reaction Rates (The Ronald Press Co., New York, 1960).

(297) *Panar, M.*, and *Roberts, J. D.*, Further evidence for benzyne as an intermediate in nucleopbilic aromatic substitution reactions, J. Amer. Chem. Soc. **82**, 3629–3632 (1960).

(298) *Raaen, V. F.*, *Tsiomis, A. K.*, and *Collins, C. J.*, A secondary isotope effect in the formation of a derivative of acetophenone-β-C^{14}, J. Amer. Chem. Soc. **82**, 5502–5503 (1960).

(299) *Rabinowitz, J. L.*, *Chase, G. D.*, *Strauss, H. D.*, and *Kline, G. B.*, Studies on isotope effects with carbonic anhydrase using ^{14}C sodium bicarbonate IV, Atompraxis **6**, 432–435 (1960).

(300) *Ron, A.*, *Halevi, E. A.*, and *Pauncz, R.*, The effect of deuteration on electron distribution and energy of conjugated molecules. Part III. LCAO–MO treatment of ethylcarbonium ion and its methyl-deuterated analogue, J. Chem. Soc. **1960**, 630–636.

(301) *Ropp, G. A.*, Studies involving isotopically labeled formic acid and its derivatives. V. Studies of the decarbonylation of formic, benzoylformic and triphenylacetic acids in sulfuric acid, J. Amer. Chem. Soc. **82**, 842–852 (1960).

(302) *Ropp, G. A.*, Studies of the cyclization of *o*-benzoylbenzoic-carboxyl-C^{14} acid, J. Org. Chem. **25**, 1255–1256 (1960).

(303) *Santoro, V.*, A simplified method for measuring various isotope effects in chemical kinetics with radioisotopes, Nuovo Cimento (Ser. 10) **15**, 865–872 (1960).

(304) *Schmid, H.*, Use of radioactive isotopes for the study of reaction mechanisms in organic chemistry, Chimia **14**, 248–261 (1960).

(305) *Simon, H.*, and *Palm, D.*, Investigation of isotope effects in the phenylhydrazone formation of various aldehydes labeled in the carbonyl group with ^{14}C and T, respectively, Chem. Ber. **93**, 1289–1295 (1960).

(306) *Stothers, J. B.*, and *Bourns, A. N.*, Carbon-13 kinetic isotope effects in the solvolysis of 1-bromo-1-phenylethane, Can. J. Chem. **38**, 923–935 (1960).

(307) *Streitwieser, A., Jr.*, Stereochemical and kinetic applications of deuterium isotope effects, Ann. N.Y. Acad. Sci. **84**, 576–582 (1960).

(308) *Vojta, G.*, A new series expansion for the reduced partition-function ratio of isotopically substituted molecules, Monatsber. Deut. Akad. Wiss. Berlin **2**, 526–530 (1960).

(309) *Vojta, G.*, Basis for statistical thermodynamics of isotope systems in chemical reactions, Kernenergie **3**, 917–927 (1960).

(310) *Vojta, G.*, Approximation formulas for tbe quantum-statistical calculation of chemical isotopic equilibria and their application to molecules witb ^{18}O, Kernenergie **3**, 927–930 (1960).

(311) *Wiley, R. H.*, and *Sale, E. E.*, Tracer techniques for tbe determination of monomer reactivity ratios. I. A direct counting technique applied to the styrene—methacrylate copolymerization, J. Polym. Sci. **42**, 479–489 (1960).

(312) *Wolfsberg, M.*, Note on secondary isotope effects in reaction rates, J. Chem. Phys. **33**, 2–6 (1960).

(313) *Wolfsberg, M.*, Isotope effects on reaction rates and the reaction coordinate, J. Chem. Phys. **33**, 21–22 (1960).

(314) *Yankwich, P. E.*, and *Ikeda, R. M.*, Intramolecular carbon isotope effect in the decarboxylation of malonic acid in dioxane solution, J. Amer. Chem. Soc. **82**, 1891–1894 (1960).

(315) *Zlotowski, I.*, and *Zielinski, M.*, Isotope effect in pyrolysis of $^{14}CH_3COONa$, Nukleonika **5**, 27–32 (1960).

(316) *Allen, J. K.*, and *Bevington, J. C.*, A tracer study of di-*tert.* butyl peroxide as an initiator for polymerization, Proc. Roy. Soc. **262A**, 271–286 (1961).

(317) *Ayrey, G.*, *Buncel, E.*, and *Bourns, A. N.*, The ylide mechanism in Hofmann elimination, Proc. Chem. Soc. London **1961**, 458–459.

(318) *Bader, R. F. W.*, and *Bourns, A. N.*, A kinetic isotope effect study of the Tschugaeff reaction, Can. J. Chem. **39**, 348–358 (1961).

(319) *Baciocchi, E.*, Isotope effect on reaction rate, Univ. Studi Trieste Fac. Sci. Ist. Chim. **No. 31**, 28–32 (1961).

(320) *Banks, B. E. C.*, *Meinwald, Y.*, *Rhind-Tutt, A. J.*, *Sheft, I.*, and *Vernon, C. A.*, Mechanism of reactions in the sugar series. Part IV. The structure of the carbonium ions formed in the acid-catalysed solvolysis of glucopyranosides, J. Chem. Soc. **1961**, 3240–3246.

(321) *Bartell, L. S.*, The role of non-bonded repulsions in secondary isotope effects. I. Alpha and beta substitution effects, J. Amer. Chem. Soc. **83**, 3567–3571 (1961).

(322) *Bartell, L. S.*, The role of nonbonded repulsions in secondary isotope effects. II. Influence on structure; gamma and more distant effects, Iowa State J. Sci. **36**, 137–146 (1961).

(323) *Bell, R. P.*, Transition states and isotope effects in proton-transfer reactions, Trans. Faraday Soc. **57**, 961–964 (1961).

(324) *Bourns, A. N.*, and *Buncel, E.*, Physical organic chemistry, Annu. Rev. Phys. Chem. **12**, 1–28 (1961).

(325) *Bunton, C. A.*, and *Shiner, V. J., Jr.*, Isotope effects in deuterium oxide solution. Part II. Reaction rates in acid, alkaline and neutral solution, involving only secondary solvent effects, J. Amer. Chem. Soc. **83**, 3207–3214 (1961).

(326) *Bunton, C. A.*, and *Shiner, V. J., Jr.*, Isotope effects in deuterium oxide solution. Part III. Reactions involving primary effects, J. Amer. Chem. Soc. **83**, 3214–3220 (1961).

(327) *Clayton, R. N.*, Oxygen isotope fractionation between calcium carbonate and water, J. Chem. Phys. **34**, 724–726 (1961).

(328) *Herzog, W., Betz, W.*, and *Neubert, A.*, Fractionation of Li isotopes in the reaction of metallic lithium with alkyl halides, Z. Naturforsch. **16A**, 242–245 (1961).

(329) *Johnston, H. S.*, and *Rapp, D.*, Large tunnelling corrections in chemical reaction rates. II, J. Amer. Chem. Soc. **83**, 1–9 (1961).

(330) *Khait, Y. L.*, Possible physicochemical applications of certain hypotheses dealing with the physical isotope effect, Kinet. Katal. **2**, 714–721 (1961).

(331) *Krohn, N. A.*, and *Smith, H. A.*, The influence of X-rays on catalytic activity as related to incorporated radioactivity, J. Phys. Chem. **65**, 1919–1920 (1961).

(332) *Lynn, K. R.*, and *Yankwich, P. E.*, Cyanide carbon isotope fractionation in the reaction of cyanide ion and methyl iodide. Carbon isotope effect in the hydrolysis of methyl iodide. J. Amer. Chem. Soc. **83**, 53–57 (1961).

(333) *Lynn, K. R.*, and *Yankwich, P. E.*, High concentration —ratio experiments: Isotope fractionation at the methyl carbon in the reaction of cyanide ion and methyl iodide. Isotope effect under conditions of equal reagent concentrations, J. Amer. Chem. Soc. **83**, 790–793 (1961).

(344) *Lynn, K. R.*, and *Yankwich, P. E.*, Isotope fractionation at the methyl carbon in the reactions of cyanide ion with methyl chloride and methyl bromide, J. Amer. Chem. Soc. **83**, 3220–3223 (1961).

(335) *Oppenheim, I.*, and *Friedman, A. S.*, Quantum statistical mechanics of isotope effects, J. Chem. Phys. **35**, 35–40 (1961).

(336) *Pajaro, G.*, and *Desio, V.*, Isotopic effects in the polymerization of ^{14}C-labeled ethylene, propylene, and styrene, Gazz. Chim. Ital. **91**, 880–888 (1961).

(337) *Popov, V. I.*, and *Roginsky, S. Z.*, The kinetic isotope effect (KIEf) and the mechanism of the oxidation of hydrogen on platinum, Kinet. Katal. **2**, 705–709 (1961).

(338) *Rabinovitch, B. S., Setser, D. W.*, and *Schneider, F. W.*, Inverse intermolecular kinetic isotope effects in unimolecular reactions. Differential quantal effects in the non-equilibrium behavior, Can. J. Chem. **39**, 2609–2611 (1961).

(339) *Ropp, G. A.*, and *Guillory, W. A.*, Isotopic studies involving formic acid and its derivatives. VII. Oxygen-18 isotope effect in the photochemical reaction of formic acid with chlorine, J. Phys. Chem. **65**, 1496–1498 (1961).

(340) *Saunders, W. H., Jr.*, Some applications of isotopic sulfur, Org. Sulfur Compounds, Chap. 5, **1**, 41–46 (1961).

(341) *Saunders, W. H., Jr.*, Kinetic isotope effects, Tech. Org. Chem., 2nd edit., Chap. 9, **8** (Part 1), 389–425 (1961).

(342) *Slater, N. B.*, Cubic potential surfaces in the transition-state theory of unimolecular reactions, J. Chem. Phys. **35**, 445–450 (1961).

(343) *Sniegoski, L. T., Frush, H. L.*, and *Isbell, H. S.*, Tritium-labeled compounds VII. Isotope effects in the oxidation of D-mannitols-C^{14} and D-mannitols-*t* to D-fructoses, J. Res. Nat. Bur. Stand. **65A**, 441–449 (1961).

(344) *Swain, C. G.*, and *Thornton, E. R.*, Effect of structural changes in reactants on the structure of transition states, Tetrahedron Lett. **1961**, 211–215.

(345) *Swain, C. G.*, and *Thornton, E. R.*, Mechanism of α-elimination by hydroxide ion on *p*-nitrobenzylsulfonium ion in aqueous solution, J. Amer. Chem. Soc. **83**, 4033–4034 (1961).

(346) *Swain, C. G.*, and *Thornton, E. R.*, Mechanism of displacement by hydroxide ion on benzylsulfonium ions in aqueous solution, J. Org. Chem. **26**, 4808–4809 (1961).

(347) *Vojta, G.*, The statistical thermodynamics of ideal gases with isotopically substituted molecules, Z. Phys. Chem. (Leipzig) **217**, 337–352 (1961).

(348) *Vojta, G.*, and *Haberlandt, R.*, The quantum statistics of nearly classical systems, Monatsber. Deut. Akad. Wiss. Berlin **3**, 278–283 (1961).

(349) *West, R., and Glaze, W.*, Lithium kinetic isotope effect in the reaction of ethyllithium with benzyl chloride, J. Chem. Phys. **34**, 685–686 (1961).

(350) *Westheimer, F. H.*, The magnitude of the primary kinetic isotope effect for compounds of hydrogen and deuterium, Chem. Rev. **61**, 265–273 (1961).

(351) *Weston, R. E., Jr.*, Isotope effects in chemical reactions, Annu. Rev. Nucl. Sci. **11**, 439–460 (1961).

(352) *Yukawa, Y.*, and *Kawakami, M.*, Reverse isotope effect of carbon-14 in the Beckmann rearrangement, Chem. Ind. (London) **1961**, 1401–1402.

(353) *Zielinski, M.*, The kinetic isotope effect of ^{14}C in the decarboxylation of picolinic acid in the melt and in solvents, Tr. Khim. Khim. Tekhnol. **4**, 707–713 (1961); Kernenergie **4/5**, 351–355 (1962).

(354) *Zlotowski, I.*, and *Zielinski, M.*, Note on the kinetic isotope effects in decarboxylation of picolinic acid in fused state and in solutions, Nucleonika **6**, 511–515 (1961).

(355) *Bell, R. P.*, and *Crooks, J. E.*, Secondary hydrogen isotope effect in the dissociation constant of formic acid, Trans. Faraday Soc. **58**, 1409–1411 (1962).

(356) *Bigeleisen, J.*, Correlation of tritium and deuterium isotope effects, Tritium Phys. Biol. Sci., Proc. Symp., Vienna, 1961 (IAEA) **1**, 161–168 (1962).

(357) *Bigeleisen, J., Haschemeyer, R. H., Wolfsberg, M.*, and *Yankwich, P. E.*, Temperature dependence of the carbon isotope effect in the dehydration of formic acid by concentrated sulfuric acid, J. Amer. Chem. Soc. **84**, 1813–1815 (1962).

(358) *Fröman, A.*, Isotope effects and electronic energy in molecules, J. Chem. Phys. **36**, 1490–1495 (1962).

(359) *Haberlandt, R.*, and *Vojta, G.*, The theory of isotope effects for restricted rotators in the crystal lattice, Kernenergie **4/5**, 321–323 (1962).

(360) *Harris, G. M.*, Application of radioisotopes to the investigation of the kinetics and mechanism of some inorganic complex compounds, Radioisotop. Phys. Sci. Ind., Proc. Conf., Copenhagen, 1960 (IAEA), **3**, 407–414 (1962).

(361) *Hill, J. W.*, and *Fry, A.*, Chlorine isotope effects in the reactions of benzyl and substituted benzyl chlorides with various nucleophiles, J. Amer. Chem. Soc. **84**, 2763–2769 (1962).

(362) *Hine, J.*, Kinetic isotope effects, Chap. 3, Part 1e, Physical Organic Chemistry, 2nd ed., pp. 71–73 (McGraw-Hill Book Co., Inc., New York, 1962).

(363) *Hodnett, E. M.*, and *Holmer, D. A.*, A study of the mechanism of interfacial polyamidation and polyesterification, J. Polym. Sci. **58**, 1415–1421 (1962).

(364) *Hodnett, E. M.*, and *Rowton, R. L.*, C^{14}-isotope effects in the decarboxylation of 2-benzoylpropionic acid, Radioisotop. Phys. Sci. Ind., Proc. Conf., Copenhagen, 1960 (IAEA), **3**, 225–233 (1962).

(365) *Isbell, H. S., Frush, H. L.*, and *Sniegoski, L. T.*, Utilization of tritium and carbon-14 in studies of isotope effects, Tritium Phys. Biol. Sci., Proc. Symp., Vienna, 1961 (IAEA) **2**, 93–101 (1962).

(366) *Isbell, H. S., Sniegoski, L. T.*, and *Frush, H. L.*, Determination of isotope effects by "double labeling". Oxidation of D-glucose with iodine, Anal. Chem. **34**, 982–984 (1962).

(367) *Johnston, H. S.*, and *Heicklen, J.*, Tunnelling corrections for unsymmetrical Eckart potential energy barriers, J. Phys. Chem. **66**, 532–533 (1962).

(368) *Johnston, H. S.*, and *Tschuikow-Roux, E.*, Hydrogen—deuterium kinetic isotope effect at very high temperature, J. Chem. Phys. **36**, 463–468 (1962).

(369) *Koch, D.*, and *Vojta, G.*, Frequency shifts and partition-function ratios for isotopic molecules as functions of the force constants, Kernenergie **4/5**, 317–321 (1962).

(370) *Krouse, H. R.*, and *Thode, H. G.*, Thermodynamic properties and geochemistry of isotopic compounds of selenium, Can. J. Chem. **40**, 367–375 (1962).

(371) *Lynn, K. R.*, and *Yankwich, P. E.*, ^{13}C kinetic isotope effects in the urease-catalyzed hydrolysis of urea. I. Temperature dependence, Biochim. Biophys. Acta **56**, 512–530 (1962).

(372) *Miller, S. I.*, Models for isotope rate effects in displacement, dissociation, elimination, and addition reactions, J. Phys. Chem. **66**, 978–983 (1962).

(373) *Monse, E. U.*, and *Spindel, W.*, Carbon and oxygen isotope exchange between CO and $Ni(CO)_4$, J. Chem. Phys. **37**, 2393–2397 (1962).

(374) *Rabinovitch, B. S.*, and *Current, J. H.*, Occurrence of large normal secondary intermolecular kinetic isotope effects in non-equilibrium systems, Can. J. Chem. **40**, 557–559 (1962).

(375) *Rapp, D.*, and *Weston, R. E., Jr.*, Comment on the calculation of rate constants from transition-state theory, J. Chem. Phys. **36**, 2807–2808 (1962).

(376) *Ropp, G. A.*, Evaluation of deuterium isotope effects in photochemical reactions of formic-*d* acid by use of C^{14}, Radioisotop. Phys. Sci. Ind., Proc. Conf., Copenhagen, 1960 (IAEA), **3**, 235–242 (1962).

(377) *Schneider, F. W.*, and *Rabinovitch, B. S.*, The thermal unimolecular isomerization of methyl isocyanide. Fall-off behavior, J. Amer. Chem. Soc. **84**, 4215–4230 (1962).

(378) *Sharp, T. E.*, and *Johnston, H. S.*, Hydrogen—deuterium kinetic isotope effect, an experimental and theoretical study over a wide range of temperature, J. Chem. Phys. **37**, 1541–1553 (1962).

(379) *Simon, H.*, and *Palm, D.*, Experimental comparison of primary and secondary isotope effects in tritium or carbon labelled compounds, Radioisotop. Phys. Sci. Ind., Proc. Conf., Copenhagen, 1960 (IAEA), **3**, 361–367 (1962).

(380) *Skorobogatov, G. A.*, Formal kinetics of some competing bimolecular reactions, and how the kinetic isotope effect influences the distribution of isotopic molecules, Izv. Akad. Nauk SSSR Otd. Khim. Nauk, **No. 11**, 1964–1977 (1962).

(381) *Stiehl, G., Kiessling, R., Kretzschmann, G.*, and *Wetzel, K.*, On the isotope effects of carbon in the system carbon-disulfide/xanthate, Kernenergie **4/5**, 332–335 (1962).

(382) *Stothers, J. B.*, and *Bourns, A. N.*, Carbon-13 kinetic isotope effects in bimolecular reactions, Can. J. Chem. **40**, 2007–2011 (1962).

(383) *Swain, C. G.*, and *Thornton, E. R.*, Effect of structural changes in reactants on the structure of transition states, J. Amer. Chem. Soc. **84**, 817–821 (1962).

(384) *Thode, H. G.*, The application of isotope effects in the study of biological and geological processes, Henry Ford Hosp. Med. Bull. **10**, 501–521 (1962).

(385) *Thornton, E. R.*, Deductions from small primary deuterium isotope effects, J. Org. Chem. **27**, 1943–1944 (1962).

(386) *Thornton, E. R.*, Solvent isotope effects in H_2O^{16} and H_2O^{18}, J. Amer. Chem. Soc. **84**, 2474–2475 (1962).

(387) *Tikhomirov, I. A.*, and *Melenevsky, V. N.*, Investigation of an isotope effect in ozone thermal decomposition, Izv. Sib. Otd. Akad. Nauk SSSR **No. 12**, 131–133 (1962).

(388) *Vojta, G.*, The quantum statistics of molecules with internal rotation: Wigner's series expansion for the partition function and thermodynamic functions of a symmetrical rotator, Ann. Phys. (Leipzig) **9**, 337–350 (1962).

(389) *Vojta, G.*, Quantum statistics of the isotope effects for restricted rotators, Z. Phys. Chem. (Leipzig) **220**, 379–390 (1962).

(390) *Vojta, G.*, The Gibbs statistics of isotopic systems, Z. Phys. Chem. (Leipzig) **220**, 420–428 (1962).

(391) *Weston, R. E., Jr.*, and *Seltzer, S.*, The secondary deuterium isotope effect in the pyrolysis of dimethylmercury, J. Phys. Chem. **66**, 2192–2200 (1962).

(392) *Weygand, F., Simon, H., Keil, K. D., Isbell, H. S.*, and *Sniegoski, L. T.*, Isotope effect in the recrystallization of D-mannose-1-*t* phenylhydrazone, Anal. Chem. **34**, 1753–1755 (1962).

(393) *Wiley, R. H.*, and *Davis, B.*, Monomer reactivity ratios for styrene—methyl-^{14}C methacrylate copolymerization, J. Polym. Sci. **62**, S132–S133 (1962).

(394) *Ayrey, G., Bourns, A. N.*, and *Vyas, V. A.*, Isotope effect studies on elimination reactions III. Nitrogen isotope effects in the E2 reaction of ethyltrimethylammonium and 2-phenylethyltrimethylammonium ions, Can. J. Chem. **41**, 1759–1767 (1963).

(395) *Bartell, L. S.*, Calculation of mean atomic positions in vibrating polyatomic molecules, J. Chem. Phys. **38**, 1827–1833 (1963).

(396) *Bartlett, P. D.*, and *Traylor, T. G.*, Oxygen-18 tracer studies of alkylperoxy radicals. I. The cumylperoxy radical and chain termination in the autoxidation of cumene, J. Amer. Chem. Soc. **85**, 2407–2410 (1963).

(397) *Bates, T. H.*, and *Bevington, J. C.*, A carbon isotope effect in the decarboxylation of the anisoyloxy radical, Nature (London) **197**, 1294–1295 (1963).

(398) *Benson, S. W.*, and *Nangia, P. S.*, Kinetic isotope effects in the pyrolysis of cyclopropane and cyclobutane, J. Chem. Phys. **38**, 18–25 (1963).

(399) *Current, J. H.*, and *Rabinovitch, B. S.*, Decomposition of chemically activated ethyl-d_3 radicals. Primary intramolecular kinetic isotope effect in a nonequilibrium system, J. Chem. Phys. **38**, 783–795 (1963).

(400) *Current, J. H.*, and *Rabinovitch, B. S.*, Large statistical secondary isotope effects in nonequilibrium reaction systems. Unimolecular decomposition of chemically activated ethyl-d_1 and ethyl-d_3 radicals, J. Chem. Phys. **38**, 1967–1973 (1963).

(401) *Falconer, W. E., Rabinovitch, B. S.*, and *Cvetanović, R. J.*, Unimolecular decomposition of chemically activated propyl radicals. Normal intermolecular secondary kinetic isotope effect, J. Chem. Phys. **39**, 40–53 (1963).

(402) *Goering, H. L., Pombo, M. M.*, and *McMichael, K. D.*, Stereochemistry of allylic rearrangements. XIII. The racemization, carboxyl-oxygen equilibration and solvolysis of *trans*-α,γ-dimethylallyl *p*-nitrobenzoate in aqueous acetone, J. Amer. Chem. Soc. **85**, 965–970 (1963).

(403) *Goldstein, M. J.*, and *Thayer, G. L., Jr.*, A two-stage, two-center decarboxylation, J. Amer. Chem. Soc. **85**, 2673–2674 (1963).

(404) *Green, M.*, and *Taube, H.*, The mechanism of base hydrolysis of substituted pentaamminecobalt(III) complexes, Inorg. Chem. **2**, 948–950 (1963).

(405) *Halevi, E. A.*, Secondary isotope effects, Progr. Phys. Org. Chem. **1**, 109–221 (1963).

(406) *Halevi, E. A.*, and *Nussim, M.*, Secondary hydrogen isotope effects. Part II. Association constants between methylbenzenes and chloranil, J. Chem. Soc. **1963**, 876–880.

(407) *Halevi, E. A., Nussim, M.*, and *Ron, A.*, Secondary hydrogen isotope effects. Part I. Strengths of α-deuterated carboxylic acids and amines, J. Chem. Soc. **1963**, 866–875.

(408) *Kresge, A. J., Lichtin, N. N.,* and *Rao, K. N.,* An inverse carbon isotope effect on the ionization of triphenylmethyl chloride. Kinetic isotope effects on S_N1 and S_N2 reactions, J. Amer. Chem. Soc. **85,** 1210–1211 (1963).

(409) *Lynn, K. R., and Bourns, A. N.,* ^{13}Carbon kinetic isotope effects and the mechanism of decarboxylation of 2,4-dihydroxybenzoic acid, Chem. Ind. (London) **1963,** 782–783.

(410) *Matteson, D. S.,* and *Waldbillig, J. O.,* A preferred inversion in an electrophilic displacement: Mercurideboronation of *exo-* and *endo*-5-norbornene-2-boronic acids, J. Amer. Chem. Soc. **85,** 1019–1020 (1963).

(411) *Raaen, V. F., Dunham, T. K., Thompson, D. D.,* and *Collins, C. J.,* Steric origin of some secondary isotope effects of deuterium, J. Amer. Chem. Soc. **85,** 3497–3499 (1963).

(412) *Richard, J., Bussière, P.,* and *Teichner, S.-J.,* Continuous measurement of the isotopic effect in the reduction of cuprous oxide by the mixture ^{12}CO—^{14}CO, J. Chim. Phys. Physicochim. Biol. **60,** 230–234 (1963).

(413) *Saunders, W. H., Jr.,* Calculations of sulphur and nitrogen isotope effects, Chem. Ind. (London) **1963,** 1661–1662.

(414) *Schneider, F. W.,* and *Rabinovitch, B. S.,* The unimolecular isomerization of methyl-d_3 isocyanide. Statistical-weight inverse secondary intermolecular kinetic isotope effects in nonequilibrium thermal systems, J. Amer. Chem. Soc. **85,** 2365–2370 (1963).

(415) *Simon, H.,* and *Müllhofer, G.,* Carbon-14 and tritium isotope effects in the Hofmann degradation of quaternary ammonium bases, Chem. Ber. **96,** 3167–3177 (1963).

(416) *Stern, M. J.,* and *Wolfsberg, M.,* Theoretical considerations on carbon isotope effects in the decarboxylation of malonic acid, J. Chem. Phys. **39,** 2776–2777 (1963).

(417) *Swain, C. G.,* and *Schowen, R. L.,* The temperature-independent factor of the kinetic isotope effect, J. Amer. Chem. Soc. **85,** 2023 (1963).

(418) *Tikhomirov, I. A.,* and *Vergun, A. P.,* Establishment and investigation of the isotope effect in the reduction of HNO_3 to NO in the presence of mercury, Izv. Sib. Otd. Akad. Nauk SSSR, Ser. Khim. Nauk, **No. 3,** 154–156 (1963).

(419) *Wiberg, K. B.,* and *Motell, E. L.,* The kinetic isotope effect in the photochlorination of methane, Tetrahedron **19,** 2009–2023 (1963).

(420) *Yankwich, P. E.,* and *Haschemeyer, R. H.,* Temperature dependence of the carbon isotope effect in the decarbonylation of liquid formic acid, J. Phys. Chem. **67,** 694–696 (1963).

(421) *Anantakrishnan, S. V.,* Limitations on the use of isotopes in reaction mechanisms. Part I. Some general considerations, Curr. Sci. **33,** 297–299 (1964).

(422) *Baertschi, P.,* Isotope effects and their significance, Z. Naturwiss.-Med. Grundlagenforsch. **2,** 22–42, (1964).

(423) *Bigeleisen, J.,* Correlation of kinetic isotope effects with chemical bonding in three-centre reactions, Pure Appl. Chem. **8,** 217–223 (1964).

(424) *Bourns, A. N.,* Kinetic isotope effect studies of some electrophilic aromatic substitution reactions, Trans. Roy. Soc. Can. **2III,** 277–291 (1964).

(425) *Bourns, A. N.,* and *Smith, P. J.,* The mechanism of the bimolecular elimination reaction of 2-arylethylammonium ions, Proc. Chem. Soc. **1964,** 366–367.

(426) *Brown, H. M.,* and *Krouse, H. R.,* Fractionation of germanium isotopes in chemical reactions, Can. J. Chem. **42,** 1971–1978 (1964).

(427) *Carmichael, H.,* and *Johnston, H. S.,* Correlation of activation energies and bond energies in CF_3 reactions, J. Chem. Phys. **41,** 1975–1982 (1964).

(428) *Collins, C. J.,* Isotopes and organic reaction mechanisms, Advan. Phys. Org. Chem. **2,** 1–91 (1964).

(429) *Davy, J. G., Guerra, C. R., Johnston, H. S., Weaver, C. F.,* and *Young, C. E.,* Hydrogen—deuterium kinetic-isotope effect: The problem of potential-energy surface, J. Chem. Phys. **41,** 1517–1518 (1964).

(430) *Fry, A.,* Application of the successive labelling technique to some carbon, nitrogen and chlorine isotope effect studies of organic reaction mechanisms, Pure Appl. Chem. **8,** 409–419 (1964).

(431) *Goering, H. L., Doi, J. T.,* and *McMichael, K. D.,* Stereochemistry of allylic rearrangements. XIV. Ion-pair return associated with the solvolysis of *cis*-5-methyl-2-cyclohexenyl *p*-nitrobenzoate in aqueous acetone, J. Amer. Chem. Soc. **86,** 1951–1957 (1964).

(432) *Goldstein, M. J.,* Multicenter cleavage of acetyl peroxide, Tetrahedron Lett. **1964,** 1601–1607.

(433) *Halevi, E. A., and Margolin, Z.,* Temperature dependence of the secondary isotope effect on aqueous alkaline ester hydrolysis, Proc. Chem. Soc. **1964,** 174.

(434) *Hering, H., LeBail, H., Sutton, J., Vanderchmitt, A., Botter, R., Ducheylard, G.,* and *Majzoub, M.,* On the conversion of oxygen to CO_2 for determination of the O isotopic content, Pure Appl. Chem. **8,** 281–286 (1964).

(435) *Hodnett, E. M.,* and *Sparapany, J. J.,* Tritium and nitrogen-15 isotope effects in the decomposition of *p*-nitrophenethyltrimethylammonium iodide, Pure Appl. Chem. **8,** 385–392 (1964).

(436) *Isbell, H. S.,* and *Sniegoski, L. T.,* Tritium-labeled compounds X. Isotope effects in the oxidation of aldoses-1-*t* with bromine, J. Res. Nat. Bur. Stand. **68A,** 145–151 (1964).

(437) *Isbell, H. S.,* and *Sniegoski, L. T.,* Tritium-labeled compounds. XI. Mechanism for the oxidation of aldehydes and aldoses-1-*t* with sodium chlorite, J. Res. Nat. Bur. Stand. **68A,** 301–304 (1964).

(438) *Klein, F. S., Persky, A.,* and *Weston, R. E., Jr.,* Deuterium-isotope effect in the chlorine exchange between hydrogen chloride and chlorine atoms. A study of models for the tunnel effect, J. Chem. Phys. **41,** 1799–1807 (1964).

(439) *Kreevoy, M. M.,* The exposition of isotope effects on rates and equilibria, J. Chem. Educ. **41,** 636–638 (1964).

(440) *Lewis, E. S.,* and *Insole, J. M.,* Intermediates in the hydrolysis of *p*-toluenediazonium ion, J. Amer. Chem. Soc. **86,** 34–38 (1964).

(441) *Lynn, K. R.,* and *Yankwich, P. E.* ^{13}C kinetic isotope effects in the urease-catalyzed hydrolysis of urea. II. Influences of reaction variables other than temperature, Biochim. Biophys. Acta **81,** 533–547 (1964).

(442) *Matteson, D. S., Waldbillig, J. O.,* and *Peterson, S. W.,* Isotope effects in mercurideboronations measured by neutron absorption, J. Amer. Chem. Soc. **86,** 3781–3783 (1964).

(443) *Raaen, V. F.,* and *Collins, C. J.,* Steric origin of some secondary isotope effects, Pure Appl. Chem. **8,** 347–355 (1964).

(444) *Rabinovitch, B. S., Gilderson, P. W.,* and *Blades, A. T.,* Inverse secondary intermolecular isotope effects in the low pressure thermal isomerization of cyclopropane, J. Amer. Chem. Soc. **86,** 2994–2996 (1964).

(445) *Rabinovitch, B. S.,* and *Setser, D. W.,* Unimolecular decomposition and some isotope effects of simple alkanes and alkyl radicals, Advan. Photochem. **3,** 1–82 (1964).

(446) *Rubin, R. J.,* Classical model for the study of isotope effects in energy exchange and particle exchange reactions, J. Chem. Phys. **40,** 1069–1077 (1964).

(447) *Salomon, M.,* Isotope effects in methyl radical abstraction reactions, Can. J. Chem. **42,** 610–613 (1964).

(448) *Saunders, W. H., Jr.*, Elimination reactions in solution, Chap. 2, The Chemistry of Alkenes (The Chemistry of Functional Groups Series), Ed. S. Patai, pp. 149–201 (Interscience Publ., New York, 1964).

(449) *Saunders, W. H., Jr.*, and *Zimmerman, S. E.*, Mechanisms of elimination reactions. V. Sulfur isotope effects in some reactions of *t*-butyldimethylsulfonium iodide, J. Amer. Chem. Soc. **86**, 3789–3791 (1964).

(450) *Schütte, H. R.*, Isotopes in organic chemistry, Z. Chem. **4**, 49–61 (1964).

(451) *Shima, M.*, Study of the sulfur isotope of synthetic melnikovite, Sci. Pap. Inst. Phys. Chem. Res. Tokyo **58**, 12–14 (1964).

(452) *Simon, H.*, and *Müllhofer, G.*, Carbon-14 and tritium isotope effects in Hofmann degradation of quarternary amines, Pure Appl. Chem. **8**, 379–384 (1964).

(453) *Thornton, E. R.*, Isotope effects, Chap. 6, Solvolysis Mechanisms, pp. 194–229 (The Ronald Press Co., New York, 1964).

(454) *Wiberg, K. B.*, Kinetic isotope effects, Part 3–4, Physical Organic Chemistry, pp. 351–364 (John Wiley and Sons, Inc., New York, 1964).

(455) *Willi, A. V.*, Studies of the calculation of kinetic isotope effects. I. A simple method for the calculation of the vibrational frequencies of molecules and transition states and its application to the ions H_3O^+ and D_3O^+ as examples, Helv. Chim. Acta **47**, 647–654 (1964).

(456) *Willi, A. V.*, Studies of the calculation of kinetic isotope effects. III. Application of the FG-matrix method to the transition state of the S_N1 solvolysis of methyl iodide in water, Ber. Bunsenges. Phys. Chem. **68**, 266–269 (1964).

(457) *Willi, A.V.*, and *Wolfsberg, M.*, The influence of "bond making and bond breaking" in the transition state on hydrogen isotope effects in linear three centre reactions, Chem. Ind. (London) **1964**, 2097–2098.

(458) *Wolfsberg, M.*, and *Stern, M. J.*, Validity of some approximation procedures used in the theoretical calculation of isotope effects, Pure Appl. Chem. **8**, 225–242 (1964).

(459) *Wolfsberg, M.*, and *Stern, M. J.*, Secondary isotope effects as probes for force constant changes, Pure Appl. Chem. **8**, 325–338 (1964).

(460) *Wood, A.*, Carbon isotope effects in the decarboxylation of oxaloacetic acid. Part 1.—Studies using $^{13}_{6}C$, Trans. Faraday Soc. **60**, 1263–1267 (1964).

(461) *Yankwich, P. E.*, and *Zavitsanos, P. D.*, Carbon isotope effects in the pyrolytic decomposition of manganous oxalate, Pure Appl. Chem. **8**, 287–304 (1964).

(462) *Yankwich, P. E.*, and *Zavitsanos, P. D.*, Carbon isotope effects in the pyrolytic decomposition of zinc oxalate, J. Phys. Chem. **68**, 1275–1278 (1964).

(463) *Zielinski, M.*, ^{13}C and ^{18}O isotope effects in the decarboxylation of quinaldic acid, J. Chem. Phys. **41**, 3646–3648 (1964).

(464) *Zollinger, H.*, Hydrogen isotope effects in aromatic substitution reactions, Advan. Phys. Org. Chem. **2**, 163–200 (1964).

(465) *Agarwala, U.*, *Rees, C. E.*, and *Thode, H. G.*, Sulphur isotope effects in the hydrogen ion decomposition of thiosulphate, Can. J. Chem. **43**, 2802–2811 (1965).

(466) *Bigeleisen, J.*, Chemistry of isotopes, Science **147**, 463–471 (1965).

(467) *Bishop, D. M.*, and *Laidler, K. J.*, Symmetry numbers and statistical factors in rate theory, J. Chem. Phys. **42**, 1688–1691 (1965).

(468) *Blades, A. T.*, and *Wallbridge, M. G. H.*, The hydrogen isotope effect in the thermal decomposition of malonic acid, J. Chem. Soc. **1965**, 792–794.

(469) *Brown, L. L.*, and *Drury, J. S.*, Nitrogen isotope effects in the decomposition of diazonium salts, J. Chem. Phys. **43**, 1688–1691 (1965).

(470) *Couvoisier, P.*, *Maurette, E.*, and *Ravoire, J.*, Isotope effect of sulfur during the oxidation of sulfur dioxide in sulfuric acid and the mechanism of the oxidation, J. Chim. Phys. Physicochim. Biol. **62**, 219–221 (1965).

(471) *Frie, W.*, Separation of isotopes in the dissociation region, Z. Phys. **185**, 493–506 (1965).

(472) *Goldstein, M. J.*, and *Thayer, G. L., Jr.*, The mechanism of a Diels—Alder reaction. I. A retrodiene decarboxylation, J. Amer. Chem. Soc. **87**, 1925–1933 (1965).

(473) *Goldstein, M. J.*, and *Thayer, G. L., Jr.*, The mechanism of a Diels—Alder reaction. II. The structure of the transition state, J. Amer. Chem. Soc. **87**, 1933–1941 (1965).

(474) *Green, M.*, *Schug, K.*, and *Taube, H.*, Isotopic fractionation in electron-transfer reactions. The role of nonbridging ligands, Inorg. Chem. **4**, 1184–1186 (1965).

(475) *Kresge, A. J.*, *Lichtin, N. N.*, *Rao, K. N.*, and *Weston, R. E., Jr.*, The primary carbon isotope effect on the ionization of triphenylmethyl chloride. Experimental determination, theoretical justification, and implications for carbon isotope effects on nucleophilic substitution at saturated carbon, J. Amer. Chem. Soc. **87**, 437–445, 5809–5810 (1965).

(476) *Nefedov, V. D.*, *Skorobogatov, G. A.*, *Smirnov, V. M.*, *Musakin, A. P.*, and *Vorob'ev, L. N.*, Microsynthesis of multiply labeled C^{14}-benzene and isotopic effects, Zh. Org. Khim. **1**, 1615–1620 (1965).

(477) *Oae, S.*, A symposium on the isotope effect. Mechanism of organic reactions and isotope effect, Kagaku (Kyoto) **20**, 3–10 (1965).

(478) *Pearson, M. J.*, *Rabinovitch, B. S.*, and *Whitten, G. Z.*, Rates of decomposition of light and deuterated alkyl radicals. 2-Hexyl and 2-hexyl-d_{12}, and 2-octyl and 2-octyl-d_{16}, J. Chem. Phys. **42**, 2470–2477 (1965).

(479) *Rabinovitch, B. S.*, *Gilderson, P. W.*, and *Schneider, F. W.*, The thermal unimolecular isomerization of methyl-d_1 isocyanide. Fall-off and inverse isotope effect, J. Amer. Chem. Soc. **87**, 158–160 (1965).

(480) *Roginsky, S. Z.*, Kinetic isotope effects of complex chemical and biochemical reactions, Abh. Deut. Wiss. Berlin, Kl. Chem., Geol. Biol., **1964**, 495–513 (1965).

(481) *Roginsky, S. Z.*, Molecular mechanism of some catalytical reactions as revealed by means of isotopic kinetical effects and experiments with tracer molecules, Proc. Int. Congr. Catal., 3rd, Amsterdam, 1964 (North-Holland Publ. Co.), **2**, 939–956 (1965).

(482) *Rösseler, M.*, and *Koch, H.*, Contribution on the kinetics of the catalytic decarboxylation of carboxylic acids in the heterogeneous phase and determination of the ^{12}C—^{14}C kinetic isotope effect, Radiochim. Acta **4**, 12–17 (1965).

(483) *Schlag, E. W.*, and *Haller, G. L.*, Symmetry numbers and reaction rates. II. The computation of the reaction-path degeneracy for bimolecular reactions, J. Chem. Phys. **42**, 584–587 (1965).

(484) *Seltzer, S.*, and *Dunne, F. T.*, The mechanism of the thermal decomposition of α-phenylethylazomethane. A two-step reaction, J. Amer. Chem. Soc. **87**, 2628–2635 (1965).

(485) *Sharma, T.*, and *Clayton, R. N.*, Measurements of O^{18}/O^{16} ratios of total oxygen of carbonates, Geochim. Cosmochim. Acta **29**, 1347–1353 (1965).

(486) *Skorobogatov, G. A.*, Formal kinetics of some competitive bimolecular reactions and the influence of the kinetic isotope effect on the distribution of isotopic molecules, Vestn. Leningrad. Univ., Fiz. Khim. No. 10, **20**, 128–141 (1965).

(487) *Stern, M. J.*, and *Wolfsberg, M.*, Isotope effects as tools for the elucidation of reaction mechanisms. Predictions from model calculations, J. Pharm. Sci. **54**, 849–858 (1965).

(488) *Thode, H. G., Shima, M., Rees, C. E., and Krishnamurty, K. V.*, Carbon-13 isotope effects in systems containing carbon dioxide, bicarbonate, carbonate, and metal ions, Can. J. Chem. **43**, 582–595 (1965).

(489) *Vojta, G.*, On series expansions in the statistical thermodynamics of isotopic systems, Z. Phys. Chem. (Leipzig) **230**, 106–111 (1965).

(490) *Yankwich, P. E.*, and *Zavitsanos, P. D.*, Carbon isotope effects in the pyrolytic decomposition of magnesium oxalate, J. Phys. Chem. **69**, 918–922 (1965).

(491) *Zielinski, M.*, ^{13}C isotope effects in the decarboxylation of malonic acid, Nukleonika **10**, 337–341 (1965).

(492) *Zielinski, M.*, Carbon-13 isotope effects in the oxidation of acetic acid, J. Phys. Chem. **69**, 1428–1429 (1965).

(493) *Borcic, S., and Sunko, D.*, Isotope effects, Nukl. Energ. **3**, 13–17 (1966).

(494) *Gatz, C. R.*, Temperature-independent factor in isotopic rate-constant ratios, J. Chem. Phys. **44**, 1861–1864 (1966)

(495) *Goldstein, M. J.*, Kinetic isotope effects and organic reaction mechanisms, Science **154**, 1616–1621 (1966).

(496) *Johnston, H. S.*, Gas Phase Reaction Rate Theory (The Ronald Press Co., New York, 1966).

(497) *Lin, J.*, and *Light, J.*, Phase-space theory of chemical kinetics. III. Reactions with activation energy. J. Chem. Phys. **45**, 2545–2559 (1966).

(498) *Saunders, W. H., Jr.*, Kinetic isotope effects, Surv. Progr. Chem. **3**, 109–146 (1966).

(499) *Saunders, W. H., Jr.*, Isotope effects in proton transfers, Chem. Ind. (London) **1966**, 663–664.

(500) *Simon, H., and Palm, D.*, Isotope effects in organic chemistry and biochemistry, Angew. Chem. Int. Ed. Engl. **5**, 920–933 (1966).

(501) *Stern, M. J.*, and *Wolfsberg, M.*, On the absence of isotope effects in the absence of force constant changes, J. Chem. Phys. **45**, 2618–2629 (1966).

(502) *Stern, M. J.*, and *Wolfsberg, M.*, Simplified procedure for the theoretical calculation of isotope effects involving large molecules, J. Chem. Phys. **45**, 4105–4124 (1966).

(503) *Thornton, E. R.*, Physical organic chemistry, Annu. Rev. Phys. Chem. **17**, 349–372 (1966).

(504) *Willi, A. V.*, Calculation of kinetic isotope effects for the reaction of methyl iodide with cyanide ion, Z. Naturforsch. **21A**, 1377–1384 (1966).

(505) *Willi, A. V.*, Calculation of kinetic isotope effects for the reaction of methyl iodide with hydroxide ion, Z. Naturforsch. **21A**, 1385–1390 (1966).

(506) *Willi, A. V.*, Calculations of kinetic isotope effects for the iodide exchange and for the solvolysis of methyl iodide, Can. J. Chem. **44**, 1889–1897 (1966).

(507) *Albery, W. J.*, Isotope effects in proton transfer reactions, Trans. Faraday Soc. **63**, 200–206 (1967).

(508) *Buddenbaum, W. E.*, and *Yankwich, P. E.*, Theoretical calculation of kinetic isotope effects. Effect of reaction coordinate variations on the temperature-independent factor, TIF, J. Phys. Chem. **71**, 3136–3143 (1967).

(509) *Chemla, M.*, Separation and physicochemical applications of isotopes, Bull. Soc. Chim. Fr. **1967**, 1457–1465.

(510) *Gatz, C. R.*, Reply to "Comment on the calculation of temperature-independent factor in isotopic rate-constant ratios", J. Chem. Phys. **46**, 824–825 (1967).

(511) *Kim, T. R.*, Kinetic isotope effect, Hwahak Kwa Kongop Ui Chinbo **7**, 77–88 (1967).

(512) *Seltzer, S.* and *Mylonakis, S. G.*, The correlation of secondary α-deuterium isotope effects with primary nitrogen isotope effects in the thermolysis of azo compounds, J. Amer. Chem. Soc. **89**, 6584–6589 (1967).

(513) *Seltzer, S., and Zavitsas, A. A.*, Correlation of isotope effects in substitution reactions with nucleophilicities. Secondary α-deuterium isotope effect in iodide-131 exchange of methyl-d_3 iodide, Can. J. Chem. **45**, 2023–2031 (1967).

(514) *Stern, M. J.*, and *Wolfsberg, M.*, Comment on the calculation of "temperature-independent factor" in isotopic rate-constant ratios, J. Chem. Phys. **46**, 823–824 (1967).

(515) *Weston, R. E., Jr.*, Transition-state models and hydrogen-isotope effects, Science **158**, 332–342 (1967).

(516) *Yankwich, P. E., and Buddenbaum*, W. E., Anomalous temperature dependence of kinetic carbon isotope effects, J. Phys. Chem. **71**, 1185–1195 (1967).

(517) *Basov, Y. G.*, and *Panchenkov, G. M.*, Calculation of isotopic separation factor in the thermal dissociation of molecules, Zh. Fiz. Khim. **42**, 520–522 (1968).

(518) *Bigeleisen, J.*, and *Ishida, T.*, Application of finite orthogonal polynomials to the thermal functions of harmonic oscillators. I. Reduced partition function of isotopic molecules, J. Chem. Phys. **48**, 1311–1330 (1968).

(519) *Chang, P. C., and Gatz, C. R.*, Kinetic isotope effects: Approximate calculations, J. Phys. Chem. **72**, 2602–2604 (1968).

(520) *Huang, T.T.-S., Kass, W. J., Buddenbaum, W. E.*, and *Yankwich, P. E.*, Anomalous temperature dependence of kinetic carbon isotope effects and the phenomenon of crossover, J. Phys. Chem. **72**, 4431–4446 (1968).

(521) *Lewis, E. S.*, and *Robinson, J. K.*, The influence of tunneling on the relation between tritium and deuterium isotope effects. The exchange of 2-nitropropane-2-*t*, J. Amer. Chem. Soc. **90**, 4337–4344 (1968).

(522) *Macdonald, D. D.*, and *Tschuikow-Roux, E.*, Temperature dependence of kinetic isotope effects in gas-phase reactions. II. The hydrogen-atom—formaldehyde reaction, J. Chem. Phys. **49**, 5345–5349 (1968).

(523) *Murrell, J. N.*, and *Laidler, K. J.*, Symmetries of activated complexes, Trans. Faraday Soc. **64**, 371–377 (1968).

(524) *Raaen, V. F., Ropp. G. A.*, and *Raaen, H. P.*, Carbon-14 (McGraw-Hill Book Co., Inc., New York, 1968).

(525) *Stern, M. J., Spindel, W.*, and *Monse, E. U.*, Temperature dependences of isotope effects, J. Chem. Phys. **48**, 2908–2919 (1968).

(526) *Tschuikow-Roux, E.*, and *Macdonald, D. D.*, Temperature dependence of kinetic isotope effects in gas-phase reactions. I. Theory of the high-temperature limit, J. Chem. Phys. **49**, 5342–5345 (1968).

(527) *Wolfsberg, M.*, Isotope effects, Annu. Rev. Phys. Chem. **20**, 449–478 (1969).

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☆ U.S. GOVERNMENT PRINTING OFFICE: 1972 O—424-021

FORM NBS-114A (1-71)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO. NBS SP-349	2. Gov't Accession No.	3. Recipient's Accession No.

4. TITLE AND SUBTITLE

Heavy-Atom Kinetic Isotope Effects, An Indexed Bibliography

5. Publication Date

June 1972

6. Performing Organization Code

7. AUTHOR(S)

Marvin J. Stern and Max Wolfsberg

8. Performing Organization

9. PERFORMING ORGANIZATION NAME AND ADDRESS

NATIONAL BUREAU OF STANDARDS
DEPARTMENT OF COMMERCE
WASHINGTON, D.C. 20234

10. Project/Task/Work Unit No.

11. Contract/Grant No.

CST 1288

12. Sponsoring Organization Name and Address

Same as No. 9.

13. Type of Report & Period Covered

NA

14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES

16. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)

A bibliography of heavy-atom kinetic isotope effects has been compiled covering the complete literature from the earliest entry found (1911) through 1965. Review articles and theoretical papers are listed through 1968. The bibliography is divided into a list of the references, an author index and a subject index. The subject index has been annotated to describe, in brief, the type of reaction being observed. The following areas have been excluded: geochemistry (except for specific laboratory reactions), living systems, mass spectrometry and electron impact, electrochemistry, diffusion-controlled processes, hot-atom chemistry, photochemistry involving selective excitation of isotopes and processes involving no chemical change.

17. KEY WORDS (Alphabetical order, separated by semicolons)

Author index; bibliography; heavy-atom isotope effects; isotope effects; kinetic isotope effects; reaction kinetics; subject index.

18. AVAILABILITY STATEMENT

[X] UNLIMITED.

[ ] FOR OFFICIAL DISTRIBUTION. DO NOT RELEASE TO NTIS.

19. SECURITY CLASS (THIS REPORT)

UNCLASSIFIED

20. SECURITY CLASS (THIS PAGE)

UNCLASSIFIED

21. NO. OF PAGES

39

22. Price

45 cents

USCOMM-DC 66244-P71

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