column was washed with aqueous ethanol until the eluate was free from chloride ion. After this the column was washed with 5% aqueous ammonium hydroxide solution and the ammoniacal eluate evaporated. The crude 2-amino-1-hydroxycyclohexanecarboxylic acid melted at 287–288° dec.; yield, 0.2 g. (78%). One crystallization from methanol raised the melting point to a constant value of 294–295° dec.; yield, 0.16 g.

Anal. Calcd. for $C_7H_{13}NO_3$: C, 52.81; H, 8.23; N, 8.81. Found: C, 53.01; H, 8.03; N, 8.78.

The residue from the pentane extract on treatment with 2,4-dinitrophenylhydrazine in methanol–hydrochloric acid under the conditions previously described gave a 77% yield of cyclohexanone 2,4-dinitrophenylhydrazone (m.p. 159–160°). This product was identified by a mixture melting point determination.

Hydrolysis of Spiro[4′-methylcyclohexane-1′,2-6-methyl-8-carbamyl-2(*H*)-3,9,4,5,6,7-hexahydrobenzo-1,3-oxazole].—Spiro[4′-methylcyclohexane-1,2-6-methyl-8-carbamyl-4,5,6,7-tetrahydrobenzo-1,3-oxazole] was hydrolyzed under the conditions described earlier for the hydrolysis of spiro[cyclohexane-1′,2-8-carbamyl-2(*H*)-3,9,4,5,6,7-hexahydrobenzo-1,3-oxazole]. The pentane extract residue on treatment with 2,4-dinitrophenylhydrazine reagent gave a 57% yield of 4-methylcyclohexanone 2,4-dinitrophenylhydrazone (m.p. 132–133°). This product was identified by a mixture melting point determination.

The acidic aqueous solution from the pentane extract was evaporated to dryness and the residue in aqueous ethanol was added to a Dowex 50-WX2 resin. 2-Amino-1-hydroxy-5-methylcyclohexanecarboxylic acid (m.p. 279–280° dec.) was isolated in 56% yield in the same manner described before for the isolation of 2-amino-1-hydroxycyclohexanecarboxylic acid. One recrystallization from methanol–ether solution raised the melting point to 288–289° dec.

Anal. Calcd. for $C_8H_{15}NO_3$: C, 55.48; H, 8.73; N, 8.09. Found: C, 55.66; H, 8.76; N, 8.14.

Solvent Effects. The Solvolysis Rates of Cyclopropylcarbinyl, 1-Methylcyclopropylcarbinyl, and 1-Phenylcyclopropylcarbinyl Arenesulfonate Derivatives

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The benzene-, *p*-methoxybenzene-, and *p*-toluenesulfonate derivatives of cyclopropylcarbinol (Ia–c), 1-methylcyclopropylcarbinol (IIa–c), and 1-phenylcyclopropylcarbinol (IIIa–c) have been solvolyzed in acetic acid at various temperatures. The relative first-order rates of acetolysis at 20° were found to be $k_{Ib} = 1$, $k_{IIb} = 4$, and $k_{IIIb} = 1.6$. The activation energy parameters for Ia–c differed greatly from those for IIa–c or IIIa–c and similarly Ib exhibited a different sensitivity to solvent ionizing strength. The β-substituent effects, differences in activation energy parameters, sensitivities to solvent ionizing strength, and solvolysis products of these arenesulfonates are discussed in terms of solvated transition state differences.

The observation that a phenyl substituent at the 1-ring position in cyclopropylcarbinyl benzenesulfonate produced no significant rate acceleration in an acetolysis reaction[1] led to a more detailed study of this phenomenon. It was of particular interest to determine the activation energy parameters for the acetolysis of cyclopropylcarbinyl arenesulfonate compounds. Such information would assist in a mechanistic diagnosis of the apparent lack of a substituent effect. In addition, the sensitivity of the solvolytic reactions of both cyclopropylcarbinyl and 1-phenylcyclopropylcarbinyl arenesulfonate derivatives to solvent ionizing strength and arenesulfonate leaving group were determined.

The kinetic data are summarized in Table I. Each of these esters was allowed to solvolyze in the indicated solvent and the course of reaction followed by titrating the liberated arenesulfonic acid. The acetolysis reactions of the cyclopropylcarbinyl arenesulfonates demonstrated the previously reported "internal return" rearrangement[2] which accounted for about one-third of the starting material. The solvolysis rates, consequently, of Ia–c were calculated from the initial slope of the rate curves.[3] All other reactions were strictly first order in arenesulfonate and furnished, within experimental error, 100% of the theoretical amount of acid present.

Table II compares the relative rates of acetolysis of three cyclopropylcarbinyl 1-methyl- and 1-phenylcyclopropylcarbinyl arenesulfonates at 20° with the relative rates of acetolysis of correspondingly substituted acyclic *p*-toluenesulfonates at 75°. It can be seen that, in the acetolysis of the cyclopropylcarbinyl esters, the rate-enhancing abilities of the methyl and phenyl groups are in distinct contrast to their effectiveness in the acetolysis of the acyclic analogs. This apparent lack of β-substituent effect is further emphasized by the fact that 1-methylcyclopropylcarbinyl chloride suffers solvolysis in 50 vol. % aqueous ethanol at 50°, some fifty times faster than cyclopropylcarbinyl chloride.[6]

Although the free energy of activation is similar for Ia–c, IIa–c, and IIIa–c, the partitioning of the thermodynamic functions of activation is markedly different for Ia–c in respect to IIa–c or IIIa–c. That the functions under discussion represent real differences and not random error is shown by the constancy of the data with the three different leaving groups.[7] While

(1) J. W. Wilt and D. D. Roberts, *J. Org. Chem.*, **27**, 3430 (1962).

(2) M. C. Caserio, W. H. Graham, and J. D. Roberts, *Tetrahedron*, **11**, 171 (1960).

(3) S. Borcic, M. Nikoletic, and D. E. Sunko, *J. Am. Chem. Soc.*, **84**, 1615 (1962).

(4) S. Winstein and H. Marshall, *ibid.*, **74**, 1120 (1952).

(5) S. Winstein, B. K. Morse, E. Grundwald, K. C. Schreiber, and J. Corse, *ibid.*, **74**, 113 (1952).

(6) E. F. Cox, M. C. Caserio, M. S. Silver, and J. D. Roberts, *ibid.*, **83**, 2719 (1961).

(7) The activation energy parameters for IIIa and IIIb previously were reported[1] on the basis of a three-point regression analysis over 12° and 15° temperature ranges, respectively. Fivefold replication of this work in the present study over 17° and 20° temperature ranges, respectively, revealed that the reported rate constant[1] for the acetolysis of IIIa at 18° was sufficiently displaced from the calculated regression line (20% low) to produce an erroneously high slope value. Also, the reported rate constant[1] for IIIb at 25° was sufficiently displaced from the calculated regression line (28% low) to produce an erroneously low slope value. Due to the few points over a limited temperature range, this error did not show up as significant in the regression analysis. Correlation coefficients of 0.999 were obtained in the present study for both IIIa and IIIb. The *t*-test gave $t = -134.3$, with 42 degrees of freedom, $P < .005$ for IIIa and $t = -239.0$, with 41 degrees of freedom, $P < .005$ for IIIb.

TABLE I

SUMMARY OF SOLVOLYSIS RATES

Arenesulfonate	Solvent	Temp., °C.	$k_1 \times 10^4$ sec.$^{-1}$
Cyclopropylcarbinyl arenesulfonates			
Benzenesulfonate (Ia)	AcOH	15.0	1.25 ± 0.09
		20.0	2.17 ± 0.08[a]
		25.0	3.45 ± 0.08
		30.0	5.43 ± 0.08
p-Toluenesulfonate (Ib)	AcOH	15.0	0.77 ± 0.10
		20.0	1.28 ± 0.08
		25.0	2.20 ± 0.09
		30.0	3.38 ± 0.07
	EtOH[b]	20.0	0.32 ± 0.01
		30.0	1.17 ± 0.03
		40.0	3.34 ± 0.02
	80% EtOH	20.0	11.33 ± 0.07
	MeOH	20.0	1.35 ± 0.02
p-Methoxybenzenesulfonate (Ic)	AcOH	20.0	0.92 ± 0.09
		25.0	1.38 ± 0.04
		30.0	2.40 ± 0.04
		35.0	3.83 ± 0.07
1-Methylcyclopropylcarbinyl arenesulfonates			
Benzenesulfonate (IIa)	AcOH	10.0	3.27 ± 0.10
		20.0	9.84 ± 0.05
		25.0	19.18 ± 0.20
p-Toluenesulfonate (IIb)	AcOH	15.0	2.88 ± 0.10
		18.0	4.12 ± 0.10
		20.0	5.06 ± 0.10
		25.0	10.38 ± 0.08
		30.0	16.67 ± 0.01
p-Methoxybenzenesulfonate (IIc)	AcOH	15.0	2.00 ± 0.07
		20.0	3.67 ± 0.10
		25.0	6.66 ± 0.10
		30.0	11.68 ± 0.15
1-Phenylcyclopropylcarbinyl arenesulfonates			
Benzenesulfonate (IIIa)	AcOH	13.0	1.10 ± 0.06[c]
		15.0	1.48 ± 0.02
		20.0	2.65 ± 0.03
		25.0	5.30 ± 0.09[d]
		30.0	9.17 ± 0.10
p-Toluenesulfonate (IIIb)	AcOH	15.0	1.03 ± 0.02
		18.0	1.53 ± 0.01[e]
		20.0	2.00 ± 0.03
		25.0	3.67 ± 0.05
		30.0	6.60 ± 0.03
	EtOH[e]	30.0	0.97 ± 0.04
		40.0	3.57 ± 0.10
		50.0	12.00 ± 0.15
	80% EtOH	20.0	6.17 ± 0.07
	MeOH	20.0	1.42 ± 0.03
p-Methoxybenzenesulfonate (IIIc)	AcOH	18.0	0.93 ± 0.01
		20.0	1.19 ± 0.01
		25.0	2.35 ± 0.02
		30.0	4.08 ± 0.08
p-Isopropylbenzenesulfonate (IIId)	AcOH[f]	20.0	1.78 ± 0.02
		25.0	3.30 ± 0.03
		30.0	5.67 ± 0.06
		35.0	10.00 ± 0.09
p-*t*-Butylbenzenesulfonate (IIIe)	AcOH[g]	20.0	1.75 ± 0.02
		30.0	5.60 ± 0.10
		35.0	10.00 ± 0.03

[a] Compares with a value of 2.19 × 10^{-4} sec.$^{-1}$ reported by Borcic, *et al.*[3]. [b] $\Delta H^* = 21.0$ kcal./mole, $\Delta S^* = -7.7$ e.u. [c] *Cf.* ref. 1. [d] Compares with previously reported[1] value of 6.18 × 10^{-4} sec.$^{-1}$. [e] $\Delta H^* = 23.9$ kcal./mole, $\Delta S^* = 1.8$. [f] $\Delta H^* = 20.6$ kcal./mole, $\Delta S^* = -5.5$ e.u. [g] $\Delta H^* = 20.5$ kcal./mole, $\Delta S^* = -6.6$ e.u.

TABLE II

RELATIVE RATES, ENTHALPIES, AND ENTROPIES OF ACTIVATION OF CYCLOPROPYLCARBINYL, 1-METHYLCYCLOPROPYLCARBINYL, AND 1-PHENYLCYCLOPROPYLCARBINYL ARENESULFONATES

(R, *p*-X-Benzenesulfonates)

R	X	Rel. rate, 20°	ΔH^*, kcal.[a]	ΔS^*, e.u.[b]
Cyclopropylcarbinyl	-H	1.0	16.3	−19.7
1-Methylcyclopropylcarbinyl	-H	4.5	19.0	−5.4
1-Phenylcyclopropylcarbinyl	-H	1.2	20.8	−4.0
Cyclopropylcarbinyl	$-CH_3$	1.0	16.7	−19.0
1-Methylcyclopropylcarbinyl	$-CH_3$	4.0	20.1	−5.2
1-Phenylcyclopropylcarbinyl	$-CH_3$	1.6	21.0	−4.2
Cyclopropylcarbinyl	$-OCH_3$	1.0	16.7	−20.0
1-Methylcyclopropylcarbinyl	$-OCH_3$	4.0	20.1	−5.6
1-Phenylcyclopropylcarbinyl	$-OCH_3$	1.3	20.9	−4.4
Isobutyl	$-CH_3$	1.0[c]	28.2	−8.0
Neopentyl	$-CH_3$	36[c]	31.5	1.0
Neophyl	$-CH_3$	93[d]	25.7	−6.4

[a] Standard deviation varied from ±0.2 to ±0.5 kcal. [b] Standard deviation varied from ±1.4 to ±3.0 e.u. [c] From data of Winstein[4] at 75°. [d] From data of Winstein[5] at 75°.

the activation energy parameters, by themselves, do not permit a rigorous assignment as to how the variation of ΔH^* or ΔS^* should be ascribed to changing solvation of either solvated ground state and solvated transition state,[8,9] the data presented in Table II along with the solvolysis products (*vide infra*) do suggest a significant difference[10] in the nature of the reactive intermediate derived from Ia–c in respect to that derived from IIa–c or IIIa–c.

Additional support is accorded this thesis by the finding that the rates of solvolysis of IIIb in four solvents at 20° are well-correlated (see Fig. 1, correlation coefficient = 0.997) by the log k_{ion} relationship,[13] whereas the rates of solvolysis of Ib are poorly correlated (see Fig. 1) by this relationship. According to Winstein, *et al.*,[13] relation 1 is equivalent to the linear relation 2 between log (f_{RX}/f_*) for the substrate RX

$$\log k_{\text{reaction}} = a \log k_{\text{ion}} + b \quad (1)$$

$$\Delta\log (f_{RX}/f_*)_{RX} = a\Delta\log (f_{RX}/f_*)_{p\text{-methoxyneophyl tosylate}} \quad (2)$$

and that of the reference substrate, *p*-methoxyneophyl *p*-toluenesulfonate. Consequently, the fact that IIIb is correlated by the given relationship in solvolytic reactions whereas Ib is not implies that

$$\Delta\log (f_{RX}/f_*)_{IIIb} \neq a' \Delta\log (f_{RX}/f_*)_{Ib}$$

(8) S. Winstein and A. Fainberg, *J. Am. Chem. Soc.*, **79**, 5937 (1957).

(9) R. E. Robertson, R. L. Hippolette, and J. M. W. Scott, *Can. J. Chem.*, **37**, 803 (1959).

(10) Admittedly, the absolute thermodynamic parameters for transition states, $F^0{}_*$ where $F^0{}_* = F^0{}_g + \delta_s F + \Delta F^*$, should be compared as there is reason to believe that the gas phase ground state energy of the cyclopropylcarbinyl system ($F^0{}_g$) is lowered due to benzyl-type resonance[11] with 1-phenyl substitution and ground state solvation energy ($\delta_s F$) has been demonstrated to be of importance in benzyl chloride solvolysis.[12] Nonetheless, the activation parameters do exhibit a decided difference in the enthalpic and entropic contributions.

(11) L. S. Ingraham, "Steric Effects in Organic Chemistry," M. S. Newman, Ed., John Wiley and Sons, Inc., New York, N. Y., 1956, pp. 518–522.

(12) S. F. Mason, *J. Chem. Soc.*, 808 (1958).

(13) S. G. Smith, A. H. Fainberg, and S. Winstein, *J. Am. Chem. Soc.*, **83**, 618 (1961).

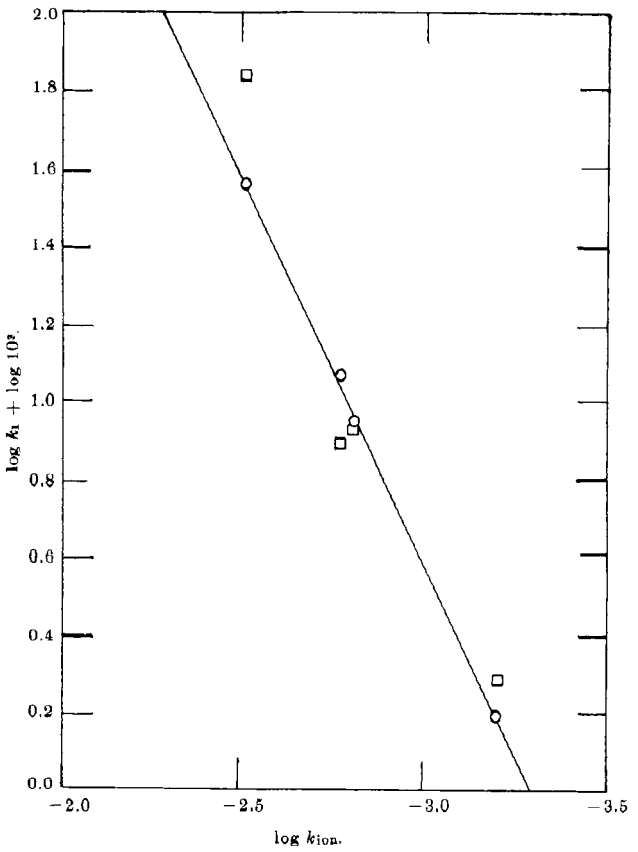
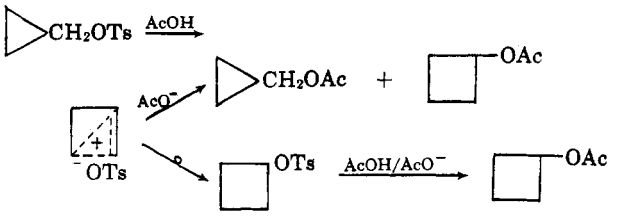


Fig. 1.—Plot of log k for 1-phenylcyclopropylcarbinyl p-toluenesulfonate (○) and cyclopropylcarbinyl p-toluenesulfonate (□) *vs.* log k for p-methoxymeophyl p-toluenesulfonate. Data taken from Table I.

This inequality buttressed with the product analysis suggests the importance of transition state coefficient differences in this study.

The evidence from kinetic data supports a difference in the nature of the solvated cationic intermediates involved in the solvolysis of I and III. The existence of a nonclassical "bicyclobutonium" ion has been well-established for the cyclopropylcarbinyl system in solvolytic reactions[2,6,14] and, therefore, one would expect a product distribution in accord with this intermediate.

The acetolysis of cyclopropylcarbinyl p-toluenesulfonate (liberation of 64–67% p-toluenesulfonic acid) gives a mixture of compounds of which approximately 96% were identified as cyclopropylcarbinyl acetate (71%) and cyclobutyl acetate (24%). Prolonged heating in the presence of the previously liberated p-toluenesulfonic acid (see Experimental for details) gave nearly 100% p-toluenesulfonic acid and approximately 95% of the product mixture was identified as cyclopropylcarbinyl acetate (55%) and cyclobutyl acetate (43%). The significant difference in reaction conditions precludes a comparison of the initial solvolysis products (liberation of 64–67% p-toluenesulfonic acid) with those obtained from complete solvolysis (liberation of nearly 100% p-toluenesulfonic acid).



The remainder of the product composition (3–7%) was accounted for by a single peak on the chromatogram, presumedly allylcarbinyl acetate, which was not identified.[15] The product identities and distributions were determined by v.p.c. The various peaks were identified by comparison with authentic samples.

Arguments previously have been advanced[1,6] to support the localization of positive charge at the methinyl carbon atom with substitution at the 1-ring position. In the case of the 1-phenylcyclopropylcarbinyl system, this would lead to a benzyl-like carbonium ion, which is supported by the finding[1] that 1-phenylcyclobutyl acetate is the exclusive product of acetolysis (in the presence of acetate ion). Based upon kinetic evidence and product analysis, the results reveal that the ion derived from the acetolysis of cyclopropylcarbinyl arenesulfonate derivatives behaves differently from ions from 1-methyl- and 1-phenylcyclopropylcarbinyl arenesulfonate derivatives. Furthermore, the results suggest that the lack of 1-ring position substituent effect can be attributed to transition state differences, due to increased localization of positive charge on the methinyl ring carbon atom with concomittant change in solvation forces.

Experimental

Cyclopropylcarbinol was prepared in 72% yield by lithium aluminum hydride reduction of cyclopropanecarboxylic acid, b.p. 124° (760 mm.), lit.[16] b.p. 126° (760 mm.).

1-Methylcyclopropylcarbinol was prepared in 70% yield by lithium aluminum hydride reduction of methyl 1-methylcyclopropanecarboxylate, b.p. 126–127° (760 mm.), lit.[6] b.p. 126° (760 mm.).

1-Phenylcyclopropylcarbinol was prepared in approximately 100% yield by lithium aluminum hydride reduction of 1-phenylcyclopropylcarbonyl chloride, m.p. 32–33°, lit.[1] m.p. 32.5–33°.

Cyclopropylcarbinyl arenesulfonates (Ia–c) were prepared according to published procedure.[16] The purities, calculated from "infinity" titers of the acetolyses at 60° and ethanolyses at 30°, ranged from 85–95%. V.p.c. revealed that most of the impurity was accounted for by unreacted cyclopropylcarbinol.

1-Methylcyclopropylcarbinyl arenesulfonates (IIa–c) were prepared according to the same procedure. Due to the thermal instability of the esters, it was necessary to use the product purified by extraction with methylene chloride followed by evaporation of the solvent at diminished pressure. The purities, calculated from infinity titers of the acetolyses at 30°, ranged from 82–96%.

1-Phenylcyclopropylcarbinyl arenesulfonates (IIIa–e) were prepared according to established procedure[1]: **1-phenylcyclopropylcarbinyl benzenesulfonate, IIIa**, m.p. 48° dec., lit.[1] m.p. 48° dec.; **1-phenylcyclopropylcarbinyl p-toluenesulfonate, IIIb**, m.p. 52° dec., lit.[1] m.p. 52° dec.; **1-phenylcyclopropylcarbinyl p-methoxybenzenesulfonate, IIIc**, m.p. 65° dec., too unstable for combustion analysis, purity calculated from infinity titers of the acetolyses at 30° was 100 ± 0.1%; **1-phenylcyclopropylcarbinyl p-isopropylbenzenesulfonate, IIId**, m.p. 58° dec., too unstable for combustion analysis, purity calculated from infinity titers of the acetolyses at 30° was 100 ± 0.1%; **1-phenylcyclopropylcarbinyl p-t-butylbenzenesulfonate, IIIe**, m.p. 66° dec., too unstable for combustion analysis, purity calculated from infinity titers of the acetolyses at 30° was 100 ± 0.1%.

(14) R. H. Mazur, W. N. White, D. A. Semenow, C. C. Lee, M. S. Silver, and J. D. Roberts, *J. Am. Chem. Soc.*, **81**, 4390 (1959).

(15) Both ethanolysis and methanolysis of Ib appear to give one component accounting for more than 95% of the products. Positive assignments of structures of these compounds has yet to be made. However, based on other work,[16] it is believed that the product of ethanolysis is ethyl cyclopropylcarbinyl ether.

(16) C. G. Bergstrom and S. Siegel, *J. Am. Chem. Soc.*, **74**, 145 (1952).

Rate measurements were accomplished by the usual techniques.[6,17] The titrating solutions were for acetolyses, 0.050 *N* sodium acetate in acetic acid and, for ethanolyses and methanolyses, 0.04 1 *N* sodium methoxide in anhydrous methanol. The indicators used were bromophenol blue and bromothymol blue, respectively.

Solvents.—Absolute ethanol was prepared according to the method of Fieser.[18] Absolute methanol was prepared by distillation from magnesium turnings. Aqueous ethanol (80% by volume) was prepared volumetrically from absolute ethanol and distilled water. Acetic acid solvent was prepared from 985 ml. glacial acetic acid (Du Pont, 99.7% min.) and 15 ml. acetic anhydride.

Treatment of Kinetic Data.—The thermodynamic activation functions were obtained by IBM 1620 computer regression analysis. Solvent ionizing strength sensitivity, *a*, and the Hammett *p*-value also were obtained by IBM 1620 computer regression analysis.[19]

Product Studies. A. Acetolysis.—Cyclopropylcarbinyl *p*-toluenesulfonate (IIIb, 885 mg.) was solvolyzed in 25 ml. of acetic acid (*cf.* above for solvent composition) containing potassium acetate (500 mg.) at 30° for 20 half-lives in one run and at 60° for 10 days in a second run. The material was added to ice–water (200 ml.) and extracted with three 60-ml. portions of ether. The ether extract was washed with saturated sodium bicarbonate followed by water, dried over sodium sulfate, and most of the ether removed by distillation. Injection of a sample of this solution into a vapor fractometer (sucrose acetate isobutyrate, 125°) gave in addition to a solvent peak one small peak (A, 5.8-min. retention time) and two large, sharp peaks (B, 7.1-min. retention time, and C, 8.0-min. retention time). A sample of authentic cyclopropylcarbinyl acetate[20] in ether gave a chromatogram with a retention time identical with peak C and, similarly, a sample of authentic cyclobutyl acetate[20] in ether gave a chromatogram with a retention time identical with peak B.

B. Ethanolysis.—Cyclopropylcarbinyl *p*-toluenesulfonate (IIIb, 1.2 g.) was solvolyzed in 50 ml. of absolute ethanol at 30° for 20 half-lives. The material was added to ice–water (200 ml.) and extracted with three 40-ml. portions of ether, dried over sodium sulfate, and most of the solvent removed by distillation. Injection of a sample of this solution into a vapor fractometer (Apiezon grease, 100°) gave, almost immediately, a strong peak corresponding to volatile solvent. The only other peak was a strong, sharp peak with a retention time of 4.9 min.

(17) Aliquot samples were removed from a single container for titrations rather than individual ampoules. This modification reduced the "prerun" solvolysis and shortened the sampling time for each individual titration.

(18) L. F. Fieser, "Experiments in Organic Chemistry," 3rd Ed., Rev., D. C. Heath and Co., Boston, Mass., 1957, p. 285.

(19) These analyses were performed through the courtesy of the Louisiana Polytechnic Institute Computer Center, Ruston, La.

(20) J. D. Roberts and V. C. Chambers, *J. Am. Chem. Soc.*, **73**, 5034 (1951).

The Conformations of Cyclic Compounds in Solution. I. Shikimic Acid

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The conformation of shikimic acid has been determined in solution and is shown to be essentially a half-chair conformation.

The importance of shikimic acid (I) as an intermediate in the conversion of carbohydrates to aromatic compounds in nature is well-known.[2] In view of this it is surprising that no attempt has been made previously to measure the precise conformation of this compound in solution. N.m.r. spectroscopy has been used to determine the precise conformations of several important cyclic biochemicals[3,4] in solution and this method has now been used to determine the conformation of shikimic acid.

Experimental

The compound used was a commercial sample from the Aldrich Chemical Co. and was used without further purification, m.p. 184.0–184.5°, $[\alpha]D$ −175° (*c* 2, water). The spectrum (Fig. 1) was measured in deuterium oxide solution with a Varian 4302 B spectrometer and a Varian V 3521 integrator for base-line stabilization. Calibration was by the usual side-band technique and, in the absence of any generally accepted n.m.r. internal standard for aqueous solutions, acetonitrile[5] (7.98 τ) was used.

The assignment of the spectrum was straightforward. The signal at lowest field could be assigned with certainty to the olefinic proton (H-2) and the multiplets at highest field must have been due to the C-6 methylene protons. Allocation of the remaining multiplets then followed, and the first-order coupling constants and chemical shifts are shown in Table I. An explicit analysis of this spectrum would involve the solution of a six-spin system which would be tedious and in fact unnecessary. It seemed improbable that second-order effects would be significant and to check this a series of partial analyses were made. The spectrum was subdivided into five sections (H-5, H-6e, H-6a), (H-3, H-4, H-5), (H-2, H-3, H-4), (H-4, H-5, H-6a), (H-4, H-5, H-6e) and each of these was analyzed[6] separately. The values thus obtained are shown in Table I together with the first-order values, and it can be seen that both sets are in close agreement. In addition to the vicinal coupling constants, long-range couplings were observed between the C-6 protons and the C-2 and C-3 protons. In view of the opposite relative signs of these couplings,[7] the values shown in Table I are probably the averaged values.

TABLE I

SPECTRAL DATA FOR SHIKIMIC ACID

Chemical shifts (τ-values)[a]

	H-2	H-3	H-4	H-5	H-6e	H-6a
First order	3.12	5.59	6.31	6.00	7.23	7.86
From analysis	3.12	5.59	6.24	5.82	7.19	7.89

Coupling constants (c.p.s.)

	$J_{2,3}$	$J_{2,6}$	$J_{3,4}$	$J_{5,6}$	$J_{4,5a}$	$J_{5,6a}$	$J_{5,6e}$	$J_{6a,6e}$
First order	4.0	1.8	3.9	1.5	8.4	6.2	5.0	18.5
From analysis	4.0	1.8[b]	3.8	1.5[b]	8.4	5.9	4.8	18.5

[a] Since spectra were measured in deuterium oxide solution, no signals were observed from –OH or $-CO_2H$. [b] Uncorrected values.

(1) University of Ottawa Postdoctoral Fellow, 1962–1963; Department of Chemistry, University of British Columbia, Vancouver 8, B. C.

(2) "Biochemists Handbook," C. Long, Ed., E. and F. N. Spon Ltd., London, 1961, p. 594.

(3) C. D. Jardetsky, *J. Am. Chem. Soc.*, **83**, 2919 (1961), and previous references.

(4) R. U. Lemieux, *Can. J. Chem.*, **39**, 116 (1961).

(5) R. A. Y. Jones, A. R. Katritzky, J. N. Murrel, and N. Sheppard, *J. Chem. Soc.*, 2576 (1962).

(6) The author is indebted to Miss O. Boshko of the Ottawa University Computing Centre for computing these analyses on an IBM 650 computer.

(7) D. D. Elleman and S. L. Manatt, *J. Chem. Phys.*, **36**, 2346 (1962).