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NEIGHBORING GROUP PARTICIPATION IN SOLVOLYSIS. VIII.[1] METHYL PARTICIPATION IN ACETOLYSIS OF 2-METHYL-2-ADAMANTYLMETHYL *p*-BROMOBENZENESULFONATE. ANGULAR DEPENDENCE OF β-METHYL CARBON-14 AND DEUTERIUM KINETIC ISOTOPE EFFECTS

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In an earlier paper of this series, we presented clear evidence for methyl participation in acetolysis of neopentyl *p*-nitrobenzenesulfonate (**1**).[2]

$$(CH_3)_3CCH_2OSO_2C_6H_4NO_2\text{-}p \qquad \mathbf{1}$$

The positive carbon-14 kinetic isotope effect observed for the methyl labeled compound $1\text{-}\gamma\text{-}^{14}C$ confirmed that the bonding of this carbon is changing at the transition state of the rate-determining ionization of the reaction. As the observation seemed important for the future application of the carbon isotope effect to the σ-participation problem, we decided to explore the accuracy and the nature of this isotope effect.

First, the measurement of the carbon-14 isotope effect in acetolysis of $1\text{-}\gamma\text{-}^{14}C$ at 100 °C was thoroughly repeated by another person using another lot of the ester in freshly purified acetic acid. The result, $k^{12}/k^{14} = 1.041 \pm 0.006$, was in fair agreement with the original value, $k^{12}/k^{14} = 1.050 \pm 0.003$.[3]

In calculation of these isotope effects, the linear regression method using Eq. 1 was applied, in which x is the fraction of reaction, and A_0 and

$$\log A_x = \log A_0 - 1/3[1 - (k^{14}/k^{12})]\log(1 - x) \qquad (1)$$

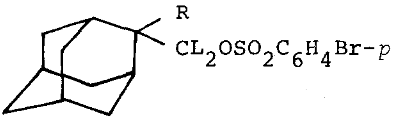
A_x are the specific activities of the recovered esters at $x = 0$ and $x = x$, respectively. The factor, 1/3, corresponds to the assumption that only one of the three methyl groups has an isotope effect and the other two have no effect.

It is apparent that errors inherent in the isotope effects calculated by use of Eq. 1 are three times as large as those in the usual cases when one particular carbon is labeled with carbon-14 and Eq. 2 is applied.

$$\log A_x = \log A_0 - [1 - (k^{14}/k^{12})]\log(1 - x) \qquad (2)$$

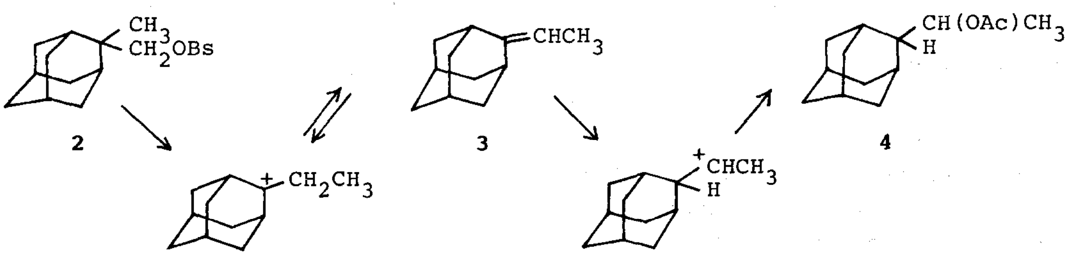
Furthermore, the correlation of the changes in the observed radioactivity to the isotope effect of only one methyl group is not self-evident. Although secondary isotope effects of significant magnitude by carbon have been rarely reported,[4] there is a fair chance that the overlapping of secondary effects by three methyl groups may cause the observed isotope effects. Mathematically, a 1% effect each by three methyl groups or a 1.5% effect each by two non-migrating methyls could make a 3% kinetic isotope effect as well.

In order to explore the uncertainties mentioned above, it is desirable to investigate the angular dependence of the isotope effect in a system in which only one particular methyl group can migrate. 2-Methyl-2-adamantylmethyl system (2) seemed a good candidate for the purpose.[5]



2a : $R = CH_3$, $L = H$
b : $R = {}^{14}CH_3$, $L = H$
c : $R = CD_3$, $L = H$
d : $R = CH_3$, $L = D$

Unbuffered acetolysis of **2a** at 100 °C gave almost exclusively an olefin (a 92±2% yield) contaminated with a small amount of an acetate (*ca.* 2%) after eight half-lives. Elemental analysis, and carbon and proton NMR, IR, and Mass spectroscopic analyses confirmed the structure of the olefin as ethylideneadamantane (**3**).[6] The acetate was also identified as 1-(2-adamantyl)ethyl acetate (**4**). A control experiment showed that **3** afforded **4** gradually under the reaction conditions. No other product with the original neopentyl moiety nor with rearranged homoadamantyl structure was detected. Addition of sodium acetate did not alter the mode of the reaction. The course of the reaction is as shown below. Thus the reaction is an ideal model of the neopentyl solvolysis in which only a particular methyl group can migrate and the other two are inhibited from migration.



Kinetics and radioassays for acetolysis of **2** were carried out according to the procedures described before.[7] The carbon-14 isotope effect for **2b** was calculated by use of Eq. 2. Results are summarized in Table 1. Data on acetolysis of **1** are included also for comparison. The γ-deuterium effect (d_9)

for **1** was measured in the present investigation under the same conditions as the others.

Table 1. Kinetic Isotope Effects in Acetolysis of 2-Methyl-2-adamantylmethyl Brosylate (**2**) and Neopentyl Nosylate (**1**)[a]

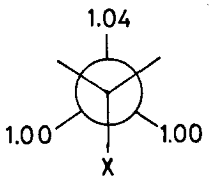
	2	**1**
$10^5 k/\mathrm{s}^{-1}$	17.30±0.06	2.82[c]
k^{12}/k^{14} at γ	1.037±0.003[b]	1.046±0.005[d]
k_H/k_D at α	1.19±0.01 (d_2)	1.187 (d_2)[c]
k_H/k_D at γ	1.123±0.002 (d_3)	1.016±0.006 (d_9)

[a] At 100 °C and 0.05 M. Average of two runs unless otherwise noted. [b] Single run. A standard deviation was calculated from an error in the slope of Eq. 2. [c] Reference 2. [d] See the text.

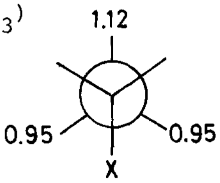
The similar magnitude of the α-deuterium isotope effects for **2** and **1** indicates that the transition state of the reaction of **2** is similar to that of **1**. The carbon-14 isotope effect at γ in **2** was as large as that in **1** and has a smaller intrinsic error. Methyl participation in the neopentyl solvolysis has thus been established unambiguously. Compensation of the positive deuterium effects of a migrating methyl by the negative effects of two non-migrating ones, which has long been postulated, has been demonstrated experimentally for the first time.[2]

If the difference in the leaving arenesulfonates is assumed to be of no consequence to these kinetic isotope effects, which does not seem unreasonable at least qualitatively,[8,9] the observed isotope effects can be allocated to the individual methyl groups from the two sets of the results (X stands for a leaving group):

k^{12}/k^{14}



k_H/k_D (d_3)



This allocation of the kinetic isotope effects to the individual β-methyl group has provided valuable information on the mechanism of the β-methyl effect on the reaction as well as the nature of the carbon and deuterium isotope effects as a tool for investigation of reaction mechanisms. Operation of the inductive effect is reflected in the negative deuterium effects of the non-migrating methyls. Deuterium is considered as more electron-releasing than hydrogen.[9] However, the distinct angular dependence of both the carbon and deuterium effects indicates the operation of other mechanisms. This angular dependence is in accord with the nature of hyperconjugation. Although the operation of C-C hyperconjugation can not be denied, theoretical estimation of secondary isotope effects shows that the decrease of a C-C stretching force constant by a factor of two, which seems too large a variation for hyperconjugation, can only produce 2.3% of the carbon-14 isotope effect.[10] Bridging of a particular methyl group is the only factor in accordance with both the angular dependence of the carbon and deuterium effects and the considerable magnitude (*ca.* 4%) of the carbon effect. Bridging and hyperconjugation are not necessarily alternative, but may cooperate together as the driving force of the reaction.[11]

In conclusion, C-C σ-participation in the neopentyl solvolysis must involve a bridged structure in its transition state. Furthermore, the carbon isotope effect is verified to be an excellent tool to explore the σ-participation, as it is insensitive to the inductive effect.

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References and Notes

1) Part VII: T. Ando, J. Yamawaki, and Y. Saito, *Bull. Chem. Soc. Jpn.*, **51**, 219 (1978).
2) T. Ando, H. Yamataka, J. Kuramochi, J. Yamawaki, and Y. Yukawa, *Tetrahedron Lett.*, **1976**, 1879.
3) In calculation of standard deviations, errors in the slopes of Eq. 1 must be triplicated. Unfortunately, the value reported in the original paper (0.001) was the one not triplicated and in error.[2]
4) V. F. Raaen, A. K. Tsiomis, and C. J. Collins, *J. Am. Chem. Soc.*, **82**, 5502 (1960); M. Saunders, L. Telkowski, and M. R. Kates, *ibid.*, **99**, 8070 (1977).
5) J. R. Alford, B. D. Cuddy, D. Grant, and M. A. McKervey, *J. Chem. Soc. Perkin trans. 1*, **1972**, 2707.
6) J. L. Fry, E. M. Engler, and P. v. R. Schleyer, *J. Am. Chem. Soc.*, **94**, 4628 (1972).
7) a) H. Yamataka, S.-G. Kim, T. Ando, and Y. Yukawa, *Tetrahedron Lett.*, **1973**, 4767; b) T. Imamoto, S.-G. Kim, Y. Tsuno, and Y. Yukawa, *Bull. Chem. Soc. Jpn.*, **44**, 2776 (1971).
8) V. J. Shiner, Jr. and R. C. Seib, *J. Am. Chem. Soc.*, **98**, 862 (1976).
9) V. J. Shiner, Jr. in "Isotope Effects in Chemical Reactions", ed by C. J. Collins and N. S. Bowman, Van Nostrand Reinhold, New York (1970), p. 151.
10) J. Bigeleisen and M. Wolfsberg, *Adv. Chem. Phys.*, **1**, 15 (1958).
11) For a review of the topic see B. Capon and S. P. McManus, "Neighboring Group Participation", Vol. 1, Plenum Press, New York (1976), pp. 31-43.

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