The close similarity of the spectra of C_3X_6 (X = H or Cl) isomer pairs, like that of C_7H_8 isomers,[7,8] suggests that the isomers decompose under electron impact largely through common intermediates. In the case of the hydrocarbons, support for this suggestion can be drawn from evidence, based on appearance-potential measurements, that the $C_3H_5^+$ ion derived from cyclopropane does not have the cyclopropyl structure and is, in fact, the same chemical species as $C_3H_5^+$ ions derived from acyclic compounds.[9,10]

The differences between the spectra of isomers suggest that all or most of the $C_2X_4^+$ and part of the CX_2^+ are formed directly from parent ions with the original cyclopropane structure. The reactions involved presumably resemble the reverse of that by which hexachlorocyclopropane was synthesized. The differences between the spectra of chlorinated and unchlorinated species apparently reflect the greater difficulty of formation of C_3Cl_6 from, and lower stability with respect to, C_2Cl_4 and CCl_2 than of C_3H_6 with respect to C_2H_4 and CH_2. Such a view is in accord with the poor yield obtained by us in the synthesis of hexachlorocyclopropane and with chemical evidence indicating that CCl_2 is more stable than CH_2. For example, dichlorocarbene is easily generated by low-energy processes such as the reaction of base with chloroform[11] or thermal decomposition of sodium trichloroacetate[12]; preparation of methylene, on the other hand, requires photolysis of ketene or diazomethane.[13]

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[8] S. Meyerson, J. D. McCollum, and P. N. Rylander, *J. Am. Chem. Soc.*, **83**, 1401 (1961).

[9] F. H. Field, *J. Chem. Phys.*, **20**, 1734 (1952).

[10] R. F. Pottie, A. G. Harrison, and F. P. Lossing, *J. Am. Chem. Soc.*, **83**, 3204 (1961).

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Intramolecular Nucleophilic Participation. III. Transition State Geometry in the Hydrolysis of *o*- and *p*-Carbomethoxycumyl Chlorides

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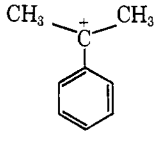
The solvolysis of *o*-carbophenoxybenzhydryl bromide takes place much more rapidly than does that of its *para* isomer.[1] The relatively high reactivity of the *ortho* isomer has been explained on the assumption that its carbophenoxy group can participate electronically in the activation process by releasing electrons to the vacant p-orbital developing at the reaction center. The *o*- and *p*-carbomethoxybenzyl bromides, on the other hand, solvolyze at comparable rates. Failure of the carbomethoxy group to participate effectively in the reaction of the *o*-substituted benzyl bromide has been explained[1,2] on the assumption that it is highly critical energetically for the development of positive charge on carbon at the reaction center that the p-orbital which is being vacated overlap the π electrons of the aromatic nucleus. For maximum overlap of this type the trigonal valences of the carbon atom in question must lie in the ring plane, an arrangement which is not favorable for effective participation by the carbomethoxy group.

The present investigation, in which the hydrolysis rates of cumyl chloride and its *o*- and *p*-carbomethoxy derivatives have been determined, has been conducted to ascertain whether or not it is also important for stabilization of the cumyl cation (I), which is tertiary in character, that the vacant p-orbital on the exocyclic carbon overlap the π molecular orbital of the ring.



I

A summary of the results of the rate runs is given in Table I. As should be characteristic of a solvolysis in which bond breaking, rather than bond making, is the dominant feature of the activation process,[3] the electron-withdrawing carbomethoxy substituent has been found to have a strong deactivating influence in cumyl chlo-

Table I

Rate Constants for Hydrolysis of the Substituted Cumyl Chlorides

$10^2[RCl]_i$ mole/l.	Solvent, % aqueous acetone[a]	Temp., °C.	$10^5 k_s$, sec.$^{-1}$
	Cumyl chloride $[C_6H_5C(CH_3)_2Cl]$		
5.00	80	25.0	103
9.56	85	25.0	68.8
1.76	90	25.0	15.0
11.3	90	25.0	14.4
16.6	90	25.0	14.5
	Av. k_s (90% aq. acetone)		14.6
	p-Carbomethoxycumyl chloride[b]		
3.69	70	25.0	4.68
8.06	70	25.0	4.65
10.8	70	25.0	3.68
	Av. k_s (25.0°)		4.34
3.86	70	36.0	19.0
7.66	70	36.0	14.8
8.36	70	36.0	14.9
	Av. k_s (36.0°)		16.2
	o-Carbomethoxycumyl chloride[c]		
3.04	70	25.0	11.3
3.94	70	25.0	11.0
6.65	70	25.0	9.2
	Av. k_s (25.0°)		10.5
4.04	70	36.0	36.8
4.45	70	36.0	33.6
	Av. k_s (36.0°)		35.2

[a] Prepared by mixing 100 − x volumes of acetone with x volumes of water to give (100 − x)% of aqueous acetone. [b] Values of E_a = 22 kcal./mole and ΔS^* = −7 e.u. have been calculated for *p*-carbomethoxycumyl chloride using the average k_s values at 25.0° and 36.0°. [c] Values of E_a = 19 kcal./mole and ΔS^* = −16 e.u. have been calculated for *o*-carbomethoxycumyl chloride using the average k_s values at 25.0° and 36.0°.

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

[2] R. E. Lovins, L. J. Andrews, and R. M. Keefer, *ibid.*, **84**, 3959 (1962).

[3] C. G. Swain and W. P. Langsdorf, Jr., *ibid.*, **73**, 2813 (1951).

ride hydrolysis (*cf.* k_s values for the substituted and unsubstituted halides). Evidence that *ortho* participation makes a dramatically significant contribution to the activation process for hydrolysis of *o*-carbomethoxycumyl chloride has not been found. Under comparable conditions the hydrolysis rate constant for the *o*-substituted halide is only twice that for the *para* isomer. Since in those cases in which the substituents are functionally incapable of participation the *o*-substituted benzyl,[1] cumyl,[4,5] and benzhydryl[1] halides are (probably because of unfavorable steric situations) generally somewhat less reactive than their *para* isomers,[1] it cannot be concluded that the *o*-COOR group makes no contribution as a neighboring group in the hydrolysis of *o*-carbomethoxycumyl chloride. It does, however, appear that the *o*-COOR group participates considerably more effectively in benzhydryl halide solvolysis than in cumyl halide solvolysis. Two possible explanations for this difference may be proposed on the grounds that a perpendicular orientation of the plane of the trigonal bonds to the exocyclic carbon atom with respect to the ring plane is not the most favored conformation for the cumyl cation (it is assumed in this discussion that the organic moiety of the transition state for hydrolysis of a cumyl halide is carbonium ion-like in character). Such a conformation provides for maximum *ortho* substituent participation.

It is proposed first that for maximum stabilization the vacant p-orbital of *o*-carbomethoxycumyl cation must indeed overlap the π orbital of the aromatic nucleus to a significant degree. In order that the plane of the trigonal valences of the exocyclic carbon of the latter ion fully coincide with the ring plane, the carboalkoxy group must, for steric reasons, be twisted somewhat out of the ring plane. The fact that *o*-carbomethoxycumyl chloride is somewhat more reactive than its *para* isomer may result, at least in part, because the carbomethoxy group of the *ortho* substituted halide is sterically prevented from entering the ring plane and thus cannot exert fully its electron-withdrawing effects on the polarization of the C–Cl bond.

Alternately it is proposed that the conformational situation in the *o*-carbomethoxycumyl cation is actually such as to provide for maximum electron release by the carbomethoxy group to the reaction center. If this is the case, the stabilizing effect thus produced by the carbomethoxy group must be canceled to a considerable degree by the loss of stability which results because under these circumstances the vacant p-orbital at the reaction center cannot overlap the π orbital of the aromatic nucleus.

Experimental

Methyl *o*- and *p*-Isopropylbenzoates.—A sample of Eastman Organic Chemicals *p*-isopropylbenzoic acid was converted to the acid chloride by refluxing for 4 hr. with thionyl chloride. The excess thionyl chloride was removed by distillation, and the residue was added dropwise to methanol. The resulting solution was refluxed for 30 min. and then distilled to obtain methyl *p*-isopropylbenzoate, b.p. 124° (16 mm.), $n^{25}\text{D}$ 1.5080.

Anal. Calcd. for $C_{11}H_{14}O_2$: C, 74.13; H, 7.92. Found: C, 74.49; H, 7.70.

To prepare methyl *o*-isopropylbenzoate, cumene was first nitrated by the procedure of Brown and Bonner,[6] and the *o*- and *p*-nitrocumenes were separated by fractionation at reduced pressure. The *p*-nitrocumene, b.p. 127° (12.5 mm.), thus obtained was converted to 2-bromo-4-nitrocumene, b.p. 166–172° (26 mm.), by treatment with bromine in the presence of silver sulfate.[7] The 2-bromo-4-nitrocumene was reduced to the corresponding amine, b.p. 175–178° (48 mm.), and the latter was deaminated by treatment of its diazonium salt with hypophosphorus acid,[7] to provide *o*-bromocumene, b.p. 104–110° (22.5 mm.), $n^{26}\text{D}$ 1.5398. This was converted to *o*-isopropylphenylmagnesium bromide by reaction with magnesium, activated with iodine, in tetrohydrofuran, and the Grignard reagent was carbonated[4] to provide *o*-isopropylbenzoic acid, m.p. 61–64° (lit.[4] m.p. 63–64°). The acid was converted to methyl *o*-isopropylbenzoate, b.p. 114–115° (16 mm.), $n^{25}\text{D}$ 1.5065, by the same procedure used in esterifying its *para* isomer.

Anal. Calcd. for $C_{11}H_{14}O_2$: C, 74.13; H, 7.92. Found: C, 74.60; H, 7.88.

Preparation of the Cumyl Chlorides by Photochlorination.—Cumene and methyl *o*- and *p*-isopropylbenzoates undergo photochlorination rapidly in carbon tetrachloride. All attempts which have been made to isolate pure samples of the carbomethoxycumyl chlorides from the crude photochlorination products of the esters have been unsuccessful. Like other substituted cumyl chlorides[4] these are highly unstable (with respect to the loss of hydrogen chloride) in the pure state. A procedure has, therefore, been developed for preparing crude samples of cumyl chloride and its carbomethoxy derivatives by photochlorination of cumene, or its substitution products, with considerably less than a molar equivalent of chlorine (to avoid formation of polychlorination products). Generally a substantial amount of chlorine was lost by volatilization during the photochlorination process. As documented later in more detail, a sample of cumyl chloride prepared in this way was essentially identical, insofar as solvolysis rate was concerned, with another sample prepared from phenyldimethylcarbinol and hydrogen chloride.

A typical preparation of a sample for rate work, using methyl *o*-isopropylbenzoate as starting material, is described. A 9.0-g. (0.051 mole) sample of the ester was cooled to 0°, and 25 ml. of a solution of 1.76 M chlorine in carbon tetrachloride (established by iodometric analysis) was added dropwise to the ester with stirring. The mixture was irradiated simultaneously in a manner similar to that used for photobromination of substituted toluenes.[8] When addition of the chlorine solution was complete, the solvent was removed over a 1-hr. period at room temperature using a rotary film evaporator. The residue contained traces of carbon tetrachloride, removable only by prolonged evaporation, a procedure which was avoided because of possible decomposition of the substituted cumyl chloride.

To initiate a rate run a 5.04-g. sample of the colorless residue was diluted to 50.0 ml. with 70% aqueous acetone. A 5.00-ml. sample of this solution was dissolved in 75 ml. of aqueous ethanol, and the resultant solution was immediately analyzed for chloride by the addition of 5.00 ml. of 0.1 N standard silver nitrate solution followed by back titration with standard 0.1 N potassium thiocyanate according to the usual Volhard procedure. Assuming that tertiary chlorides, but not primary or secondary chlorides, are rapidly solvolyzed, in 80% aqueous ethanol[9] under these conditions, the initial concentration of *o*-carbomethoxycumyl chloride in the aqueous acetone solution was calculated as $6.65 \times 10^{-2}\,M$.

The Rate Runs with the Cumyl Chlorides.—Aqueous acetone solutions were prepared from the crude photochlorination product as described in the preceding paragraph. Samples (5 ml.) of these rate mixtures were removed from time to time and shaken with mixtures of water and ether. The chloride contents of the aqueous phases were determined by the addition of 5 ml. of 0.1 N silver nitrate followed by back titration with 0.1 N potassium thiocyanate solution using the standard Volhard procedures. Other details of the kinetic experiments, including the purification of solvents, were much the same as those of earlier experiments on the solvolysis of benzyl and benzhydryl bromides.[1]

The solvolysis rate constants, k_s, as defined in equation 1

$$-d[\mathrm{RX}]/dt = k_s[\mathrm{RX}] \qquad (1)$$

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(4) H. C. Brown, J. D. Brady, M. Grayson, and W. H. Bonner, *J. Am. Chem. Soc.*, **79**, 1897 (1957).

(5) H. C. Brown, Y. Okamoto, and G. Ham, *ibid.*, **79**, 1906 (1957).

(6) H. C. Brown and W. H. Bonner, *ibid.*, **76**, 605 (1954).

(7) M. Crawford and F. H. C. Stewart, *J. Chem. Soc.*, 4443 (1952).

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(9) G. A. Russell and H. C. Brown, *J. Am. Chem. Soc.*, **77**, 4025 (1955) .

were calculated from the slopes of plots log $([v_i - v_\infty]/[v_t - v_\infty])$ *vs.* time, where v is the volume of standard potassium thiocyanate solution used in the Volhard analysis of rate samples and the subscripts, i, t, and ∞, apply, respectively, to samples taken at the outset of reaction, at time t and at infinite reaction time. These plots generally were linear to at least 80% of completion of the reactions, and the analysis for chloride ion at infinite reaction time checked well with the analysis for tertiary chloride at the outset of reaction (see preceding).

Two sets of check experiments were conducted to establish the validity of rate constants obtained in runs with unpurified samples of the carbomethoxycumyl chlorides (obtained by the photochlorination procedure) as comparative measures of the relative reactivities of the tertiary halides. In the first case a pure sample of cumyl chloride was prepared from phenyldimethylcarbinol and hydrogen chloride[4] and its solvolysis rate in 90% aqueous acetone at 25° was compared with that of a crude sample prepared by photochlorination of cumene in an over-all procedure similar to that described for the runs on the carbomethoxycumyl chlorides. The k_s values for these two samples were respectively 14.5×10^{-5} sec.$^{-1}$ and 15.1×10^{-5} sec.$^{-1}$.

The second check experiment was designed to determine the possible influence of unphotochlorinated cumenes and of traces of carbon tetrachloride solvent on solvolysis rate constants evaluated in rate runs using crude samples of the cumyl chlorides (prepared by the photochlorination procedure described earlier). A sample of cumyl chloride, prepared from phenyldimethylcarbinol and hydrogen chloride, was used in making a rate run (25°) in which the initial concentrations of materials in 90% aqueous acetone solution were 0.113 M cumyl chloride, 0.590 M carbon tetrachloride, and 0.31 M cumene. The k_s value for this run was 14.4×10^{-5} sec.$^{-1}$

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Nucleophilic Substitution at the Pyridazine Ring Carbons. II. Synthesis of Pyridazinonyl- and Bispyridazinonylpyridazines[1,2]

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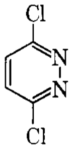
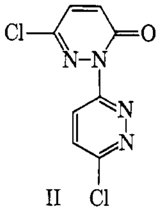
While preparing 3,6-dichloropyridazine (I), Druey and co-workers[3] isolated a small amount of another compound which on the basis of analytical, molecular weight, and infrared data was assigned the structure 3-(3′-chloro-6′(1′*H*)-pyridazinonyl)-6-chloropyridazine (II).

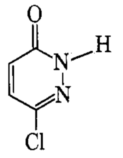

I

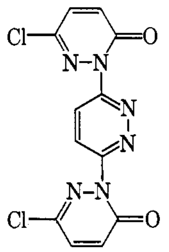

II

Feuer and Rubenstein[4] published experimental details for obtaining this product in small yield (less than 11%) by means of a long and tedious process.

Since compound II would be a starting material with interesting possibilities for synthetic work, possessing two halogens with strikingly different activities toward substitution, a search was undertaken in this laboratory for a synthetic route for preparation of this compound from readily obtainable materials.

The approach to this goal was to accomplish a nucleophilic displacement of one of the halogens of compound I using 6-chloro-3-(2*H*)-pyridazinone (III) as the nucleophile. It is of interest to note the difference of activity toward nucleophilic substitution of the chloro atom in compound III and the chloro atoms in compound I. Actually, compound III is prepared by boiling compound I in 3 *N* sodium hydroxide[5] or in 10% hydrochloric acid.[6] Once the pyridazinone is formed, the remaining chloro atom is stable toward nucleophilic attack by these reagents. Since attempts to synthesize II in an aqueous media failed,[3,4] different solvents were tested, such as xylene, tetrahydronaphthalene, and dichloropyridazine, the latter being the most successful. With a molar ratio of dichloropyridazine to 6-chloro-3(2*H*)-pyridazinone of 2:1, yields averaging 66% of compound II were obtained. In addition, a small amount (about 11%) of a higher melting compound was obtained which differed markedly in physical properties and solubility from compound II. Elemental and spectral analysis suggest the formation of a bispyridazinonylpyridazine, compound IV.


III


IV

By changing the molar ratio of 3,6-dichloropyridazine to 6-chloro-3(2*H*)-pyridazinone from 2:1 to the reverse ratio, 1:2, a 75% yield of compound IV was obtained. Compound IV was also prepared by heating compound II with excess compound III. It is of interest to note that compound III is stable at temperatures well over 200° and does not react with itself. Thus, the nucleophilic attack on compound II clearly occurs at the pyridazine ring carbon to give compound IV.

This method was used successfully to prepare 3-(6′(1′*H*)-pyridazinonyl)-6-chloropyridazine (V) and 3,-6-bis(6′(1′*H*)-pyridazinonyl)pyridazine (VI). 3,6-Dichloropyridazine (I) was condensed with 3(2*H*)pyridazinone (VII) in the preceding manner. Compound VII forms an extremely stable hydrate.[7] Anhydrous VII was prepared previously by decarboxylation[8,9] of carboxy-3(2*H*)-pyridazinone or by hydrogenation of 4,5-dichloro-3(2*H*)-pyridazinone[12] with isolation according to special techniques described by Eichenberger

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(1) Presented before the Pacific Southwest Regional Meeting of the American Chemical Society, December 1, 1962.

(2) For paper I, see P. Coad, R. A. Coad, S. Clough, J. Hyepock, R. Salisbury, and C. Wilkins, *J. Org. Chem.*, **28**, 218 (1963).

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