

Substitution at a Saturated Carbon Atom. IV. A Clarification of the Mechanism of Solvolyses of 2-Octyl Sulfonates. Stereochemical Considerations¹

Henry Weiner⁵ and Richard A. Sneen

Contribution from the Department of Chemistry, Purdue University,
Lafayette, Indiana. Received September 17, 1964

Solvolytic substitutions at a simple saturated secondary carbon atom are shown to proceed via completely stereospecific displacement processes. The features of these reactions which had led to their being considered "borderline"⁶ solvolyses, over-all inversion of configuration frequently accompanied by partial racemization, are shown to result, during solvolyses in aqueous dioxane of 2-octyl sulfonates, from a stereospecific backside attack by the "inert" component of the solvent mixture, dioxane, competitive with a stereospecific inverting backside attack by water. The intermediate oxonium ion, produced on attack by dioxane, undergoes subsequent attack by water to produce retained alcohol. Thus "racemization" is seen to result from a competition between a stereospecific inversion process (attack by water) to produce inverted alcohol and a stereospecific double inversion process (initial attack by dioxane) ultimately to produce retained alcohol. Consistent with this thesis is the fact that solvolysis of 2-octyl methane-sulfonate in pure water furnishes completely inverted 2-octanol. Acetone too has been implicated as an effective nucleophile. Thus solvolysis of 2-octyl brosylate in methanolic acetone furnishes, in addition to the expected 2-octyl methyl ether, $15 \pm 5\%$ of 2-octanol. Acetone apparently competes with methanol as a nucleophile, furnishing an intermediate acetoxonium ion which would be expected ultimately to furnish 2-octanol.

Substitution at a saturated carbon atom has been and perhaps remains the most actively studied reaction in all of organic chemistry. The brilliant, early investigations of the Ingold school, dating from the 1930's, established the framework for an understanding of the mechanisms of substitution reactions, a framework which serves today, elaborated upon but essentially unaltered. Thus the bimolecular, nucleophilic substitution mechanism, SN₂, continues to accommodate data for displacements at primary carbon atoms; and the unimolecular, nucleophilic substitution mechanism, SN₁, when expanded to include ion-pair phenomena, rationalizes much of the behavior of tertiary carbon atoms.

Somewhat less satisfactory has been the theory when applied to substitutions at secondary carbon atoms, particularly to solvolytic displacements. Here in this mechanistic "borderline"⁶ region the facts on occasion

would appear to require a mechanism intermediate between the SN₁ and SN₂ extremes^{6,7} or, alternatively, two operative mechanisms, distinct SN₁ and SN₂ processes in competition.^{8,9} Other features of these borderline solvolyses have also proved puzzling and it was to these problems that we addressed ourselves. A summary of our results, which clarify many of the hitherto unexplained features of these reactions, together with their mechanistic implications, provide the subject matter of this and the accompanying paper.¹² Our results lead us to formulate a rather detailed picture of the solvolyses of secondary systems which, in mixed solvents, must include *two* intermediates: (1) an ion (oxonium or acetoxonium) formed by the intervention of the "inert" component of the solvent mixture (dioxane or acetone), and (2) an ion pair. Suggestive evidence will also be provided which indicates that a reaction which shows all of the stereochemical and kinetic characteristics of an SN₂ displacement may involve in its rate-determining step attack by nucleophile on preformed ion pair.

The present paper focuses attention on the evidence for the intervention of "inert" solvents as nucleophiles. The accompanying paper¹² will concentrate on the evidence for ion-pair intermediates in these solvolysis reactions of secondary systems.

Results and Discussion

The substrates chosen for this investigation were sulfonate esters of optically active 2-octanol. Solvolyses were conducted in a wide variety of solvent systems which varied from pure methanol to pure water and which included mixtures of dioxane-water, dioxane-methanol, acetone-water, and acetone-methanol. Added nucleophiles (particularly azide ion) were used to probe for the presence of reactive intermediates during solvolyses. Particular attention was paid to the kinetics of solvolyses¹² and to the stereochemistry of the products.

Intervention of "Inert" Solvents in Solvolyses of 2-Octyl Sulfonates. Dioxane.^{2,4} Solvolysis of optically active 2-octyl brosylate in 75 vol. % aqueous dioxane at

(1) Based on the Ph.D. Thesis of H. Weiner, Purdue University, 1963; parts I,² II,³ and III⁴ have appeared as preliminary communications.

(2) H. Weiner and R. A. Sneen, *J. Am. Chem. Soc.*, **84**, 3599 (1962).

(3) H. Weiner and R. A. Sneen, *ibid.*, **85**, 2181 (1963).

(4) H. Weiner and R. A. Sneen, *Tetrahedron Letters*, No. 20, 1309 (1963).

(5) Predoctoral Fellow of the National Institutes of Health, 1962-1963.

(6) M. L. Bird, E. D. Hughes, and C. K. Ingold, *J. Chem. Soc.*, 634 (1954).

(7) S. Winstein, E. Grunwald, and H. W. Jones, *J. Am. Chem. Soc.*, **73**, 2700 (1951).

(8) V. Gold, *J. Chem. Soc.*, 4633 (1956).

(9) Recent reports^{10,11} suggest that there are indeed two separate mechanisms operative in certain selected secondary systems in which the nucleophile is an anion but evidence on this point for solvolysis reactions has been more elusive.

(10) G. Kohnstam, A. Queen, and B. Shillaker, *Proc. Chem. Soc.*, 157 (1959).

(11) A. Fava, A. Iliceto, and A. Ceccon, *Tetrahedron Letters*, No. 11, 685 (1963).

(12) H. Weiner and R. A. Sneen, *J. Am. Chem. Soc.*, **87**, 292 (1965).

65° furnished, in addition to small amounts of olefins, inverted 2-octanol of 77% optical purity.^{13,14} However, when solvolysis was conducted in the presence of 0.0307 M sodium azide, the resulting inverted 2-octanol, formed now in competition with 2-octyl azide, proved to be 100% optically pure. Thus sodium azide is influencing the stereochemical course of the solvolysis reaction. At intermediate concentrations of added sodium azide, 2-octanol of intermediate degrees of optical purity was produced.¹⁵ These data are summarized in Table I together with similar data for sol-

Table I. Optical Purity of 2-Octanol and 2-Octyl Azide from the Solvolyses of 0.018 M 2-Octyl Brosylate in Aqueous Dioxane at 65° with Added Sodium Azide

Solvent, % dioxane	[NaN ₃] × 10 ² , M	2-Octanol, %	Optical purity of 2-octanol, ^a %	Optical purity of 2-octyl azide, ^a %
75	...	100	76.8	...
75	0.633	91.2	65.9	41.6
75	1.26	73.0	76.3	71.8
75	1.27	73.0	76.0	67.4
75	1.78	...	87.3	75.4
75	3.07	...	103	96.0
75	3.07	35.1	107	105
75	6.02	22.4	100	100
66.67	...	100	77.0	...
66.67	0.562	...	78.5	26.0
66.67	1.50	...	101	...
66.67	2.99	...	99.9	...
50 ^b	...	100	87.5	...
50 ^b	3.11	74.4	75.5	91.5
50 ^b	9.30	48.2	95.6	91.5
25 ^b	...	105	94.5	...
25 ^b	3.26	83.0	96.4	80.0
25 ^b	4.43	78.3	97.8	80.0
Water ^c	103	...
Water ^c	10.65	...	98.6	95.5

^a Products were in all cases inverted. ^b 2-Octyl methanesulfonate (0.011–0.016 M) replaced the brosylate in these cases. ^c Methanesulfonate (0.0026–0.0052 M) replaced the brosylate.

volyses in other solvent systems where a similar, although somewhat less pronounced, phenomenon was observed. It is suggested that the function of sodium azide in suppressing racemization is to react selectively with some intermediate which, in the absence of azide ion, gives rise to a noninverted (retained or racemized) solvolysis product.

The nature of this intermediate becomes evident when the data of Table II are considered. Particularly striking among the entries in this table is the fact that solvolysis of optically active 2-octyl methanesulfonate in pure water furnishes completely inverted 2-octanol.

(13) The optical stability of 2-octanol under the reaction conditions was established by the nearly constant optical activity of the reaction mixture after 7 and 30 half-lives of solvolysis; see Table VI of ref. 12.

(14) 2-Octanol was isolated from the reaction mixture by extraction into pentane, concentration, and purification by gas chromatographic separation. Its purity was established by microanalysis and its specific rotation was measured at 365 mμ, 25°, on a Rudolph, modified Model 200, photoelectric polarimeter.

(15) It will be noted (Table I) that at low concentrations of sodium azide, e.g., at 0.00633 M salt in 75% aqueous dioxane, the product 2-octanol is formed with lower optical purity than in the absence of salt. In the accompanying paper¹² it will be shown that this results from a salt-catalyzed racemization of starting material which takes place at an ion-pair stage.

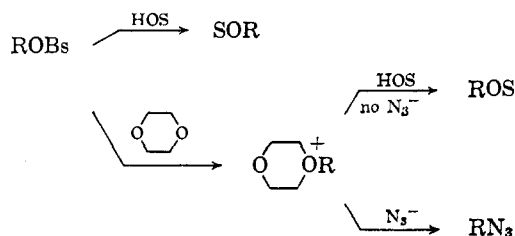
Table II. Optical Purity of 2-Octanol and of 2-Octyl Methyl Ether from the Solvolyses of 2-Octyl Sulfonates in Aqueous and Methanolic Dioxane at 65°

Solvent, % dioxane ^a	2-Octyl sulfonate ^b	[Ester] × 10 ² , M	Optical purity of solvolysis product, % ^{c,d}
75 D:W	OBs	1.78	76.8
66.67 D:W ^e	OBs	1.78	77.0
50 D:W	OMs	1.62	87.5
25 D:W	OMs	1.18	94.5
Water	OMs	0.349	103
90 D:M	OBs	1.8	92
50 D:M	OBs	1.8	97
Methanol	OBs	1.8	100

^a D = dioxane, W = water, and M = methanol. ^b *p*-Bromobenzene = OBs; methane = OMs. ^c Products were inverted. ^d 2-Octanol in aqueous dioxane and 2-octyl methyl ether in methanolic dioxane. ^e $k_t = 5.80 \pm 0.06 \times 10^{-4} \text{ sec.}^{-1}$.

The optical purity of 2-octanol from solvolyses in various aqueous dioxane solutions is seen to be an inverse function of the dioxane concentration; in solvents of higher dioxane concentration (and therefore of lower ionizing power), 2-octanol of lower optical purity is formed. Similarly solvolysis in pure methanol furnishes the completely inverted 2-octyl methyl ether,¹⁶ whereas in methanolic dioxane solvolyses the optical purity of product is seen again to be an inverse function of dioxane concentration.

The conclusion would seem to be inescapable that dioxane competes effectively with its cosolvent (water or methanol) as a nucleophile to produce an intermediate oxonium ion¹⁷ whose subsequent reaction with water (or methanol) furnishes retained 2-octanol (or 2-octyl methyl ether) by a double inversion process. The apparent racemization observed in the solvolysis of optically active 2-octyl brosylate is then seen to result from a competition between a stereospecific mechanism for inversion (attack by water or methanol) and a stereospecific mechanism for retention (attack by dioxane).¹⁸ These conclusions are summarized in the accompanying scheme.¹⁹



(16) It has been reported that ethanolysis of 2-octyl tosylate (0.2 M) takes place with essentially complete inversion of configuration: see A. Streitwieser, Jr., and A. C. Weiss, Jr., *J. Org. Chem.*, **27**, 290 (1962).

(17) It has been established that oxonium ions serve as intermediates in solvolyses of primary alkyl sulfonates: A. Streitwieser, Jr., and S. Andreades, *J. Am. Chem. Soc.*, **80**, 6553 (1958).

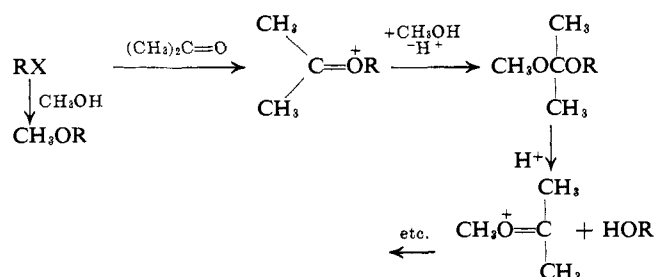
(18) The scheme predicts that the 2-octyl azide formed on solvolysis in the presence of sodium azide would be retained. In actual fact 2-octyl azide always proved to be inverted, although with varying degrees of optical purity (Table I). This will be shown¹² to result from a competitive inversion mechanism for 2-octyl azide formation, direct displacement by azide ion. However, it can be seen that, under conditions where the competing displacement mechanism is of minimal importance, that is at low concentrations of sodium azide, the resulting 2-octyl azide is of lower optical purity.

(19) Throughout this and the accompanying paper¹² the convention will be observed that a derivative of 2-octanol in which the substituent succeeds the alkyl group, RX, will have a given configuration. Its mirror image will be represented as XR.

*Intervention of "Inert" Solvents in Solvolyses of 2-Octyl Sulfonates. Acetone.*³ Our identification of dioxane as a nucleophile, competitive with water or methanol, in the solvolyses of 2-octyl sulfonates led us to search for similar phenomena in other mixed solvents containing "inert" components. A different probe would be necessary however to detect a similar nucleophilic involvement of acetone in solvolyses conducted in aqueous acetone since the anticipated acetoxonium ion would be expected to furnish ultimately inverted alcohol without cleavage of the 2-octyl-oxygen bond.²⁰ And, in fact, solvolysis of 2-octyl brosylate in 80 vol. % aqueous acetone at 65° furnished inverted 2-octanol, 99% optically pure²¹ (see Table IV of ref. 12).

Evidence for nucleophilic intervention by acetone was obtained, however, in an experiment in which 2-octyl brosylate was solvolyzed in 80 vol. % methanolic acetone. Along with the expected 2-octyl methyl ether, the reaction furnished 2-octanol.^{22a} By vapor phase chromatographic analysis the alcohol was determined to constitute $15 \pm 5\%$ of the solvolysis mixture. Control experiments (see Experimental) established that neither adventitious water nor water formed in condensation reactions of the solvent is able to account for the formation of alcohol.

The formation of alcohol under these conditions would seem to implicate acetone as an effective nucleophile, the mixed methyl 2-octyl ketal of acetone (or 2-octyl 2-propenyl ether) serving as an intermediate.^{22b}



Confirmation of the suggested scheme has come from the following experiments. (1) When solvolysis was conducted in the same solvent system in the presence of a slight excess of 2,6-lutidine, no 2-octanol was detected by v.p.c. Under these buffered conditions the mixed ketal is presumably stable. However, neutralization of this reaction mixture with *p*-toluenesulfonic acid resulted in the formation of 2-octanol (by v.p.c.). (2) Although attempts to isolate the mixed ketal in a pure state have not as yet been successful, a precursor of acetone has been shown to be present among the products of a basic solvolysis (lutidine). Thus when the reaction mixture was concentrated by distillation and diluted with ether to precipitate the amine salts, a residue was obtained whose infrared spectrum was transparent in the carbonyl region.

(20) J. J. Cawley and F. H. Westheimer, *Chem. Ind.* (London), 656 (1960).

(21) This result, incidentally, suggests that aqueous acetone should be the solvent system of choice for the solvolytic conversion of the sulfonate ester of a simple secondary alcohol to its epimer.

(22) (a) Isolated by preparative vapor phase chromatography; identity established by microanalysis and infrared spectrum. (b) A referee has made the interesting suggestion that the effective nucleophile may be the hemiacetal formed by the addition of methanol to acetone. While we think it improbable, such an interpretation of our data would be consistent with all available facts.

However, when this residue was treated with acidic 2,4-dinitrophenylhydrazine reagent, a solid, identified as the 2,4-dinitrophenylhydrazone of acetone, was formed.

Conclusions

It is clear that there is nothing borderline about the behavior of 2-octyl sulfonates, even in highly ionizing solvents such as water. They undergo solvolyses by processes which are SN₂ in character. Apparent racemization in mixed solvents is but the result of competitive but stereospecific displacement processes.²³

To our knowledge there is not a single piece of evidence in the literature which requires that substitution at a secondary carbon atom, whether the leaving group is a halide or sulfonate ion and whether the nucleophile is a neutral solvent molecule or a negative anion, be other than cleanly uni- or bimolecular.²⁴ Confusion about the mechanism of substitution reactions at secondary carbon atoms in the past has undoubtedly resulted from the lack of recognition of the ability of supposedly inert solvents to function as nucleophiles, and from the lack of recognition of the importance of ion pairs as intermediates which provide a mechanism for the racemization of starting material.^{12, 25}

It would seem that caution should be advised about the representation of reactions of *simple* secondary systems as proceeding through free carbonium ion intermediates. Although ion pairs are definitely implicated as intermediates in reactions of these systems,¹² free carbonium ions have not been established.

Experimental

2-Octyl p-Bromobenzenesulfonate. In a stoppered erlenmeyer flask, equipped with magnetic stirring, were placed 25 ml. of pyridine and 5 ml. of 2-octanol. The reaction mixture was cooled with ice-water and to it was then slowly added 10.5 g. of *p*-bromobenzenesulfonyl chloride. The mixture was stirred at ice temperatures for 6 to 8 hr. The ester was isolated by adding 50 ml. of ice-water followed by extracting five times with 50-ml. portions of ether. The combined ethereal extracts were washed successively with 50 ml. of 10% hydrochloric acid, 50 ml. of water, 20 ml. of 10% cadmium chloride, and 25 ml. of water, and were then dried over magnesium sulfate. The ether was removed under vacuum at room temperature. The oil formed was dissolved in methanol (2 g. of alcohol for each gram of oil). Precipitation occurred at Dry Ice temperatures. Repeated cooling of the mother liquor yielded additional crystals. These were removed, dried under vacuum, and stored in a desiccator under refrigeration. The yield of 2-octyl brosylate averaged 80–90%, m.p. 40–41° (lit.²⁶ m.p. 40–41°).

Optically Active 2-Octyl p-Bromobenzenesulfonate. Optically active 2-octanol, resolved by the method of

(23) That the displacements are, at least on occasion, attacks by nucleophile on preformed ion pair rather than on covalent starting material will be established in the accompanying paper.¹²

(24) Or a combination of distinct uni- and bimolecular processes.^{10, 11} Neighboring group phenomena and steric congestion at the point of attack will of course favor the former as, e.g., in the solvolyses of cholesteryl derivatives.

(25) A. Streitwieser, Jr., and T. D. Walsh, *Tetrahedron Letters*, No. 1, 27 (1963).

(26) R. C. Cary, J. F. Vitche, and R. L. Shriner, *J. Org. Chem.*, 1, 280 (1936).

Kenyon,²⁷ was treated as described above for the preparation of the inactive ester. Since the product is a low melting solid it was isolated rapidly, preferably in a refrigerated room. The yield was 70–80%, m.p. 29–30° (lit.²⁶ m.p. 30°).

Optically Active 2-Octyl Methanesulfonate. In a stoppered erlenmeyer flask, with magnetic stirring, were placed 25 ml. of pyridine and 5 ml. of optically active 2-octanol. The mixture was cooled to nearly 0°, after which 3 ml. of methanesulfonyl chloride was added. The mixture was stirred under refrigeration for ca. 3 hr. The ester was isolated by pouring the product mixture into a cooled mixture of 100 ml. of 6 N hydrochloric acid and 50 ml. of ether. The ethereal layer was washed successively with 50 ml. of water, 20 ml. of a 10% cadmium chloride solution, and 20 ml. of water and then was dried over magnesium sulfate. The ether was removed at room temperature and the oil was precipitated from ca. 4 ml. of a mixture of 10% ether–90% pentane. Since the ester melts at ca. –30°, only small amounts of solid could be removed at a time. The cooling was repeated many times in order to obtain a good yield. The solid was dried under a vacuum of 1–2 mm. for 3 days, during which time it was kept at Dry Ice temperatures. It was found that the compound underwent racemization, even at 5°, the temperature at which it was stored.

Anal. Calcd. for C₉H₂₀SO₃: C, 51.89; H, 9.68; S, 15.39. Found: C, 52.04; H, 9.76; S, 15.38.

Reagents and Chemicals. Commercial dioxane was purified by Fieser's method²⁸ and was stored under nitrogen. Methanol was purified by refluxing overnight with magnesium; after distillation it was stored under nitrogen. Pure deionized water was obtained by passing once deionized water through a Barnstead mixed ion-exchange bed. Commercial acetone was allowed to reflux with potassium permanganate; after the addition of Drierite, the solvent was distilled through a Todd column.

Commercial pentane was purified by distillation from sodium after it had been allowed to reflux for a few hours. Commercial pyridine was allowed to reflux for a few hours over potassium hydroxide before distillation. 2,6-Lutidine (500 g.) was dried over calcium hydride; the decanted solution was then distilled from 20 g. of boron trifluoride etherate²⁹ and stored in a desiccator. Lithium perchlorate and lithium acetate were supplied by Mr. K. M. Lewandowski.³⁰ Commercial sodium azide was dissolved in hot water and the solution was then filtered; the solution was cooled to 0° at which temperature ethanol was added. The precipitated salt was dried and stored in a desiccator. All other reagents were the commercial forms and were used without further purification.

Preparation of Samples. Solutions were first prepared by pipetting the required volume of each solvent into an erlenmeyer flask; e.g., 75% aqueous dioxane was prepared from three volumes of dioxane and one volume of water. The ester was weighed

into a volumetric flask to which solvent was then added. If salts were present either the reaction mixture was initially prepared from the organic solvent and a standard aqueous solution of the salt, or it was prepared by adding the salt to the volumetric flask together with the ester. Pure solvents were then added to give the proper volume. The volumetric flasks were placed in a rate bath for the desired time. A 6-ml. sample was removed and saved. This small sample was either titrated if the product ratio was desired or subjected to flame ionization gas chromatography for product analysis.

Isolation of Products. The contents of the volumetric flask were emptied into a 1-l. separatory funnel. Purified pentane (100 ml.) was added, followed by 500 ml. of distilled water. The aqueous portion was then extracted four more times with 100-ml. portions of pentane. The organic portion was then washed with three 50-ml. portions of water. The pentane solution was dried over magnesium sulfate, and pentane was then removed on a mechanically rotated solvent stripper at room temperature. When the volume of pentane was reduced to ca. 75 ml. it was extracted with three 20-ml. portions of water and redried, and the excess pentane was removed under vacuum. The residual oils usually represented about a 75% recovery of products.

Alternative Isolation of Products. If methanol or a combination of methanol–acetone was used as the solvent, the bulk of the liquid was removed by a slow distillation through an 18-in. packed column. The oily residue was then added to water and extracted with pentane as above. When lutidine was present, it was found that it or its salts could not be removed by simple extraction. The residue was treated with dry ether and cooled, the lutidine brosylate salt precipitating. Often repeated ether treatment was necessary to remove the last traces of this salt.

Purification of Products. The residue was subjected to gas chromatography for separation and isolation of products. A 5 ft. × 0.5 in. product column was used. Many packings and column temperatures were used. It was found that 20% Carbowax 20M on Chromosorb W, 60/80 mesh, was a satisfactory packing. A temperature of 140° with a flow rate of helium of 60 to 80 ml./min. was found to give good separation of all products.

Optical Measurements. The determination of optical purity was made by weighing a small sample, usually ca. 10 mg., into a volumetric flask of 1.5 to 2.0 ml. whose volume had been determined to ±0.001 ml. It was found that a Hamilton syringe was a convenient device for transferring the small sample. All optical measurements were obtained with a Rudolph Model 200 photoelectric spectropolarimeter. The measurements were obtained at 365 mμ using a General Electric mercury arc No. AH-4 as the source. It was important to correct for birefringence. To do this, a blank reading of the empty polarimeter tube was taken before each ampoule was analyzed. It was noted that this blank was necessary since any change in tightness of the end plates of the polarimeter tube caused a significant change in the blank reading. Readings for any one point were always reproducible to ±0.002°. A 1-dm. polarimeter tube, center-filling, was employed.

(27) A. I. Vogel, "A Textbook of Practical Organic Chemistry," 3rd Ed., Longmans, Green and Co., London, 1956, p. 505.

(28) L. F. Fieser, "Experiments in Organic Chemistry," 2nd Ed., D. C. Heath and Co., Boston, Mass., 1941, p. 368.

(29) S. Johnson, Ph.D. Thesis, Purdue University, 1953.

(30) R. A. Sneed, K. M. Lewandowski, I. A. I. Taha, and B. R. Smith, *J. Am. Chem. Soc.*, 83, 4843 (1961).

Flame Ionization Gas Chromatography. All product runs and kinetic runs were subjected to this sensitive device. A 20% Carbowax 20M column was found to be a very effective column. The solid support was a silicone treated Chromosorb W, 60/80 mesh. Temperatures varied from 75 to 125° depending upon the samples analyzed; column lengths from 4 to 6 ft. all gave about the same efficiency in separation. The instrument used was an Aerograph Model 600.

Products from the Solvolysis of 2-Octyl Brosylate in 80 Vol. % Methanolic Acetone. Products of two types were formed, those related to the octyl system and those related to the solvent system. These will be discussed in turn.

The expected product, 2-octyl methyl ether, was first observed in the chromatogram from a flame ionization gas chromatography unit (retention time, 10 min. on a 5% silicone oil SE 30 column packed on Chromosorb W, 60/80 mesh). It was also isolated from the reaction mixture by preparative gas chromatography (the technique has been discussed previously). Identification was by its infrared and n.m.r. spectra and by its analysis.

Anal. Calcd. for $C_9H_{20}O$: C, 74.93; H, 13.98. Found: C, 75.27; H, 14.11.

A second octyl derivative was also identified. This was 2-octyl alcohol, detected by gas chromatography (retention time, 34 min., identical with authentic material). The product also was isolated by preparative gas chromatography. The identification of this component was by its infrared and n.m.r. spectra, which were identical with those of the authentic compound, and by its microanalysis.

Anal. Calcd. for $C_8H_{18}O$: C, 73.78; H, 13.93. Found: C, 74.04; H, 14.09.

In order to establish that the 2-octanol formed under these conditions did not result from a direct reaction of 2-octyl brosylate with water, perhaps present as an impurity in the solvent system or formed during condensation reactions of the solvent (*vide infra*), control experiments were carried out. A solution of 0.0180 M 2-octyl brosylate in 80 vol. % methanolic acetone was prepared. This solution was divided into ten portions which were then placed in ampoules, to some of which was added water while to others were added both water and 2,6-lutidine. The ampoules were then sealed and were allowed to react for 10 half-lives (2-octyl brosylate) at the solvolysis temperature.¹² The infinity solutions were then subjected to flame ionization gas chromatography. Table III presents the results of the experiments.

It will be seen that, in the absence of base, the amount of 2-octanol formed proved to be independent

of the concentration of added water while in the presence of base no 2-octanol was ever detected. Furthermore when flask 8 was neutralized with toluenesulfonic acid and heated for an additional five half-lives at 65°, 2-octanol was detected in the chromatogram.

Table III. Formation of 2-Octanol during the Solvolysis of 0.0180 M 2-Octyl Brosylate in 80 Vol. % Methanolic Acetone with and without Added Water and 2,6-Lutidine at 65°

Flask	[Water] $\times 10^2, M$	[2,6- Lutidine] $\times 10^2, M$	Peak area ^a
1	18
2	0.11	..	17
3	0.55	..	19
4	1.10	..	17
5	2.20	..	18
6	1.10	1.76	..
7	0.55	1.76	..
8	1.10	3.52	..
9	0.55	3.52	..
10	..	2.20	..

^a Area under the curve was integrated automatically with a disk integrater, Model 207, produced by Disc Instruments, Inc.

Accompanying 2-octyl methyl ether and 2-octanol as products of the solvolysis of 2-octyl brosylate in 80 vol. % methanolic acetone were products derived from the solvent system. Isolated in largest quantity (by preparative v.p.c.) was mesityl oxide, $CH_3COCH=C(CH_3)_2$, an aldol condensation product of acetone. It was identified by its infrared and nuclear magnetic resonance spectra which were identical with those of authentic material. Microanalysis confirmed the assigned structure.

Anal. Calcd. for $C_6H_{10}O$: C, 73.43; H, 10.27. Found: C, 73.32; H, 10.10.

A second isolated condensation product was diacetone alcohol, $CH_3COCH_2C(OH)(CH_3)_2$, identified by its infrared spectrum and by microanalysis.

Anal. Calcd. for $C_6H_{12}O_2$: C, 62.04; H, 10.42. Found: C, 61.54; H, 10.47.

Finally an interesting keto ether, 2-methyl-2-methoxy-4-pentanone, $CH_3COCH_2C(OCH_3)(CH_3)_2$, whose structure was deduced from its infrared and nuclear magnetic resonance spectra, was isolated. Microanalysis verified its composition.

Anal. Calcd. for $C_7H_{14}O_2$: C, 64.58; H, 10.84. Found: C, 64.42; H, 10.76.

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