

$\beta$ -DEUTERIUM KINETIC ISOTOPE EFFECTS  
IN THE SOLVOLYSIS OF 2-ARYL-1,1,1-TRIFLUORO-2-PROPYL TOSYLATES  
AND OF 2-ARYL-2-PROPYL *p*-NITROBENZOATES.  
EVIDENCE FOR A VARIATION OF THE CONTRIBUTION OF  $\alpha$ -METHYL SUBSTITUENT IN  
STABILIZING CATIONIC REACTION CENTERS WITH DIFFERENT ELECTRON DEMAND

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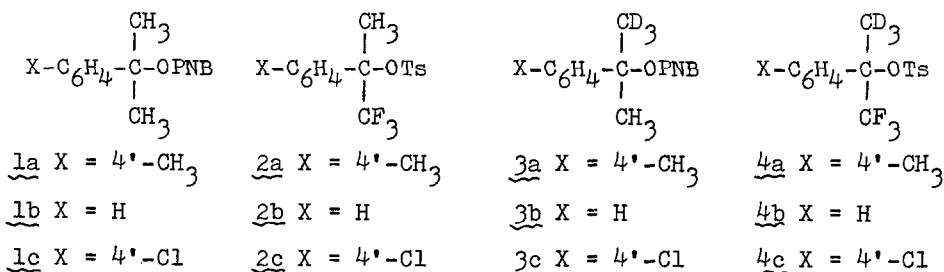
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**Abstract:** A very high  $\beta$ -deuterium kinetic isotope effect,  $k(\text{CH}_3)/k(\text{CD}_3) = 2.13$  at  $60^\circ\text{C}$ , was found for the solvolysis of 2-(3'-chlorophenyl)-1,1,1-trifluoro-2-propyl tosylate (2c) and the  $\alpha$ - $\text{CD}_3$  analogue (4c), and the effect decreased with increasing electron attracting of the substituent on the aromatic ring which showed the variation of the contribution of  $\alpha$ -methyl group to the stabilization of the cationic reaction center in the transition state.

Deuterium kinetic isotope effect (KIE) has long been a useful tool in the study of mechanisms of solvolytic reactions.<sup>1-3</sup> In limiting  $\text{S}_{\text{N}}1$  reactions a decreasing  $\beta$ -D KIE of an  $\alpha$ -methyl group is likely the result of increasing stabilization of the cationic reaction center by the other  $\alpha$ -substituent if the hyperconjugative contribution is important. Indeed, Shiner and coworkers observed a small change of the  $\beta$ -D KIE from 1.22 to 1.13 for the solvolysis of 1-aryl-1-chloroethanes in different solvent systems as the aryl group changing from phenyl to *p*-anisyl.<sup>4</sup> However, the nucleophilic solvent assistance<sup>5</sup> cannot be ignored in the case of these secondary substrates, and the influence of the solvent ionizing power on KIE is complicated because random correlations have been found in several cases such as *t*-butyl chloride<sup>6</sup> and 7-methyl-7-norbornyl tosylate.<sup>7</sup> We now wish to report the observation of distinct changes of  $k(\text{CH}_3)/k(\text{CD}_3)$  with different aryl substituents in the solvolysis of tertiary benzylic substrates in 80% ethanol at  $60^\circ\text{C}$ , from 1.02 to 1.40 for *p*-nitrobenzoates 1 and 3, and from 1.04 to 2.13 for tosylates 2 and 4. It gives a definite evidence for a variation of the contribution of the  $\alpha$ -methyl group in stabilizing cationic reaction centers with different electron demand. The value of 2.13, though an extrapolated one, is likely the highest  $\beta$ -D KIE noted for solvolysis at  $60^\circ\text{C}$ .<sup>5</sup>

2-Aryl-2-propyl *p*-nitrobenzoates 1a-1c, 2-aryl-1,1,1-trifluoro-2-propyl tosylates 2a-2c and their  $\beta,\beta,\beta$ -trideuterio derivatives (3a-3c and 4a-4c) were prepared from alcohols with *n*-butyllithium and followed by the reaction with the acid chloride.<sup>9</sup> The alcohols were made from Grignard addition of methylmagnesium

iodide or methyl- $d_3$ -magnesium iodide<sup>10</sup> to the corresponding acetophenones<sup>11</sup> and  $\alpha,\alpha,\alpha$ -trifluoroacetophenones,<sup>9</sup> respectively. The kinetics of solvolysis were followed titrimetrically up to two half-lives. The KIE was measured by running the reactions side by side in the same constant temperature bath. The deviation was less than 2% in two independent experiments and excellent linear regression for 10-12 points, with the correlation coefficient  $r > 0.99$ , was obtained in every case. The pertinent kinetic data are shown in Table I.



To minimize the possible error introduced from the long extrapolation of the rate data at high temperatures the  $\beta$ -D KIE,  $k_1/k_3$  and  $k_2/k_4$ , were compared at 60°C. Since the KIE has been measured in the same solvent mixture for tertiary benzylic substrates, no complication of solvent effect needs to be considered. The KIE is essentially the same in both substrates containing electron donating 4'-methylphenyl substituent. It increases as the aryl group changes to phenyl, and to 3'-chlorophenyl in both cases, and a larger increment is realized in the  $\alpha$ -trifluoromethyl compounds ( $k_2/k_4$  vs  $k_1/k_3$ ). Obviously the  $\alpha$ -methyl group is able to stabilize the cationic transition state, and its contribution is greater to the less stable ones. The KIE for 2c over 4c is remarkably high, 2.13 at 60°C which is among the highest ones for solvolytic reactions recorded to date.<sup>8,12</sup> The possible intervention of rate-determining elimination or hydride-shift<sup>13</sup> can be ruled out from the following study. The substrate 2c was dissolved in D<sub>2</sub>O and ethanol- $d_6$  mixture, 20/80 v/v, and was sealed in an NMR tube. The reaction rate and the composition of the products were monitored by <sup>1</sup>H NMR. At 80°C no olefin could be detected in the first 10% of reaction, and about 30% olefin was found in the product at the completion of solvolysis. Gas chromatographic analysis of the final mixture on a carbowax 20M column indicated no rearranged product and a ratio of 36:36:28 for alcohol:ether:olefin. The rate of substitution could be calculated as  $4.38 \times 10^{-6} \text{ s}^{-1}$ , which is nearly the same as the extrapolated one (Table I). Hence, these results are likely to be compatible with the proposal of a hyperconjugative stabilization of the cationic transition state observed in the solvolysis of other systems.<sup>14-16</sup>

Moreover, the present study results in an interesting mechanistic implication. The significant increase of  $\beta$ -D KIE with the changing of aryl substituents shows that the contribution of the  $\alpha$ -methyl group to the stabilization of the cationic reaction center at the transition state varies with different electron demand. However, both the *p*-nitrobenzoate 1<sup>17</sup> and the tosylate 2<sup>9</sup> exhibited excellent

Table I. Kinetic data of solvolysis in 80% ethanol.<sup>a</sup>

Substrate	k(°C), s <sup>-1</sup>	k(60°C), s <sup>-1</sup>	ΔH <sup>‡</sup> , kcal/mol	ΔS <sup>‡</sup> , eu	k(CH <sub>3</sub> )/k(CD <sub>3</sub> ) 60°C	k(CH <sub>3</sub> )/k(CD <sub>3</sub> ) 25°C
<u>1a</u>	2.93 x 10 <sup>-4</sup> (50) 1.60 x 10 <sup>-5</sup> (25)	8.30 x 10 <sup>-4</sup> b	21.7	-7.8	1.02 <sup>c</sup>	1.12 <sup>c</sup>
<u>1b</u>	2.26 x 10 <sup>-4</sup> (75)	4.57 x 10 <sup>-5</sup>	23.9	-6.7	1.18 <sup>d</sup>	
<u>1c</u>	8.99 x 10 <sup>-5</sup> (100) 3.22 x 10 <sup>-5</sup> (90)	1.02 x 10 <sup>-6</sup> b	27.0	-5.1	1.40 <sup>e</sup>	
<u>3a</u>	2.80 x 10 <sup>-4</sup> (50) 1.43 x 10 <sup>-5</sup> (25)	8.12 x 10 <sup>-4</sup> b	22.2	-6.3		
<u>3b</u>	1.99 x 10 <sup>-4</sup> (75)	3.88 x 10 <sup>-5</sup>	24.6	-5.2		
<u>3c</u>	7.35 x 10 <sup>-5</sup> (100) 2.55 x 10 <sup>-5</sup> (90)	7.27 x 10 <sup>-7</sup> b	27.8	-3.2		
<u>2a</u>	3.32 x 10 <sup>-4</sup> (30) 1.70 x 10 <sup>-4</sup> (25)	1.01 x 10 <sup>-2</sup> b	22.4	-0.48	1.04 <sup>f</sup>	1.14 <sup>f</sup>
<u>2b</u>	3.48 x 10 <sup>-4</sup> (75)	6.65 x 10 <sup>-5</sup>	24.9	-3.0	1.38 <sup>g</sup>	
<u>2c</u>	4.19 x 10 <sup>-4</sup> (125) 3.71 x 10 <sup>-5</sup> (100) 1.34 x 10 <sup>-5</sup> (90) 4.35 x 10 <sup>-6</sup> (80) b	3.86 x 10 <sup>-7</sup> b	26.8	-7.9	2.13 <sup>h</sup>	
<u>4a</u>	2.87 x 10 <sup>-4</sup> (30) 1.49 x 10 <sup>-4</sup> (25)	9.69 x 10 <sup>-3</sup>	22.9	0.91		
<u>4b</u>	2.68 x 10 <sup>-4</sup> (75)	4.83 x 10 <sup>-5</sup>	25.7	-1.3		
<u>4c</u>	3.74 x 10 <sup>-4</sup> (125) 2.45 x 10 <sup>-5</sup> (100) 8.50 x 10 <sup>-6</sup> (90)	1.81 x 10 <sup>-7</sup> b	30.7	-2.8		

<sup>a</sup> ± 1%. <sup>b</sup> Extrapolated value. <sup>c</sup>  $k_{1a}/k_{3a}$ . <sup>d</sup>  $k_{1b}/k_{3b}$ . <sup>e</sup>  $k_{1c}/k_{3c}$ . <sup>f</sup>  $k_{2a}/k_{4a}$ .  
<sup>g</sup>  $k_{2b}/k_{4b}$ . <sup>h</sup>  $k_{2c}/k_{4c}$ .

linear correlations from Hammett-Brown<sup>18</sup> and Yukawa-Tsuno<sup>19</sup> treatments of the rate data, respectively. Hence, neither treatment is sensitive to the change of the contribution of α-methyl group, and its accuracy to describe the resonance effect of the aryl group to the cationic transition state should be redefined. Further work in this aspect is in progress.

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