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# Neighboring Carbon and Hydrogen. XXVIII. $Ar_2$ -6 Participation in Solvolysis of Some $\omega$ -Aryl-1-alkyl Bromobenzenesulfonates<sup>1,2</sup>

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In searching for Ar<sub>2</sub>-participation in solvolysis, acetolysis and formolysis of suitably substituted  $\omega$ -aryl-1-alkyl *p*-bromo-benzenesulfonates have been studied. In the case of 4-aryl-1-butyl bromobenzenesulfonates, substantial rate enhancements bencenessinonates have been studied. In the case of  $4-ary_{1-1}$ -bitry bromobenzenesinonates, substantial rate enhancements are ascribed to in-result from introduction of one or two *m*-methoxyl groups into the benzene ring. These enhancements are ascribed to in-creased importance of Ar<sub>2</sub>- assisted ionization in solvolysis. The product of formolysis of 4-(3,5-dimethoxyphenyl)-1-butyl *p*-bromobenzenesulfonate contains mainly 5,7-dimethoxytetralin, formate ester being a minor product. The product composition agrees within experimental error with that predicted from the  $k_{\Delta}$  and  $k_{a}$  values obtained by dissection of the solvolysis rate constant by the method outlined in the previous paper. For Ar<sub>2</sub>-*n* participation, the rate sequence is  $5 \ll 6 \gg 7$ , only Ar<sub>2</sub>-6 being important in the present work. The observed sequence contrasts with that observed for Ar<sub>1</sub>-*n*, for which  $5 \gg 6$ . This contrast may be understood by considering the respective transition states for the rate-determining steps. The  $S \gg 6$ . This contrast may be understood by considering the respective transition states for the rate-determining steps. The comparison of rates of Ar<sub>1</sub>- and Ar<sub>2</sub>-assisted ionizations discloses that Ar<sub>1</sub>-5 and Ar<sub>2</sub>-6-assisted ionizations have nearly equal rates for equivalent degrees of activation of the benzene ring.

In this paper are presented more data bearing on anchimeric effects of aryl groups more distant than beta. In contrast with the  $\omega$ -aryl-1-alkyl bromobenzenesulfonates stressed in the previous paper,<sup>3</sup> the compounds treated in the present manuscript were substituted so as to favor Ar<sub>2</sub>- rather than Ar<sub>1</sub>participation in the rate-determining ionization step. The results obtained in the study of these compounds supply considerable orientation on the scope of Ar<sub>2</sub>-participation and the comparison of such participation with the Ar<sub>1</sub>-variety.

 $\omega$ -Aryl-1-alkyl Systems.—The list of *p*-bromobenzenesulfonates examined in the present study is shown in Table I, which also summarizes their solvolysis rate constants.

The alcohols which were required for preparation of the bromobenzenesulfonates were obtained by a variety of methods. Of the propanols, 3-manisyl-1-propanol was prepared in fair yield by the reduction of *m*-methoxycinnamic acid with lith-ium aluminum hydride. 3-(3,5-Dimethoxyphenyl)-1-propanol was obtained by a lithium aluminum hydride reduction of 3-(3,5-dimethoxyphenyl)-propanoic acid, the latter being derived from the malonic ester synthesis on 3,5-dimethoxybenzyl chloride.

Of the butanols, 4-m-anisyl-1-butanol was prepared in poor yield from  $\gamma$ -m-anisylpropylmagnesium chloride and formaldehyde. 4-(3,4-Dimethoxyphenyl)-1-butanol was prepared by a lithium aluminum hydride reduction of 4-(3,4-dimethoxyphenyl)-butanoic acid, the latter being obtained by Clemmensen reduction of the Friedel-Crafts succinoylation product from veratrole.<sup>4</sup> The 4-(3,5dimethoxyphenyl)-1-butanol was prepared by the reaction of  $\beta$ -3,5-dimethoxyphenylethylmagnesium bromide with ethylene oxide. The required bromide was obtained from a displacement reaction on the *p*-bromobenzenesulfonate of  $\beta$ -3,5-dimethoxyphenylethanol. The preparation of this material by way of 3,5-dimethoxyphenylacetic acid has been described previously.5

(1) Research supported by the Office of Naval Research.

(2) Most of the material of this paper has been reported in summary: (a) Paper by S. Winstein at the Symposium on Dynamic Stereochemistry of the Chemical Society, Manchester, England, March 31, 1954 (see Chemistry & Industry, 562 (1954); (b) S. Winstein, R. Heck, S. Lapporte and R. Baird, Experientia, 12, 138 (1956).

(3) R. Heck and S. Winstein, THIS JOURNAL, 79, 3105 (1957).

- (4) M. Haq, M. Kapur and J. N. Ray, J. Chem. Soc., 1087 (1933).
  (5) S. Winstein and R. Heck, THIS JOURNAL, 78, 4801 (1956).

The pentanol, 5-(3,4-dimethoxyphenyl)-1-pentanol, was prepared by a Friedel-Crafts reaction between veratrole and glutaric anhydride,6 followed by Clemmensen and lithium aluminum hydride reductions.

Kinetic Search for  $Ar_2$ -Participation.—All the substances investigated displayed good first-order behavior in acetolysis and formolysis. As regards enhancement of solvolysis rate by methoxyl substitution in the benzene ring, no substantial rate enchancement is observed with the  $\omega$ -aryl-1propyl esters, as was pointed out already in the previous paper.<sup>3</sup> This is true even for 3,5-dimethoxyl substitution.

In the 4-phenyl-1-butyl series, substantial rate enhancements are observed<sup>2</sup> on addition of mmethoxyl groups to the benzene ring. Thus, 4-manisyl-1-butyl p-bromobenzenesulfonate is 1.86 times as reactive, and the 4-(3,5-dimethoxyphenyl)-1-butyl ester I, 6.24 times as reactive, as the 4phenyl-1-butyl derivative in formic acid at 75°. The rate comparisons are summarized in Table II. In line with the previous arguments,<sup>8</sup> the observed rate enhancements are ascribed to increased importance of Ar<sub>2</sub>-participation in the case of solvolysis of the *m*-methoxyl-substituted derivatives.

The procedure for dissecting the solvolysis rate constant into  $k_{\Delta}$ , the rate constant of anchimerically assisted ionization, and  $k_s$ , the rate constant of anchimerically unassisted solvolysis, which was applied previously,3 may be employed on the present data. Using a  $k_s$  equal to that for 4-phenyl-1-butyl p-bromobenzenesulfonate,<sup>3</sup> one obtains the  $k_{\Delta}$ and  $k_{\Delta}/k_{s}$  values summarized in Table II. As in the case of Ar<sub>1</sub>-participation,<sup>2,3</sup> two methoxyl groups suffice to make Ar2-participation dominate formolysis of a 4-aryl-1-butyl ester. Just as for  $Ar_1$ -participation,<sup>3</sup> the importance of  $Ar_2$ -participation is greater in formic acid than in acetic acid solvent.

Since  $k_{\Delta}$  is responsible for most of the formolysis rate constant of the 4-(3,5-dimethoxyphenyl)-1-butyl derivative I, the value for  $\Delta S^{\pm}$  listed in Table I, namely, -15.8 e.u., is the value for Ar<sub>2</sub>-6-assisted ionization. This is lower than the value<sup>3</sup> for Ar<sub>1</sub>-5-assisted ionization, and not very different from the value for anchimerically unassisted formolysis.

(6) R. D. Haworth and J. R. Atkinson, J. Chem. Soc., 797 (1938).

	Summa	RY OF SOLVOL	YSIS RATE	Constants		
Compound	Solvent	Temp., °C.	[ROBs] 10 <sup>*</sup> M	$k (\text{sec.}^{-1})$	$\Delta H^{\pm}$ , kcal./mole	ΔS <sup>‡</sup> , e.u.
m-CH <sub>3</sub> OC <sub>6</sub> H <sub>4</sub> (CH <sub>2</sub> ) <sub>3</sub> OBs	HOAe	75.00	2.43	$(1.11 \pm 0.02) \times 10^{-6}$		
$3,5-(CH_{\$}O)_2C_6H_3(CH_2)_3OBs$	HOAc HCOOHª HCOOHª	75.00 50.00 75.00	$3.42 \\ 2.94 \\ 2.94$	$\begin{array}{rrrr} (1.10 \pm .04) \times 10^{-6} \\ (1.70 \pm .09) \times 10^{-6} \\ (2.15 \pm .04) \times 10^{-5} \end{array}$	22.0	-17.0
m-CH <sub>2</sub> OC <sub>6</sub> H <sub>4</sub> (CH <sub>2</sub> ) <sub>4</sub> OBs	HOAc HOAc	$\begin{array}{c} 75.00 \\ 100.00 \end{array}$	$\begin{array}{c}2.94\\2.75\end{array}$	$(2.02 \pm .02) \times 10^{-6}$ $(2.31 \pm .01) \times 10^{-5}$	24.5	-14.6
	HCOOHª HCOOHª	$\begin{array}{c} 75.00 \\ 100.20 \end{array}$	2.53 2.53	$\begin{array}{rrr} (6.24 \pm .06) \times 10^{-5} \\ (5.92 \pm .10) \times 10^{-4} \end{array}$	22.4	-13.9
$3,4-(CH_3O)_2C_6H_3(CH_2)_4OBs$	НОАс НОАс НСООН <sup>ь</sup>	$75.00 \\ 100.05 \\ 75.00$	$2.74 \\ 2.74 \\ 2.62$	$\begin{array}{rrrr} (3.30 \pm .02) \times 10^{-6} \\ (3.59 \pm .13) \times 10^{-5} \\ (1.08 \pm .02) \times 10^{-4} \end{array}$	23.9	-15.3
$3,5-(CH_3O)_2C_6H_3(CH_2)_4OBs$	HCOOHª HCOOHª	$\begin{array}{c} 50.00\\ 75.00\end{array}$	$\frac{2.83}{2.84}$	$\begin{array}{rrrr} (1.88 \pm .04) \times 10^{-5} \\ (2.09 \pm .09) \times 10^{-4} \end{array}$	20.9	-15.8
3,4-(CH <sub>3</sub> O) <sub>2</sub> C <sub>6</sub> H <sub>8</sub> (CH <sub>2</sub> ) <sub>5</sub> OBs <sup>a</sup> 0.0315 <i>M</i> sodium formate.	HCOOH <sup>a</sup> <sup>b</sup> 0.0302 <i>M</i> soc	75.00 lium formate.	2.72 ° 0.0291 J	$(3.50 \pm .06) \times 10^{-5}$ M sodium formate.		

TABLE I SUMMARY OF SOLVOLYSIS RATE CONSTANTS

TABLE II

Analysis of Solvoly	sis Rate	S OF SOME	4-Aryl	-1-BUTYL	p-Bromon	BENZENES	ULFONATES	ат 75.00	0
Compound	Rel AcOH	rates HCOOH	10 <sup>6</sup> k <sub>8</sub>	AcOH 10 <sup>6</sup> k <sub>Δ</sub>	$k_{\Delta}/k_{s}$	10 <sup>5</sup> k,	$-\text{HCOOH}_{10^{5k}\Delta}$	$k_{\Delta}/k_{\rm s}$	Rel. k∆ HCOOH
C <sub>6</sub> H <sub>5</sub> (CH <sub>2</sub> ) <sub>4</sub> OBs	1.00	1.00	1.37	$0.08^{a}$	0.06	2.78	0.65*	0.23	<b>1</b> .00°
m-CH <sub>3</sub> OC <sub>6</sub> H <sub>4</sub> (CH <sub>2</sub> ) <sub>4</sub> OBs	1.39	1.86	1.37	0.65	0.47	2.78	3.46	1.24	5.32
$3,4-(CH_{3}O)_{2}C_{6}H_{3}(CH_{2})_{4}OBs$	2.28	3.15	1.37	1.93	1.41	2.78	8.02	2.88	12.3
$3,5-(CH_3O)_2C_6H_3(CH_2)_4OBs$		6.24				2.78	18.1	6.51	27.9
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<sup>a</sup> Not apportioned between Ar<sub>1</sub>-5 and Ar<sub>2</sub>-6.

Formation of Tetralin.—The products of formolysis of 4-(3,5-dimethoxyphenyl)-1-butyl p-bromobenzenesulfonate (I) were examined in the usual way.<sup>3</sup> Reduction of the crude formolysis products with lithium aluminum hydride and chromatography on alumina yielded a minor alcohol fraction and a major more easily eluted fraction. The alcohol yielded a p-nitrobenzoate which was shown by mixed melting point to be the p-nitrobenzoate of the parent alcohol, 4-(3,5-dimethoxyphenyl)-1-butanol (III).

The major fraction was a colorless liquid, inert to potassium permanganate in acetone. Dehydrogenation of this material with chloranil<sup>7</sup> produced 1,3dimethoxynaphthalene (VI) which was characterized by mixed melting point of its picrate with the authentic material described previously.<sup>8</sup> Thus, the major solvolysis product was 5,7-dimethoxytetralin (V), the same substance obtained in formolysis of 4-(2,4-dimethoxyphenyl)-1-butyl *p*-bromobenzenesulfonate,<sup>8</sup> the isomer of I substituted so as to favor Ar<sub>1</sub>-5 participation.

The products observed in formolysis of the 4-(3,5-dimethoxyphenyl)-1-butyl derivative I agree closely with those predicted on the basis of the  $k_s$ and  $k_{\Delta}$  values in Table II, assuming  $k_s$  is associated with formation of formate II and  $k_{\Delta}$  associated with formation of tetralin V. As is clear from Table III, the observed per cent. tetralin in the product agrees within experimental error with the value, 100  $k_{\Delta}/(k_{\Delta} + k_s)$ , just as in the previous cases favoring Ar<sub>1</sub>participation.<sup>3</sup> The available facts, therefore, suggest that the formolysis of the 4-(3,5-dimethoxyphenyl)-1-butyl derivative I proceeds to the extent

(7) R. T. Arnold and C. J. Collins, THIS JOURNAL, 61, 1407 (1939).

of 12% by the anchimerically unassisted process leading to formate II, and to the extent of 88% by anchimerically assisted ionization. Anchimerically assisted ionization must be very predominantly



 $Ar_{2}-6$  in type, probably leading to an intermediate IV. Loss of a proton by IV leads to tetralin V.

TABLE I	Π
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Products of Formolysis of 4-(3,5-Dimethoxyphenyl)-1butyl p-Bromobenzenesulfonate at 75°<sup>a</sup>

Total yield, %	ко́н	% Tetralin	$\frac{100 \ k\Delta}{k\Delta + k_{\rm B}}$
87.5	12.0	88.0	86.6
° 0.0454 M R( 75,0°,	DBs; 0.0515	M NaOCHO;	12 hours at

Ar<sub>2</sub>-Participation and Ring Size. Comparison with Ar<sub>1</sub>.—The tendency for Ar<sub>2</sub>-7 participation in formolysis was assessed roughly by measuring relative rates of formolysis of 5-phenyl-1-pentyl and 5-(3,4-dimethoxyphenyl)-1-pentyl p-bromobenzenesulfonates. While the latter substance is substituted to favor both Ar<sub>2</sub>-7 and Ar<sub>1</sub>-6 participations, it was easily available, and its rate could be used to set an upper limit on the rate enhancement due to Ar<sub>2</sub>-7-participation. As is brought out in Table IV, any increase in rate due to 3,4-dimethoxyl substitution in the 5-phenyl-1-pentyl system is small. Consequently, the  $k_{\Delta}$  calculated on the assumption that  $k_s$  is equal to the rate constant of the 5-phenyl-1-pentyl ester is also small.

#### TABLE IV

Analysis of Rates of Formolysis of 5-Aryl-1-pentyl p - Bromobenzenesulfonates at  $75^\circ$ 

Compound	Rel. rate	10 <sup>5</sup> k <sub>s</sub>	10⁵ k∆	$k_{\Delta}/k_{s}$
$C_6H_5(CH_2)_5OBs$	1.00	3.39		
$3,4-(CH_{3}O)_{2}C_{6}H_{3}(CH_{2})_{5}-$				
OBs	1.03	3.39	0.11	0.03

As is brought out in Table V, the available data on relative rates of Ar<sub>2</sub>-assisted solvolysis suggest the sequence of ring sizes, 5 << 6 >> 7. With the  $\omega$ -aryl-1-alkyl bromobenzenesulfonates of the type reported in the present article, only Ar<sub>2</sub>-6 participation, not Ar<sub>2</sub>-5 or Ar<sub>2</sub>-7, has proved important.<sup>8</sup>

TARTE V

	110000 (			
<b>RELATIVE RATE</b>	s of Ar <sub>2</sub> -n F	ING CLO	OSURES	
Ar group	Solvent	Size of 5	ring beir 6	ng formed 7
$\omega$ -(3-Methoxyphenyl)	HOAc HCOOH	0.06ª	$\begin{array}{c} 1.00\\ 1.00\end{array}$	<0.04 <sup>b</sup>
ω-(3,5-Dimethoxy- phenyl)	нсоон	0.01°	1.00	

<sup>a</sup> Values calculated using the rate of 3-phenyl-1-propyl pbromobenzenesulfonate as  $k_s$ . <sup>b</sup> The value obtained from 5-(3,4-dimethoxyphenyl)-1-pentyl p-bromobenzenesulfonate.



 $Ar_2$  5 participation becomes important (P. Magee, unpublished work).

It is interesting that a maximum in rate is observed for n = 6 in the case of Ar<sub>2</sub>-participation, whereas the rate sequence observed<sup>3</sup> for Ar<sub>1</sub> was 5 >> 6. This contrast is relatively easy to understand by considering the transition states for the Ar<sub>1</sub>- and Ar<sub>2</sub>-assisted ionizations. These may be represented by VII and VIII, respectively, C<sub>1</sub> and C<sub>2</sub> denoting the respective carbon atoms of the neighboring phenyl group. The partial bonds between C<sub>a</sub> and the leaving group, and between C<sub>1</sub> or C<sub>2</sub> and C<sub>a</sub> in the transition state for the rate-determining step are symbolized by dotted lines. Also shown are the angles,  $\theta_{\alpha}$  and  $\theta_{G}$ .



In the transition states, the angle  $\theta_{\alpha}$  would have the value of 90° if the usual hybridization at  $C_{\alpha}$  is assumed. In order to estimate  $\theta_G$ , we should take into account the fact that the degree of involvement of the aryl group with  $C_{\alpha}$  is quite small. For Ar<sub>1</sub>, the low degree of involvement of aryl was clear from the relatively small effect of methoxyl substitution.<sup>3</sup> As is clear from Table II, methoxyl substitution has only a relatively small effect on rate in the case of  $Ar_2$  also. This low degree of involvement of phenyl in the transition state suggests a value of  $\theta_{\rm G}$  close to 90°, the approach of  $C_{\alpha}$  to  $C_1$  or  $C_2$  of the benzene ring being from a direction perpendicular to the plane of the benzene ring. Examination of models which employ a value of 90° for both  $\theta_{\alpha}$  and  $\theta_{\rm G}$  shows the transition state to be relatively strainless for  $Ar_{1}$ -5. However, it is quite strained in  $Ar_{2}$ -5, and becomes relatively comfortable when ring size is increased to Ar<sub>2</sub>-6.

Comparing rates of  $Ar_1$ - and  $Ar_2$ -assisted solvolysis, the available data show that rates are comparable for  $Ar_1$ -5 and  $Ar_2$ -6 for equal degrees of activation of the benzene ring with methoxyl groups. This comparison is shown explicitly in Table VI.

TADLE VI

	TUDDD AT		
Comparison of Ar1-5 A	ND Ar2-6 R	ING CLOS	URES AT 75°
Compound	Main participation type	10° k AcOH	(sec. <sup>-1</sup> ) HCOOH
$m-(CH_3O)C_6H_4(CH_2)_4OBs$	s Ar <sub>2</sub> -6	0.65	34.6
p-CH <sub>3</sub> OC <sub>6</sub> H <sub>4</sub> (CH <sub>2</sub> ) <sub>4</sub> OBs	Ar <sub>1</sub> -5	0.53	33.0
3,5-(CH <sub>3</sub> O) <sub>2</sub> C <sub>6</sub> H <sub>3</sub> (CH <sub>2</sub> ) <sub>4</sub> - OBs	Ar <sub>2</sub> -6		181
2,4-(CH <sub>3</sub> O) <sub>2</sub> C <sub>6</sub> H <sub>3</sub> (CH <sub>2</sub> ) <sub>4</sub> - OBs	Ar1-5	4.89	312

From this table it is evident that  $Ar_{1}$ -5 is slightly slower than  $Ar_{2}$ -6 in the case of mono-methoxylsubstituted neighboring phenyl. On the other hand,  $Ar_{1}$ -5 is faster than  $Ar_{2}$ -6 for di-methoxyl-substituted neighboring phenyl. An amusing consequence of this is that the rate of formation of the tetralin V is smaller by the more direct  $Ar_{2}$ -6 route from I than it is by the less direct  $Ar_{1}$ -5 route from 4-(2,4-dimethoxyphenyl)-1-butyl p-bromobenzenesulfonate.<sup>3</sup>

Since a maximum in rate occurs at the 5-ring for  $Ar_{1}$ - and the 6-ring for  $Ar_{2}$ -participation, and since Ar<sub>1</sub>-5-assisted ionization results in final formation of a six-membered ring, the present results help one understand the pronounced tendency toward closure of 6- rather than 5-membered rings in cyclode-hydrations and related reactions.<sup>9</sup> For neighboring vinyl rather than aryl, closure of 6-rings is similarly favored.10

An interesting compound, not yet commented on, whose solvolysis rate was investigated, is 4-(3,4dimethoxyphenyl)-1-butyl p-bromobenzenesulfonate. This material is substituted so as to favor both Ar<sub>1</sub>-5 and Ar<sub>2</sub>-6 participation. If both Ar<sub>1</sub>-5 and Ar<sub>2</sub>-6 participations were completely independent of each other, and if a second methoxyl (meta to the substitution spot) had no significant effect on rate, one could expect  $k_{\Delta}$  for the 3,4-dimethoxyl case to equal approximately the sum of the  $k_{\Delta}$  values for the 4-methoxyl and 3-methoxyl cases. Actually,  $k_{\Delta}$  for the 3,4-dimethoxyl case exceeds the calculated value. For example, in formic acid,  $k_{\Delta}$  is  $8.02 \times 10^{-5}$ sec. $^{-1}$ , as shown in Table II, while the calculated sum of the separate  $k_{\Delta}$  values is  $6.76 \times 10^{-5}$  sec.<sup>-1</sup>. The lack of agreement could conceivably be due to a rate-enhancing effect of a *meta* methoxyl group on either  $Ar_{1}$ -5 or  $Ar_{2}$ -6 or both. Such an effect is observed in bromination of the benzene ring.<sup>11</sup> However, it is doubtful that the Ar1-5 and Ar2-6 participation reactions in hand are sufficiently electron-demanding to bring forth a rate-enhancing response from a meta methoxyl group. For example, in Ar1-3 participation, which is even more electron-demanding than the present examples of  $Ar_{1}-5$  and  $Ar_{2}-6$ , a meta methoxyl is rate-retarding.5

It seems possible that Ar<sub>1</sub>-5 and Ar<sub>2</sub>-6 participations are not completely distinct in cases such as the 4-(3,4-dimethoxyphenyl)-1-butyl derivative. Whether  $C_{\alpha}$  is lodging onto  $C_1$  or  $C_2$  of the benzene ring, it seems likely that, in the transition state, there is some bonding interaction between  $C_{\alpha}$  and  $C_2$  in the case of Ar<sub>1</sub>-5 and between  $C_{\alpha}$  and  $C_1$  in the case of  $Ar_2$ -6.

### **Experimental Part**

3-m-Anisyl-1-propanol.-The reduction of m-methoxycinnamic acid<sup>12</sup> with lithium aluminum hydride by the usual method gave 3-m-anisyl-1-propanol, b.p. 135-140° (3.5 mm.), n<sup>25</sup>D 1.5339, in 57.5% yield. **3-(3,5-Dimethoxyphenyl)-propanoic Acid.**—To a solution of 3.6 g. of sodium metal in 200 ml. of anhydrous ethanol

was added 39 g. of ethyl malonate, followed by 20 g. of 3,5dimethoxybenzyl chloride.<sup>10</sup> After the historic off, and fluxed overnight, most of the alcohol was distilled off, and the residue was mixed with cold dil. hydrochloric acid. The product was extracted with ether. The extract was washed with water, and the solvent was evaporated. The residue

(10) E.g., (a) R. P. Linstead, A. B. Wang, J. H. Williams and K. P. Errington, J. Chem. Soc., 1136 (1937); (b) R. P. Linstead, A. H. Millidge and A. L. Walpole, *ibid.*, 1140 (1937). (11) P. B. D. de la Mare and C. A. Vernon, *ibid.*, 1764 (1951).

(12) S. N. Chakravarti, R. D. Haworth and W. H. Perkin, ibid., 2269 (1927).

(13) R. Adams, S. MacKenzie, Jr., and S. Loewe, THIS JOURNAL, 70, 666 (1948).

was refluxed for 4 hours with 25 g. of sodium hydroxide in 100 ml. of water and 50 ml. of ethanol. About 100 cc. of the solvent was distilled, and water was added to the residue. A trace of oil was extracted with ether and the aqueous solution was acidified. The crude malonic acid was heated to 150° until carbon dioxide evolution ceased, and then the product was distilled *in vacuo*. The acid, b.p. 177-178° (3 mm.), crystallized on standing. Recrystallization from a mixture of ether and petroleum ether gave 15.5 g. of material  $m_2$  50.61% (around 16.62%) rial, m.p. 59-61° (reported<sup>14</sup>61-62°). 3-(3,5-Dimethoxyphenyl)-1-propanol.—The reduction of

3-(3,5-dimethoxyphenyl)-propanoic acid with lithium alumi-num hydride gave the desired alcohol, b.p. 145–150° (3 mm.),  $n^{25}D$  1.5332, in 63% yield; the remainder of the un-reacted acid was recovered reacted acid was recovered.

Anal. Caled. for C<sub>11</sub>H<sub>16</sub>O<sub>2</sub>: C, 67.32; H, 8.22. Found: C, 66.83; H, 8.18.

The p-bromobenzenesulfonate of this alcohol was obtained as a viscous liquid,  $n^{25}$ D 1.5689, 93.3% pure as determined by equivalent weight measurements in acetic and formic acid,

by the low temperature procedure previously described.<sup>5</sup> 4-m-Anisyl-1-butanol.—This alcohol, b.p. 112° (0.5)mm.),  $n^{25}$ D 1.5260, was prepared in poor yield by the action of the Grignard reagent from 3-*m*-anisylpropyl chloride,

4-(3,4-Dimethoxyhenyl)-butanoic Acid.—The Clemmensen reduction of 3-(3,4-dimethoxybenzoyl)-propanoic acid4 gave 4-(3,4-dimethoxyphenyl)-butanoic acid, m.p. 56-58° after crystallization from a mixture of ether and pentane.

Anal. Caled. for C<sub>12</sub>H<sub>16</sub>O<sub>4</sub>: C, 64.27; H, 7.19. Found: C, 64.15; H, 6.99.

4-(3,4-Dimethoxyphenyl)-1-butanol.--The reduction of the above acid with lithium aluminum hydride gave impure 4-(3,4-dimethoxyphenyl)-1-butanol, b.p.  $155-157^{\circ}$  (3 mm.),  $n^{28}$ D 1.5343, in 30% yield. The remainder of the material

was unreacted acid. 2-(3,5-Dimethoxyphenyl)-ethyl Bromide.—A solution of 50 g. of lithium bromber and 35 g. of 2-(3,5-dimethoxy-phenyl)-ethyl p-bromobenzenesulfonats<sup>5</sup> in 500 cc. of pure acetone was refluxed for one hour. The acetone was dis-tilled off, the residue was dissolved in water, and the bromide was extracted with ether. The extracts were washed with water, dried and distilled. The bromide, b.p.  $125-128^{\circ}$  (1.5 mm.),  $n^{25}$ D 1.5573, m.p. 24-26°, weighed 20.5 g.

Anal. Calcd. for C10H13O2Br: C, 49.00; H, 5.34. Found: C, 49.03; H, 5.39.

4-(3,5-Dimethoxyphenyl)-1-butanol.—To a Grignard re-agent prepared from 20 g. of 2-(3,5-dimethoxyphenyl)ethyl bromide under dry nitrogen, an excess of ethylene oxide was added. The solution was refluxed for three hours and worked up with an ammonium chloride solution. Distillation gave 8 g. of forerun and 7 g. of still impure alcohol, b.p.  $162-168^{\circ}$  (2 mm.),  $n^{25}D$  1.5297,  $n^{25}D$  1.5290 after another distillation.

The residue from the above distillation could be distilled at high temperatures. Two recrystallizations from absolute ethanol yielded 2 g. of a substance, m.p. 100.5-101.5°, probably 1,4-di-(3,5-dimethoxyphenyl)-butane.

Anal. Caled. for C<sub>20</sub>H<sub>26</sub>O<sub>4</sub>: C, 72.70; H, 7.93. Found: C, 72.43; H, 7.63.

The *p*-nitrobenzoate of the above alcohol was prepared by the conventional pyridine method and chromatographed on alumina with 50% ether-pentane. Two recrystallizations from methanol gave the compound, m.p.  $65-66^\circ$ , in the form of small yellow needles. The mixed m.p. with 4-(2,4-di-methoxyphenyl)-1-butyl *p*-nitrobenzoate was  $44-51^{\circ}$ .

Anal. Calcd. for C<sub>19</sub>H<sub>21</sub>O<sub>6</sub>N: C, 63.50; H, 5.89. Found: C, 63.65; H, 5.57.

5-(3,4-Dimethoxyphenyl)-pentanoic Acid.—The Clem-mensen reduction of 4-(3,4-dimethoxybenzoyl)-butanoic acid<sup>§</sup> afforded a 50% yield of 5-(3,4-dimethoxyphenyl)-pentanoic acid. The substance, recrystallized twice from petroleum ether (b.p. 60-80°), formed colorless crystals, m.p. 75-76°

Anal. Calcd. for C<sub>13</sub>H<sub>18</sub>O<sub>4</sub>: C, 65.53; H, 7.61. Found: C, 65.79; H, 7.75.

5-(3,4-Dimethoxyphenyl)-1-pentanol.-A solution of 8 g. of the above acid in 400 ml. of ether was refluxed with 3 g. of

(14) A. H. Salaway, J. Chem. Soc., 97, 2412 (1910).

<sup>(9)</sup> E.g., (a) R. O. Roblin, Jr., D. Davidson and M. T. Bogert, THIS JOURNAL, 57, 151 (1935); (b) M. T. Bogert, Jr. and D. Davidson, ibid., 56, 185 (1934); (c) J. v. Braun and K. Weissbach, Ber., 64, 1785 (1931).

				Angive			
			Car	bon	Hyd	Hydrogen	
Compound	M.p., °C.	Formula	Calcd.	Found	Calcd.	- Found	
m-CH <sub>3</sub> OC <sub>6</sub> H <sub>4</sub> (CH <sub>2</sub> ) <sub>3</sub> OBs	36-38	$C_{16}H_{17}O_4SBr$	49.88	49.72	4.44	4.27	
m-CH <sub>3</sub> OC <sub>6</sub> H <sub>4</sub> (CH <sub>2</sub> ) <sub>4</sub> OBs	36-38	C17H19O4SBr	51.13	51.08	4.80	4.75	
$3,4-(CH_3O)_2C_6H_3(CH_2)_4OBs$	68-71	$C_{18}H_{21}O_5SBr$	50.35	50.65	4.93	4.80	
$3,5-(CH_{3}O)_{2}C_{6}H_{3}(CH_{2})_{4}OBs$	56 - 57	$C_{18}H_{21}O_5SBr$	50.35	50.20	4.93	4.83	
$3,4-(CH_{3}O)_{2}C_{6}H_{3}(CH_{2})_{5}OBs$	73 - 73.5	$C_{19}H_{23}O_5SBr$	51.47	51.19	5.23	4.99	

TABLE VII

#### PROPERTIES AND ANALYSES OF SOME *p*-BROMOBENZENESULFONATES

lithium aluminum hydride for 12 hours. The alcohol, b.p.  $160-163^{\circ} (2 \text{ mm.}), n^{25} \text{D} 1.5278$ , was a viscous colorless liquid weighing 5 g. A small sample was redistilled for analysis;  $n^{25} \text{D} 1.5272$ .

Anal. Calcd. for  $C_{13}H_{20}O_3$ : C, 69.61; H, 8.99. Found: C, 69.87; H, 8.78.

2-(3,4-Dimethoxyphenyl)-ethanol.—The reduction of 3,4dimethoxyphenylacetic acid with lithium aluminum hydride by the usual method afforded a 37% yield of alcohol, b.p.  $140-143^{\circ}$  (3 mm.), m.p.  $43-45^{\circ}$ .

Anal. Caled. for  $C_{10}H_{14}O_3$ : C, 65.91; H, 7.75. Found: C, 65.86; H, 7.75.

Preparation of Bromobenzenesulfonates and Kinetic Measurements.—The *p*-bromobenzenesulfonates of the various alcohols were prepared by the low temperature method described previously.<sup>5</sup> Physical properties and analyses of these derivatives are summarized in Table VII.

Kinetic measurements were carried out as described previously.<sup>6</sup>

Formolysis Products of 4-(3,5-Dimethoxyphenyl)-1-butyl p-Bromobenzenesulfonate.—A solution of 1.95 g. of the p-bromobenzenesulfonate was solvolyzed for ten hours at 75°

in a solution of 0.35 g. of sodium formate in 100 ml. of anhydrous formic acid. The resulting solution was diluted with 700 ml. of water and extracted with 500 ml. of petroleum ether in three portions. The extracts were washed with water and a sodium bicarbonate solution. The solvent was carefully distilled off, and the residue was reduced with 2 g, of lithium aluminum hydride.

2 g. of lithium aluminum hydride. The reduced product was chromatographed on 50 g. of alumina. The first fraction was eluted with 500 ml. of pentane. This solution contained 0.67 g. of 5,7-dimethoxy-tetralin, b.p. 100° (1.55 mm.), n<sup>25</sup>D 1.5452. This material was dehydrogenated with 2 g. of chloranil in boiling xylene as described previously.<sup>3,7</sup> The 1,3-dimethoxynaphthalene formed gave 0.35 g. of pure picrate, m.p. 140-141°, mixed m.p. with the picrate obtained from the corresponding solvolysis product from 4-(2,4-dimethoxyphenyl)-1-butyl p-bromobenzenesulfonate,<sup>3</sup> 140-141°.
A second fraction from the chromatography was eluted

A second fraction from the chromatography was eluted with 700 ml. of ether. There was obtained from this fraction 0.10 g. of alcohol,  $n^{25}$ D 1.5310, which formed 0.11 g. of a nitrobenzoate, m.p. 64.5-66°, mixed m.p. with 4-(3,5dimethoxyphenyl)-1-butyl nitrobenzoate, 65-66°.

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[CONTRIBUTION FROM THE INSTITUTE OF SCIENTIFIC AND INDUSTRIAL RESEARCH, OSAKA UNIVERSITY]

# Reactivities of Several ω-Substituted Primary Alkyl Bromides with Tertiary Amines<sup>1,2</sup>

## By Katsuhiko Akagi, Shigeru Oae<sup>3,4</sup> and Masuo Murakami

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Rate constants, heats of activation and entropies of activation have been determined for a series of reactions between  $\omega$ -substituted primary alkyl bromides and tertiary amines in two different solvents, *i.e.*, nitrobenzene and 50% ethanol. Alternation of reactivities was observed when nitrobenzene was used as a solvent, but no such phenomenon was observed when the solvent was 50% ethanol. The phenyl group showed little polar influence on the reactivities.

Our previous investigations<sup>5</sup> have been extended to the quaternization reactions of  $\omega$ -substituted primary alkyl bromides with tertiary amines in two different solvents, *i.e.*, nitrobenzene and 50% ethanol, with the thought that these quaternization reactions might give a different trend from those of the reactions of the same bromides with thiosulfate ion, since it has been suggested<sup>6</sup> that the polar characteristic of the quaternization reaction is quite different.

Many studies of the quaternization reaction of alkyl halides with tertiary amines have been reported and our present experiments were carried out

(1) Paper VI on "Relative Reactivities of Organic Halides in Displacement Reactions," Paper V, THIS JOURNAL, **78**, 4034 (1956).

(2) Presented at the 9th General Meeting of the Japanese Chemical Society, Kyoto, April, 1956.

(3) John Harrison Laboratory of Chemistry, University of Pennsylvania, Philadelphia 4, Pa.

(4) To whom requests for reprint may be addressed.

(5) K. Akagi, S. Oae and M. Murakami, THIS JOURNAL, **78**, 4034 (1956).

(6) C. K. Ingold, "Structure and Mechanism in Organic Chemistry," Cornell University Press, Ithaca, N. Y., 1953, p. 346. following the typical procedure used by Laidler and Hinshelwood<sup>7</sup> and later by Brown and Eldred.<sup>8</sup>

#### Experimental

The methods of preparations and purifications of all the organic halides have been described elsewhere.<sup>5</sup> The nitrobenzene was purified by partially freezing the fractionated material, which melted around  $5.0-5.7^\circ$ . The portions which melted from  $5.5-5.7^\circ$  were collected for use. Ethanol 50%, was made as reported in the previous paper.<sup>5</sup> Investigation of Products.—It is known that primary alkyl halides gives quaternary animonium salts in quantitation.

Investigation of Products.—It is known that primary alkyl halides gives quaternary ammonium salts in quantitative yield<sup>9</sup> and also that  $\beta$ -haloalkyl alcohols give quaternary ammonium chlorides in the reaction with trimethylamine.<sup>10</sup> No report has indicated any formation of olefin in the reaction of primary halide with tertiary amine.

In this study, the reaction products were investigated only in the case of  $\beta$ -bromoethyl ether in both 50% ethanol and in nitrobenzene, because among those studied kinetically this compound would be the most likely to give elimination products. The mixture of 1.53 g. of  $\beta$ -bromoethyl ethyl ether and 1.01 g. of triethylamine was placed in a 25-ml.

- (9) O. Westphal and D. Jerchel, Ber., 73B, 1002 (1940).
- (10) J. W. LeHeus, Arch. Pharm., 262, 570 (1924).

<sup>(7)</sup> K. J. Laidler and C. N. Hinshelwood, J. Chem. Soc., 858 (1938).

<sup>(8)</sup> H. C. Brown and N. R. Eldred, THIS JOURNAL, 71, 445 (1949).