amines show the same behavior as primary and secondary amines with *p*-nitrophenyl acetate,[3] suggests that the application of the "element effect" to these reactions in this way is not valid. Such a correlation shows only that the two compounds being compared have similar transition states for each individual reaction under consideration; if there is a change in the nature of the transition state with changing nucleophile (as there is in the reactions of oxyanions with *p*-nitrophenyl acetate), the correlation shows that this change takes place in a similar manner for both compounds.

It has been pointed out previously that the argument for rate-determining attack of strongly basic amines on phenyl acetate based on the observed products of the hydrolysis of phenyl N-methylacetimidate depends on the uncertain assumption that any tetrahedral intermediate be at equilibrium with respect to proton transfer steps and raises difficulties of interpretation for reactions of weakly basic tertiary amines.[3] The argument for rate-determining amine attack in reactions of phenyl acetates is, therefore, not conclusive, although we believe it is likely that such attack is involved in the rate-determining step of most such reactions. As noted above, this attack may be interpreted in terms of a more or less concerted mechanism, in which bond breaking is in some way coupled to bond making.

Intramolecular Nucleophilic Participation. VIII. Acetolysis of *o*- and *p*-Nitro- and *o*- and *p*-Carbophenoxybenzhydryl Bromides

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Abstract: In acetic acid, in the presence of sufficient sodium acetate to prevent accumulation of hydrogen bromide in the medium, *o*-nitrobenzhydryl bromide solvolyzes to form *o*-nitrosobenzophenone. When hydrogen bromide is present at moderate concentration, the solvolysis product is exclusively 5-bromo-3-phenyl-2,1-benzisoxazole. Solvolysis rate constants evaluated from the results of runs in which either hydrogen bromide or sodium acetate is initially present are in good agreement. This suggests that the alternate products are derived from a common intermediate formed in the slow step of the reaction. The reactions are considered to proceed with participation of the *o*-nitro group as an internal nucleophile, and this supposition is greatly strengthened by the observation that at 45° the acetolysis rate constant for the bromide in question is of the order of 1500 times that for its *para* isomer. At 45° the acetolysis rate constant for *o*-carbophenoxybenzhydryl bromide is *ca.* 150 times larger than that for its *para* isomer, and this is considered as indicative of the capacity of *o*-$COOC_6H_5$ to participate. The $k(ortho)/k(para)$ rate constant ratio for the acetolysis of *o*- and *p*-bromobenzhydryl bromides is of the order of 0.05–0.06 at 45°. This ratio may be used as a rough estimate of the magnitude of steric retardation to acetolysis of benzhydryl bromide as produced by a nonparticipating *ortho* substituent (Br).

The *o*-nitro- and *o*-carbophenoxybenzhydryl bromides hydrolyze significantly more rapidly than do their *para* isomers.[1,2] This is considered to be illustrative of the capacity of the *ortho* substituents in question to participate as internal nucleophiles in reactions at aromatic side chains. In the case of the reaction of *o*-nitrobenzhydryl bromide this explanation is strengthened by the observation that the organic hydrolysis product is *o*-nitrosobenzophenone. Also pertinent in this connection are the facts that *o*-nitrobenzhydrol is converted to the nitroso ketone by *p*-toluenesulfonyl chloride in pyridine and to 5-chloro-3-phenyl-2,1-benzisoxazole by thionyl chloride in chloroform.[3] Furthermore the bromine analog of this isoxazole derivative has been obtained as a product of reaction of *o*-nitrodiphenylmethane and N-bromosuccinimide.[2]

A study of the acetolysis of the nitro- and carbophenoxybenzhydryl bromides has been undertaken with two objectives in mind. First, the substances generated in the reaction of *o*-nitrobenzhydryl bromide have been investigated to determine whether or not the identity of the solvolysis product of this halide is affected by changes in acidity of the medium. It has, in fact, been found that the conditions can be altered so that either *o*-nitrosobenzophenone or 5-bromo-3-phenyl-2,1-benzisoxazole are obtained as the exclusive organic product of the reaction in acetic acid. Second, a comparison of the relative reactivities of each pair of the *ortho*- and *para*-substituted benzhydryl bromides has been made to test the premise that the solvolytic rate influence of a participating *ortho* substituent should become more obvious when an aqueous medium is replaced by one less favorably constituted to provide for nucleophilic solvation of carbon at the reaction center.

Experimental Section

Materials. The *o*- and *p*-nitrobenzhydryl bromides[2,4] and the *o*- and *p*-carbophenoxybenzhydryl bromides[1] were prepared as described previously. The method of preparation of *o*- and *p*-bromodiphenylmethanes has also been described elsewhere.[5] The *o*- and *p*-

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(1) A. Singh, L. J. Andrews, and R. M. Keefer, *J. Amer. Chem. Soc.* **84**, 1179 (1962).

(2) A. D. Mease, M. J. Strauss, I. Horman, L. J. Andrews, and R. M. Keefer, *ibid.*, **90**, 1797 (1968).

(3) W. B. Dickinson, *ibid.*, **86**, 3580 (1964).

(4) E. A. Jeffery, R. K. Bansal, L. J. Andrews, and R. M. Keefer, *J. Org. Chem.*, **29**, 3365 (1964).

(5) S. S. Friedrich, L. J. Andrews, and R. M. Keefer, *ibid.*, **35**, 744 (1970).

bromobenzhydryl bromides[6,7] were obtained through the reaction of *o*- and *p*-bromodiphenylmethanes, respectively, with N-bromosuccinimide in carbon tetrachloride solvent.

Reagent grade acetic acid (Baker and Adamson) was dried by refluxing it with acetic anhydride (1 ml of the anhydride/25 ml of the acid) for several hours. The acid recovered by distillation through a Widmer column was analyzed by the Karl Fischer method and found to contain no more than 0.01% water. J. T. Baker Chemical Co. hydrogen bromide was used to prepare acetic acid solutions of the hydrogen halide, and these were analyzed gravimetrically. Solutions of mercuric acetate, sodium bromide, and anhydrous sodium acetate were prepared from reagent grade samples of the salts.

Products and Rates of Acetolysis of *o*-Nitrobenzhydryl Bromide. The identification of the reaction products, as influenced by changes in reaction conditions, was accomplished primarily by spectrophotometry. Samples of *o*-nitrosobenzophenone and 5-bromo-3-phenyl-2,1-benzisoxazole obtained previously[2] were used in establishing the spectra of these substances in acetic acid. The former has its visible absorption peak at 765 mμ (ϵ 6060) and a peak at 270 (8600). The latter has absorptions at 249, 257, and 352 mμ with ϵ values, respectively, of 14,000, 17,250, and 14,700. At 352 mμ, ϵ for the nitroso ketone is 900. The parent *o*-nitrobenzhydryl bromide did not absorb significantly at the wavelengths at which measurements were made (352 and 765 mμ). Rate samples were contained in 1-cm absorption cells which were stored in the temperature-controlled housing of a Beckman DU spectrophotometer during the course of the measurements. Pure solvent was used in the blank cells.

Preliminary runs were made in which the optical densities of solutions of the bromide (1×10^{-1} *M*) in pure acetic acid were measured at 765 mμ as a function of time. The maximum absorption, which was reached in a few minutes at 45°, corresponded to the production of only a small amount of nitrosobenzophenone (of the order of 6–7%). This absorption then diminished gradually with time. The product solutions from several such runs were stored for several days and then combined and diluted with water. The resultant solution was extracted with ether, and the ether phase was washed and dried. The solid remaining after evaporation of the ether had an nmr spectrum (in CCl_4) which was identical with that of 5-bromo-3-phenyl-2,1-benzisoxazole. After recrystallization from methanol the isoxazole derivative had a melting point and mixture melting point with an authentic sample of 114–115°.

Additional pilot runs were conducted in which the optical densities of dilute (2×10^{-4} to 5×10^{-4} *M*) solutions of *o*-nitrobenzhydryl bromide in acetic acid were recorded at 352 mμ as a function of time. The formation of the isoxazole was subject to a period of induction which shortened as the initial concentration of the bromide increased (of the order of 13 min at 45° at an initial bromide concentration of 2×10^{-4} *M*). Reaction then proceeded to provide isoxazole, as calculated from final values of the optical density, in yields of the order of 90%.

The course of reaction of nitrosobenzophenone with HBr was followed by observing changes in the absorption (352 mμ) of the ketone (1×10^{-4} *M*) in acetic acid solutions of varying HBr content. At HBr concentrations ranging from 0.01 to 0.1 *M* quantitative conversion of the ketone to 5-bromo-3-phenyl-2,1-benzisoxazole was found to occur very rapidly at 25°. At 10^{-3} *M* HBr concentration a half-life of the order of 1 hr was observed for the reaction.

A series of rate runs at 25 and 45° were carried out in which the initial *o*-nitrobenzhydryl bromide concentration was of the order of 5×10^{-5} to 1.8×10^{-4} *M* and the acetic acid solvent contained HBr in 0.01 or 0.1 *M* concentration. Optical density measurements at 352 mμ were made during the course of the reactions, which were followed virtually to completion. Rate constants, *k*, for production of the bromophenylisoxazole, as defined by eq 1, were calculated from the slopes of straight lines obtained by plotting $\log (d_\infty - d_t)_{352\ \mathrm{m}\mu}$ *vs.* time, where d_∞ and d_t are optical densities at 352 mμ at completion of reaction and time *t*, respectively. Under these conditions no induction periods in the formation of the isoxazole were observed.

$$-\mathrm{d}[\mathrm{RBr}]/\mathrm{d}t = \mathrm{d}[\mathrm{isoxazole}]/\mathrm{d}t = k[\mathrm{RBr}] \qquad (1)$$

In another series of runs at higher initial concentrations of the substituted benzhydryl bromide ($\sim 10^{-2}$ *M*), sodium acetate (0.02–0.05 *M*) was included in the media in quantities in excess of the starting bromide. Under these circumstances the reaction product was the nitroso ketone. Optical density measurements were conducted at 765 mμ, and rate constants (eq 2) were calculated from the straight lines obtained by plotting values of $\log (d_\infty - d_t)_{765\ \mathrm{m}\mu}$ *vs.* time.

$$-\mathrm{d}[\mathrm{RBr}]/\mathrm{d}t = \mathrm{d}[\text{nitroso ketone}]/\mathrm{d}t = k[\mathrm{RBr}] \qquad (2)$$

In one run with 90 vol % acetic acid as the solvent the nitroso ketone was formed quantitatively. The rate constant was calculated from optical densities recorded at 765 mμ as described in the preceding paragraph. The nitroso ketone is actually converted to the isoxazole at a reasonably rapid rate in 0.1 *M* solutions of HBr in 90% aqueous acetic acid but only very slowly in 0.01 *M* HBr solutions. It was established through observation of the growth of the isoxazole absorption peak at 352 mμ that in solutions originally 5×10^{-5} *M* in nitroso ketone the half-life for the conversion is about 20 min at the former and 5700 min at the latter concentration of the hydrogen halide.

A more convenient method than that used previously[2] was devised to prepare solid *o*-nitrosobenzophenone. A solution of 0.144 g (4.93×10^{-4} mol) of *o*-nitrobenzhydryl bromide in 30 ml of a 0.05 *M* solution of sodium acetate in acetic acid was allowed to stand for 24 hr after preparation. It was then diluted with 3 vol of water and extracted with ether. The green ether phase was washed with dilute sodium hydroxide solution and dried. The solid remaining after removal of the ether was recrystallized from ethyl acetate to provide 0.053 g (51% yield) of the nitroso ketone, mp 126.5–127.5° (lit.[2] mp 127–128°).

Kinetics of Acetolysis of *p*-Nitro-, *o*- and *p*-Carbophenoxy, and *o*- and *p*-Bromobenzhydryl Bromides. A sample of the bromide in question was weighed into a volumetric flask, and the temperature of the flask was adjusted to the temperature of the rate run. Solvent which contained known quantities of sodium acetate and (in some cases) sodium bromide and which had been equilibrated to this same temperature was added to the mark. The contents of the flask were mixed and 5-ml samples were withdrawn from time to time. These were delivered into flasks containing 5 drops of bromophenol blue indicator, and the solutions were analyzed for excess acetate ion by titration with a standard solution of perchloric acid in acetic acid (0.02–0.03 *M*) to the colorless end point. When relatively reactive *o*-carbophenoxybenzhydryl bromide was used, the flasks into which rate samples were added were cooled prior to the addition. Concentrations of organic bromide at time *t* during the course of a run, $[\mathrm{RBr}]_t$, were calculated on the assumption that $[\mathrm{RBr}]_i - [\mathrm{RBr}]_t = [\mathrm{OAc}^-]_i - [\mathrm{OAc}^-]_t$ and solvolysis rate constants *k* (eq 3) were calculated from the slopes of plots of $\log (\mathrm{RBr})_t$ *vs.* time.

$$-\mathrm{d}[\mathrm{RBr}]/\mathrm{d}t = -\mathrm{d}[\mathrm{NaOAc}]/\mathrm{d}t = \mathrm{d}[\mathrm{NaBr}]/\mathrm{d}t = k[\mathrm{RBr}] \qquad (3)$$

The Product of Acetolysis of *o*-Carbophenoxybenzhydryl Bromide. A 1.5-g (0.00408 mol) sample of *o*-carbophenoxybenzhydryl bromide was dissolved in 100 ml of 0.05 *M* sodium acetate in dry acetic acid. The mixture was allowed to stand at 45° for 1 week. At the end of this time the acetic acid was removed under vacuum, and anhydrous ether was added to the solid residue. The undissolved salts were filtered off and the ether solution was concentrated by use of a rotary vacuum evaporator. The residue was recrystallized from mixed hexanes yielding white crystals identified as *o*-carbophenoxybenzhydryl acetate: mp 95–97°; nmr (CCl_4) δ 2.02 (s, 3, CH_3), 7.25 (m, 13, arom), 7.71 (s, 1, C*H*), and 8.04 ppm (m, 1, arom, *o* to C=O); ir (Nujol mull) 1715 cm^{-1} (C=O).

Anal. Calcd for $C_{22}H_{18}O_4$: C, 76.29; H, 5.25. Found: C, 76.26; H, 5.19.

Results

As outlined in detail in the Experimental Section, *o*-nitrobenzhydryl bromide reacts in dilute solution in acetic acid with the rapid conversion of a small fraction of the halide to *o*-nitrosobenzophenone (I). The quantity of the nitroso ketone in the mixture reaches a maximum value and then drops off with time. The major product of the acetolysis is 5-bromo-3-phenyl-2,1-benzisoxazole (II). Its formation is subject to an induction period which is associated with the accumulation in the medium of sufficient hydrogen

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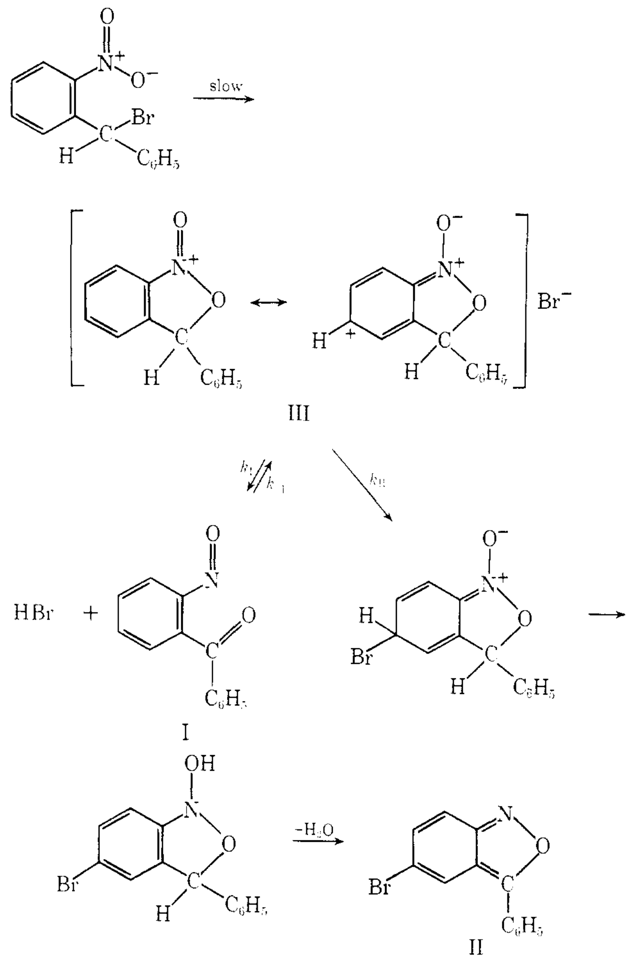
(6) H. G. Morren, S. Trolin, R. Denayer, E. Grivsky, and J. Maricq, *Bull. Soc. Chim. Belg.*, **60**, 282 (1961).

(7) *Chem. Abstr.*, 47, P 3882*f* (1953).

bromide—a product of the reaction leading to nitroso ketone formation—to change the identity of the product from I to II. When the acetolysis is conducted with hydrogen bromide initially present in the medium at a concentration substantially higher than that of the organic bromide, the isoxazole (II) is formed quantitatively. If sodium acetate is initially present in sufficient quantity to trap the generated hydrogen bromide, the organic product is exclusively the nitroso ketone (I). In dilute solutions of hydrogen bromide in acetic acid the nitroso ketone is converted to isoxazole at a rate which is very rapid when the hydrogen halide concentration is of the order of 0.01 *M*. These observations can be accounted for in terms of a reaction path in which the products I and II are generated from acetolysis of the parent bromide by way of a common intermediate (III) as shown in Scheme I.

Scheme I



The breakdown of III to nitroso ketone and hydrogen bromide is pictured as reversible, and the conversion of III to the isoxazole is depicted as irreversible. This is consistent not only with the shift of product from I to II as the hydrogen bromide content of the medium increases but also with the observed stability of the isoxazole with respect to decomposition of nitroso ketone in a solution of sodium acetate in acetic acid. Presumably the rate constant k_{I} is larger than k_{II}, and when acetate ion is present to deplete the system of free HBr and to assist in proton removal from III, nitroso ketone formation takes over as the dominant product-generating step.

It is possible, of course, that there is no common intermediate for I and II. That is, the *immediate* product of reaction may be nitroso ketone which then reacts rapidly with HBr, if present, to form II by a path not involving III. The results so far obtained actually do not provide evidence on which to decide whether reaction occurs by this process or the one discussed above.

The results of a kinetic study of the acetolysis of *o*-nitrobenzhydryl bromide are summarized in Table I. The rate constants for reactions in the presence of sodium acetate are in good agreement with those obtained from runs with hydrogen bromide present in the medium at the outset of reaction, as is to be expected if either of the pathways proposed above is followed.

In dilute solution in 90% aqueous acetic acid solvolysis of the bromide (0.02 *M* initially) occurs considerably more rapidly than in the water-free solvent, as is to be expected. In this case the product of reaction, like that for solvolysis of the halide in 90% aqueous acetone,[2] is the nitroso ketone. With water in the medium the reactivity of hydrogen bromide is sufficiently reduced through solvation so that conversion of the nitroso ketone to the isoxazole at low hydrogen bromide concentrations does not occur rapidly. Further details concerning the ease of formation of the isoxazole from the nitroso ketone in 90% aqueous acetic acid are given in the Experimental Section.

Rate constants for the acetolysis of *p*-nitro, *o*- and *p*-carbophenoxy, and *o*- and *p*-bromobenzhydryl bromides are summarized in Table II. At 45° the solvolysis constant for *o*-nitrobenzhydryl bromide is 67×10^{-5} sec^{-1} (Table I), a value which is 1450 times as large as that for *p*-nitrobenzhydryl bromide at the same temperature. At 25° this rate constant ratio, *k*(*ortho*)/*k*(*para*), is larger—approximately 3000 (see Table III). On the other hand the *k*(*ortho*)/*k*(*para*) rate constant ratio for the acetolysis of *o*- and *p*-bromobenzhydryl bromides is of the order of 0.05–0.06 at 45° (note that the reaction of the *para* isomer is subject to a small salt effect). This value may be used as a rough estimate of the magnitude of steric retardation to acetolysis of benzhydryl bromide as produced by a nonparticipating *ortho* substituent (Br). On this basis it can be concluded that at 45° *o*-nitrobenzhydryl bromide is of the order of 25,000–30,000 times as reactive as it would be if the nitro group were not capable of participation.[8] This is a much larger value than the *ortho*/*para* isomer reactivity ratios which have been observed (of the order of 100/1 or less when the steric factor is neglected) in connection with previous studies conducted in this laboratory of *ortho*-substituent participation in solvolyses of benzyl and benzhydryl halides in aqueous acetone or dioxane.[1,2,9] Apparently the influence of a nucleophilic *ortho* substituent in facilitating reaction through internal solvation of carbon at the reaction center during the

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(8) M. Hojo, T. Ichi, Y. Tamaru, and Z. Yoshida [*J. Amer. Chem. Soc.*, **91**, 5170 (1969)] have noted a rate enhancement of similar proportions, as produced by the *ortho* substituent in the acetolysis of *o*- and *p*-dithiacyclopentyl-substituted benzyl chlorides.

(9) For the two previous papers in this series, see (a) M. J. Strauss, L. J. Andrews, and R. M. Keefer, *J. Amer. Chem. Soc.*, **90**, 3473 (1968); (b) M. J. Strauss, I. Horman, L. J. Andrews, and R. M. Keefer, *J. Org. Chem.*, 33, 2194 (1968).

Table I. Rate Constants for the Acetolysis of *o*-Nitrobenzhydryl Bromide

$10^4[\mathrm{RBr}]_i$,[a] mol/l.	Medium	Temp, °C	10^5k_1, sec^{-1}	Product
0.507–1.78	HOAc, $[\mathrm{HBr}]_i$ = 0.01 *M*	25	8.4 ± 0.4	II
0.480–1.13	HOAc, $[\mathrm{HBr}]_i$ = 0.1 *M*	25	9.4 ± 0.7	II
			Av 8.9	
164	HOAc, $[\mathrm{NaOAc})_i$ = 0.02 *M*	25	9.0	I
49.6–153	HOAc, $[\mathrm{NaOAc}]_i$ = 0.05 *M*	25	9.5 ± 0.5	I
			Av 9.3	
0.904–0.972	HOAc, $[\mathrm{HBr}]_i$ = 0.01 *M*	45	64.8 ± 2.5	II
0.863–0.781	HOAc, $[\mathrm{HBr}]_i$ = 0.1 *M*	45	70.0 ± 2.5	II
			Av 67.4	
77.5–102	HOAc, $[\mathrm{NaOAc}]_i$ = 0.05 *M*	45	67.3 ± 2.3	I
205	90% aq HOAc v/v	25	69.0	I

[a] In most cases several runs were made, in which $[\mathrm{RBr}]_i$ was varied over the indicated range.

Table II. Rate Constants for Acetolysis of $C_6H_5CH(Br)C_6H_4X$

X	$[\mathrm{RBr}]_i$,[a] mol/l.	$[\mathrm{NaOAc}]_i$, mol/l.	$[\mathrm{NaBr}]_i$, mol/l.	Temp, °C	10^6k_1, sec^{-1}
p-NO_2	0.0216–0.0380	0.05		45.0	0.474 ± 0.013
p-NO_2	0.0107–0.0198	0.02		45.0	0.457 ± 0.002
p-NO_2	0.0164–0.0172	0.02	0.006	45.0	0.471 ± 0.002
					Av 0.467
p-NO_2	0.0108–0.0200	0.02		65.0	5.07 ± 0.02
p-$COOC_6H_5$	0.0158–0.0242	0.05		45.0	3.22 ± 0.02
p-$COOC_6H_5$	0.0109	0.02		45.0	3.20
p-$COOC_6H_5$	0.0111	0.02	0.006	45.0	3.24
					Av 3.22
o-$COOC_6H_5$	0.0153–0.0167	0.05		45.0	489 ± 1[b]
o-$COOC_6H_5$	0.0107	0.02		45.0	400[b]
o-$COOC_6H_5$	0.0099	0.02	0.006	45.0	134[b]
p-Br	0.0223–0.0296	0.05		45.0	67.0 ± 0.5
p-Br	0.0103–0.0196	0.02		45.0	56.6 ± 1.0
o-Br	0.0256	0.05		45.0	3.50
o-Br	0.0103–0.0207	0.02		45.0	3.28 ± 0.02
					Av 3.39

[a] With most of the bromides several runs were made, in which $[\mathrm{RBr}]_i$ was varied over the indicated range. [b] Initial rate constants. The slope of the plot of log [RBr] *vs. t* drifted downward significantly during the course of the run.

Table III. Activation Energies and Entropies for Acetolysis of Benzhydryl and *o*- and *p*-Nitrobenzhydryl Bromides [$C_6H_5CH(Br)C_6H_4X$]

X	Medium	10^5k_1, sec^{-1} (av) 25°	45°	65°	E_a, kcal/mol	$\Delta S^{\ddagger}$,[a] eu
o-NO_2	HOAc, $[\mathrm{HBr}]_i$ = 0.01–0.10 *M*	8.9	67		19	−15
o-NO_2	HOAc, $[\mathrm{NaOAc}]_i$ = 0.02–0.05 *M*	9.3	67		19	−16
p-NO_2	HOAc, $[\mathrm{NaOAc}]_i$ = 0.02–0.05 *M*	0.00312[b]	0.0467	0.507	25.5	−9.4
H[c]	HOAc, $[\mathrm{LiOAc}]_i$ = 0.068 *M*	1.67	18.3		22.6[d]	−6.6

[a] At 25°. [b] Calculated from value at 45°. [c] S. Winstein, A. H. Fainberg, and E. Grunwald, *J. Amer. Chem. Soc.*, **79**, 4146 (1957). [d] Calculated from the data reported in footnote *c*.

activation process is magnified as the medium becomes less suited to function as that solvating agent. Acetic acid is less effective than aqueous acetone or dioxane in providing for nucleophilic solvation in displacement processes.[10] It is also interesting that the *ortho–para* dissociation (eq 4) rate constant ratios for isomeric

$$O_2NC_6H_4ICl_2 \longrightarrow O_2NC_6H_4I + Cl_2 \qquad (4)$$

nitroiodobenzene dichlorides are of the order of 1000/1 in acetic acid at 25°, and a similar reactivity ratio has been reported for the *o*- and *p*-carbomethoxyiodobenzene dichlorides.[11] In these reactions iodine rather than carbon acquires positive charge during activation, and the polarization process is assisted by appropriately constituted nucleophilic *ortho* substituents.

The average rates and activation parameters for acetolysis of benzhydryl[12] and *o*- and *p*-nitrobenzhydryl bromides are summarized in Table III. The activation energy for the acetolysis of *o*-nitrobenzhydryl bromide is considerably less than that for its *para* isomer and for benzhydryl bromide. Also, the activation entropy for the *ortho*-substituted halide is much more negative than that for its *para* isomer and for benzhydryl bromide. These observations reflect the high degree of effectiveness of the *ortho* substituent as a participant in the acetolysis of *o*-nitrobenzhydryl bromide. It is also noteworthy that the rate of acetolysis of *o*-nitrobenzhydryl bromide is significantly greater than that of benzhydryl bromide under similar conditions. This is contrary to prediction, as based on

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(10) A. Streitweiser, Jr., "Solvolytic Displacement Reactions," McGraw-Hill Book Co., Inc., New York, N. Y., 1962.

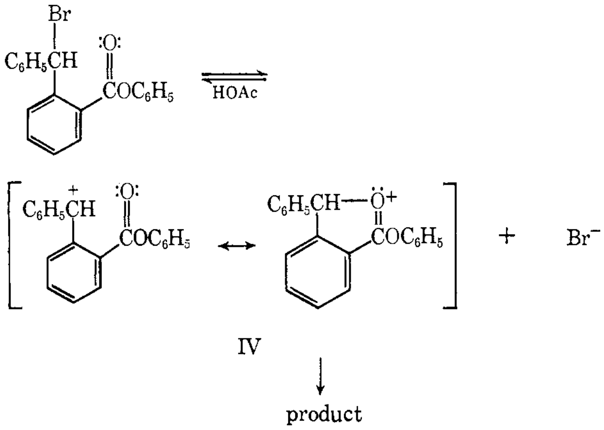
(11) (a) L. J. Andrews and R. M. Keefer, *J. Amer. Chem. Soc.*, **81**, 4218 (1959); (b) E. A. Jeffery, L. J. Andrews, and R. M. Keefer, *J. Org. Chem.*, **30**, 617 (1965).

(12) See Table III, footnote *c*.

a consideration of inductive and steric effects associated with the *o*-nitro substituent.

In the absence of added base (sodium acetate in this case) the acetolyses of *o*- and *p*-carbophenoxybenzhydryl bromides do not proceed to completion; rather an equilibrium is established. In a solution in which the initial concentration of either of the isomeric bromides is 0.010, this is attained at 45° when the hydrogen bromide content of the medium approximates 0.005 *M*. This is reminiscent of the behavior of *t*-butyl chloride in its reaction with acetic acid.[13]

A comparison of the reactivities of *o*- and *p*-carbophenoxybenzhydryl bromides in acetic acid (containing sodium acetate) is complicated by the fact that the observed rate constants for the *ortho* isomer exhibit a downward drift during the course of the reaction (Table II). This is attributed to common ion rate depression and is associated with the stabilizing influence of the participating *o*-carbophenoxy group on the reaction intermediate (IV). The extent of the common ion effect is readily magnified by the inclusion of sodium bromide in the starting reaction mixture (Table II). The acetolysis of *p*-carbophenoxybenzhydryl bromide, on the other hand, is not subject to common ion rate depression. Presumably this reaction proceeds by way of a carbonium ion which is much less stable than that involved in the acetolysis of the *ortho* isomer. The acetolyses of the *o*- and *p*-nitrobenzhydryl bromides are also not subject to common ion rate depression. In the case of *o*-nitrobenzhydryl bromide acetolysis, the product-forming processes—in which the intermediate III (either as an ion pair or a free cation) loses a proton to form nitroso ketone (I) or incorporates bromide ion at a ring position to form a precursor of the isoxazole (II)—apparently are much faster than the reaction in which a cationic intermediate is subject to reaction with external bromide to regenerate the starting material.



The rate constants reported in Table II for the acetolysis of *o*-carbophenoxybenzhydryl bromide in the presence of sodium acetate (and sodium bromide in one case) are the estimated initial rates. For these runs, in which the rate constants drifted downward during the course of reaction, the estimated initial rates were obtained by linear extrapolation of a plot of point-to-point rate constants (calculated using the integrated expression from eq 3) *vs.* percentage reaction. The data presented in Table II indicate that the *k*(*ortho*)/*k*(*para*) rate constant ratio for solvolysis of the carbophenoxybenzhydryl bromides is on the order of 120–150 at 45°. It appears that the reactivity ratio for these two halides is significantly less than that for the analogous nitrobenzhydryl bromides. This would seem to suggest that the *o*-carbophenoxy group is much less effective than an *o*-nitro substituent as a participant in the acetolysis of a substituted benzhydryl halide. No unequivocal statement can be made in this context, since no information is available at this point concerning the extent to which the acetolysis rate constant for each of the halides in question is affected by internal return processes in which an ion pair intermediate reverts to starting material.

Acknowledgment. The authors are indebted to the National Science Foundation for a grant in support of this research.

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[13] A. H. Fainberg and S. Winstein, *J. Amer. Chem. Soc.*, **78**, 2770 (1956).