for bromine and iodine, preferably a cyclic ion intermediate of the type $\underset{\oplus}{\underset{\diagdown X \diagup}{CH_3-CH-CH_2}}$ (XVII). Intermediate XVI would be preferred to the isomeric primary carbonium ion intermediate and, for this mechanism, predominant formation of the Markownikoff product would be expected. The orientation of ring opening of XVII would be expected to be similar to that for acid-catalyzed ring opening of propylene oxide. Here the transition state structure corresponding to XIV might be expected to have even greater importance than in the acid-catalyzed epoxide reactions, and hence more secondary attack by the incoming base is not unexpected.

Dewael[9] has reported that 1-chloro-2-propanol and 2-chloro-1-propanol react with potassium cyanide to give the same product, 3-hydroxybutyronitrile. Inasmuch as the bromohydrins have now been shown to react with sodium iodide by a normal exchange reaction, the isomerization observed by Dewael was probably due, as he assumed, to preliminary formation of epoxide from the chlorohydrin in the basic medium, followed by opening of the epoxide ring by cyanide ion, and not to a neighboring group effect.

The sulfuric acid-catalyzed hydrations of allyl chloride and of allyl bromide are interesting in that the chloride shows only unrearranged addition whereas the bromide gives a small amount of the rearranged product 2-bromo-1-propanol. This may be explained by the neighboring group effect[10] of the bromine in forming an intermediate cyclic ion of the structure $\underset{\oplus}{\underset{\diagdown Br \diagup}{CH_3-CH-CH_2}}$.

Acknowledgment.—The authors wish to express their appreciation to the Office of Naval Research for a grant under which this study was conducted.

LAWRENCE, KANSAS

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[9] A. Dewael, *Bull. soc. chim. Belg.*, **33**, 504 (1924).

[10] See S. Winstein and E. Grunwald, THIS JOURNAL, **70**, 828 (1948).

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, DUKE UNIVERSITY]

The Ortho Substitution Rearrangement *versus* β-Elimination of Certain Quaternary Ammonium Ions with Sodium Amide. Extension of the Method of Synthesis of Vicinal Alkyl Aromatic Derivatives[1]

BY CHARLES R. HAUSER AND ALFRED J. WEINHEIMER

RECEIVED JUNE 12, 1953

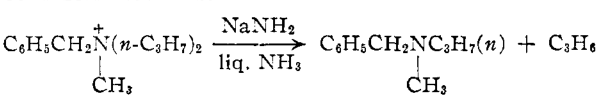
Certain benzyl quaternary ammonium ions having both methyl and higher alkyl groups were found to undergo, with sodium amide in liquid ammonia, both the ortho substitution rearrangement and β-elimination. Quaternary ammonium ion III underwent largely β-elimination, but quaternary ions V and VII exhibited more of the rearrangement than β-elimination. The latter ion formed on rearrangement the ortho ethyl derivative (VIII), the methiodide of which was further rearranged to give the 2,3-methylethyl derivative (X). The methiodide of X was still further rearranged to form the 2,3,4-dimethylethyl derivative (XI). These results support the aromatic nucleophilic displacement mechanism proposed previously.

It has previously been shown[2] that, with sodium amide in liquid ammonia, quaternary ammonium ion I undergoes the ortho substitution rearrangement to form *o*-methylbenzyldimethylamine in 96% yield, whereas quaternary ammonium ion II exhibits exclusively β-elimination to give benzyldi-*n*-propylamine and propylene. The former reaction involves an α-hydrogen of a methyl group, and the latter, a β-hydrogen of a *n*-propyl group. Similarly, certain other quaternary ammonium ions that have only α-hydrogen atoms were shown to exhibit the rearrangement,[2] whereas benzyltri-*n*-butylammonium ion, which has also β-hydrogens, underwent exclusively β-elimination.[2]

$C_6H_5CH_2\overset{+}{N}(CH_3)_3$ I

$C_6H_5CH_2\overset{+}{N}(n\text{-}C_3H_7)_3$ II

In the present investigation, certain benzyl quaternary ammonium ions that have both methyl and higher alkyl groups were found to undergo with sodium amide in liquid ammonia both the ortho substitution rearrangement and β-elimination. Thus, benzyl quaternary ammonium ion III, which has one methyl group and two *n*-propyl groups, underwent largely β-elimination to form benzyl methyl-*n*-propylamine (IV) (70%), but a little of the rearrangement also appeared to occur. In this case, the β-elimination furnishes a convenient method for the preparation of tertiary amine IV which, because each of its alkyl groups is different, could presumably not be readily synthesized by the more common methods.



$$\underset{\text{III}}{C_6H_5CH_2\overset{+}{\underset{|\atop CH_3}{N}}(n\text{-}C_3H_7)_2} \xrightarrow[\text{liq. }NH_3]{NaNH_2} \underset{\text{IV}}{C_6H_5CH_2\underset{|\atop CH_3}{N}C_3H_7(n)} + C_3H_6$$

On the other hand, benzyl quaternary ammonium ion V, which has two methyl groups and one *n*-propyl group, underwent slightly more rearrangement to form tertiary amine VI (52%) than β-elimination to give benzyldimethylamine (40%). As anticipated, relatively less (30%) of the latter amine from β-elimination was obtained when the reaction was carried out at −70° instead of the usual −33°, although the yield of VI from the rearrangement was only slightly greater (56%). The rearrangement is represented below. The structure of the product VI was established by its oxidation to

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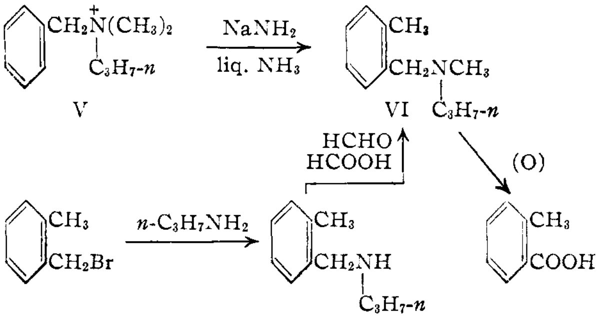
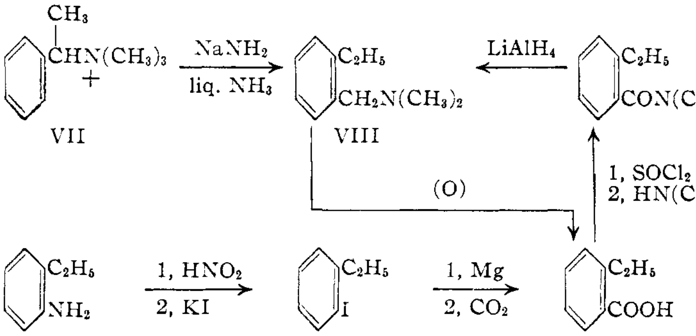
[1] Supported by the Office of Naval Research and the Duke University Research Council.

[2] S. W. Kantor and C. R. Hauser, THIS JOURNAL, **73**, 4122 (1951).

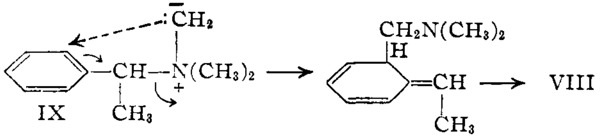
o-toluic acid and by an independent synthesis from *o*-xylyl bromide.



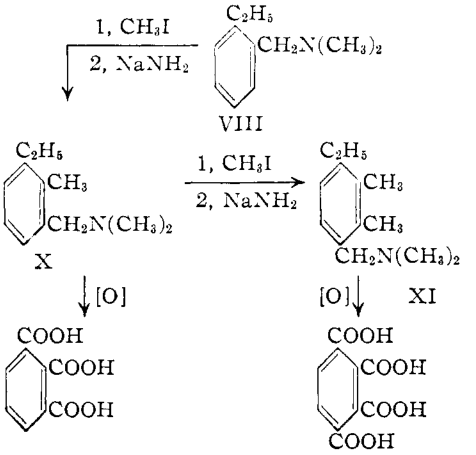
Likewise, quaternary ammonium ion VII, which has three methyl groups and an α-methyl group capable of taking part in β-elimination, underwent more of the rearrangement to form tertiary amine VIII (42%) than β-elimination to give styrene (14%) (which was obtained partly as polystyrene). In this case, dimeric and trimeric amines were also formed in an estimated total yield of 22%. Such dimeric and trimeric amines have previously been obtained in certain reactions of this type.[2] The rearrangement is represented below. The structure of the product VIII was established by oxidation to 2-ethylbenzoic acid and by an independent synthesis starting with 2-ethylaniline.



The fact that the rearrangement of quaternary ion VII forms ortho ethyl derivative VIII rather than an ortho methyl derivative is in agreement with the aromatic nucleophilic displacement mechanism proposed previously for this type of rearrangement.[2] Indeed, this result shows conclusively that the reaction does not involve the migration of a methyl group from nitrogen to the aromatic ring which might appear to occur in the rearrangement of I to *o*-methylbenzyldimethylamine. In the present case, the mechanism would involve intermediate carbanion IX with which the carbanion resulting from ionization of the hydrogen alpha to the benzene ring would presumably be in equilibrium.



The rearrangement of quaternary ion VII to tertiary amine VIII furnishes the first step in an extension of the method described previously for the synthesis of vicinal methyl derivatives. To illustrate this extension, in which vicinal methyl ethyl derivatives are obtained, the methiodide of tertiary amine VIII was further rearranged to amine X, and the methiodide of the latter amine, still further rearranged to amine XI. The structures of these tertiary amines were established by oxidation to hemimellitic acid and prehnitic acid, respectively.



It seems likely that certain other α-alkylbenzyltrimethylammonium ions could similarly be rearranged to form the corresponding *o*-alkylbenzyldimethylamines, and that these, as well as the ethyl derivatives obtained in the present investigation, could be converted to vicinal alkyl aromatic hydrocarbons or benzyl alcohols by methods described previously.[2,3]

Experimental[4]

Quaternary Ammonium Iodides.—To a well-stirred, cooled solution of the appropriate tertiary amine (0.3–1.0 mole) in absolute methanol (0.5–1.0 volume) was added dropwise a solution of methyl iodide (25% excess) in absolute methanol (1–2 volumes) at such a rate that the mixture refluxed gently. After refluxing 0.5 hour, the mixture was cooled, and a large excess (3–6 volumes) of ether added. The precipitate was collected on a sintered glass funnel and washed with ether until the filtrate was colorless. The results are summarized in Table I. The melting points of the quaternary ammonium salts on which the yields are based were only one to two degrees lower than those reported in the table.

The sources of the tertiary amines employed were as follows: di-*n*-propylbenzylamine, b.p. 108–108.5° at 10 mm., was prepared in 70% yield from 0.5 mole each of benzyl chloride and di-*n*-propylamine at 120° overnight in a pressure bottle[5]; α,N,N-trimethylbenzylamine, b.p. 92–93° at 30 mm., was obtained from Carbide and Carbon Chemical Company[6]; amines VIII and X were obtained from the rearrangements of the iodide of VII and of the methiodide of VIII, respectively (see below).

***n*-Propylbenzyldimethylammonium Bromide (V).**—This salt, which was difficult to obtain in the crystalline form,[7] was prepared from 1.725 moles of *n*-propyl bromide and 1.66 moles of dimethylbenzylamine, b.p. 71–73° at 23 mm. (obtained from Rohm and Haas Company)[6] in 150 ml. of absolute methanol. After refluxing 15 hours, the solvent

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(3) W. R. Brasen and C. R. Hauser, *J. Org. Chem.*, **18**, 806 (1953).

(4) Melting points and boiling points are uncorrected. Analyses are by Galbraith Microanalytical Laboratories, Knoxville, Tenn.

(5) J. von Braun and R. Schwarz, *Ber.*, **35**, 1281 (1902).

(6) We are indebted to this company for a generous sample of the amine.

(7) *Cf.* E. Wedekind and F. Ney, *Ber.*, **45**, 1312 (1912).

TABLE I

QUATERNARY AMMONIUM IODIDES FROM TERTIARY AMINES AND METHYL IODIDE

t-Amine	Quaternary iodide	Yield, %	Recrystallizing solvent	M.p., °C.	Carbon, % Calcd.	Carbon, % Found	Hydrogen, % Calcd.	Hydrogen, % Found	Nitrogen, % Calcd.	Nitrogen, % Found
Di-*n*-propylbenzyl	III	97	Methanol–EtAc	168.5–169	50.45	50.39	7.26	7.26	4.20	4.27
α,N,N-Trimethylbenzyl	VII	95	Ethanol–EtAc	145–146[a]						
2-Ethylbenzyldimethyl (VIII)	Methiodide of VIII	97	Ethanol	239[b]	47.22	47.19	6.61	6.63	4.59	4.74
2-Methyl-3-ethylbenzyldimethyl (X)	Methiodide of X	95	Methanol	242[b]	48.91	48.94	6.95	6.90	4.39	4.34

[a] Reported m.p. 144.5–145.5°, G. Norcross and H. T. Openshaw, *J. Chem. Soc.*, 1174 (1949). [b] Shrinking point; it did not melt completely even at 255°.

TABLE II

TERTIARY AMINES AND OTHER PRODUCTS FROM QUATERNARY AMMONIUM SALTS WITH SODIUM AMIDE

Salt	Amine	B.p., °C.	Mm.	Yield, %	Carbon and hydrogen, % Calcd.	Carbon and hydrogen, % Found	Nitrogen, % Calcd.	Nitrogen, % Found	Picrate M.p., °C.	Picrate Nitrogen, % Calcd.	Picrate Nitrogen, % Found
Iodide of III	Benzylmethyl-*n*-propyl- (IV)	100–101	20	70[a]	C, 80.92 H, 10.50	81.12 10.51	8.58	8.49	117–117.5[b]	14.28	14.24
Bromide of V	Benzyldimethyl-	96–98	55	39[c]							
	o-Xylyl-*n*-propylmethyl- (VI)	137–138	55	52	C, 81.30 H, 10.80	81.39 10.95	7.90	8.05	125.5–126[b]	13.79	13.72
Iodide of VII	Styrene	144–145		14[d]							
	o-Ethylbenzyldimethyl- (VIII)	100–101	25[e]	42[f]	C, 80.92 H, 10.50	81.00 10.37	8.58	8.41	140.5–141[g]	14.28	14.32
	Dimeric amine	166–167	5	11[h]	C, 85.34 H, 9.42	85.57 9.33	5.24	5.28			
Methiodide of VIII	2-Methyl-3-ethylbenzyldimethyl- (X)	119	19.5	90	C, 81.30 H, 10.80	81.29 11.01	7.90	7.78	114–114.5[b,i]	13.79	13.78
Methiodide of X	2,3-Dimethyl-4-ethylbenzyldimethyl- (XI)	106–107	5	46	C, 81.61 H, 11.06	81.86 10.96	7.32	7.41	105.5–106.5[b]	13.33	13.29

[a] Material, b.p. 119–120° at 11 mm., apparently di-*n*-propyl-*o*-xylylamine (6%) was obtained; it gave an oily picrate. [b] Recrystallized from methanol. [c] Methiodide, m.p. 179–180°; reported 179°, H. Emde, *Arch. Pharm.*, **247**, 353 (1909). [d] Obtained partly as polystyrene. The 2,4-dinitrobenzenesulfenyl chloride adduct of the styrene, melted at 142–142.5°; reported 143–143.5°, N. Kharasch and C. M. Buess, THIS JOURNAL, **71**, 2724 (1949). [e] n^{25}_D 1.5030. [f] The amine became yellow after a few days, but it was readily purified and recovered (90%) by refluxing with dilute sulfuric acid a few hours followed by neutralization with alkali. [g] Recrystallized from ethanol. *Anal.* Calcd. for $C_{17}H_{20}N_4O_7$: C, 52.04; H, 5.14. Found: C, 52.03; H, 5.10. [h] The residue, presumably the trimeric amine (11%), began to distil at 225° at 5 mm. [i] *Anal.* Calcd. for $C_{18}H_{22}N_4O_7$: C, 53.17; H, 5.46. Found: C, 53.39; H, 5.62.

was evaporated at the water-pump, and the residual oil cooled overnight in the refrigerator. The resulting mixture of crystals and oil was filtered and the crystals washed with hot acetone. More crystals were obtained from the filtrate; total yield, 85%, m.p. 138–139° and 139–140° after two recrystallizations from acetone.

Anal. Calcd. for $C_{12}H_{20}NBr$: C, 55.82; H, 7.81; N, 5.43. Found: C, 55.87; H, 7.72; N, 5.45.

Reactions of Quaternary Ammonium Salts with Sodium Amide.—To a stirred suspension of sodium amide in liquid ammonia (usually 0.5–1.0 mole of sodium amide in 0.6–1.0 liter of ammonia) was added during 10–20 minutes approximately 0.5 of a molecular equivalent of the solid quaternary ammonium salt, and the stirring continued 15–60 minutes longer. Excess solid ammonium chloride was added, the liquid ammonia replaced by ether, and the resulting mixture shaken with water. The ether layer was extracted several times with 5 *N* sulfuric acid, and amines removed from the acid extracts in the usual manner.[2] In certain cases neutral products were isolated from the ether solutions left after the acid extractions. Acidification of the original aqueous layer usually yielded small amounts of unidentified red oils. Samples of the amines were converted to picrates. The results are summarized in Table II.

Proof of Structures of Amines from Rearrangement of Quaternary Ions (See Table II). (A) By Oxidation.—Two grams of amine VI (from V) was stirred 20 hours with 10 g. of potassium permanganate in 100 ml. of 1% sodium hydroxide to give 0.4 g. of *o*-toluic acid, m.p. and mixed m.p. 104–104.5°.

Three grams of amine VIII (from VII) was stirred 5 hours with 150 ml. of 5 g. of potassium permanganate in 150 ml. of 0.5% sodium hydroxide, then decolorized with bisulfite, to give 0.6 g. of 2-ethylbenzoic acid, m.p. 64.5–65.5° after recrystallization from water. The mixed melting point with authentic 2-ethylbenzoic acid (m.p. 65–65.5°) prepared as described below was 65–65.5°.

To 5 g. of amine X (from the methiodide of VIII) was added in portions during 20 hours 50 g. of potassium permanganate in 200 ml. of 0.5% sodium hydroxide, the mixture being refluxed during the addition and for 16 hours longer. After filtering, the solution was adjusted to *p*H 6, and a solution of barium chloride added. The precipitated barium salt was dried (9.1 g.) and added to a slight excess of sulfuric acid in 50 ml. of water, digested for 1 hour, and filtered. The filtrate was concentrated to 10 ml. and cooled, giving 2.3 g. of hemimellitic acid dihydrate, which lost water at 100° and melted at 193–194° dec. On drying in a vacuum desiccator, there was obtained 1.9 g. of the anhydrous acid, m.p. 189–190° dec. (reported m.p. 190°[8]); the melting point was not depressed by admixture with a sample reported previously.[2]

Five grams of amine XI (from the methiodide of X) was oxidized as described above for X. The filtrate from the digestion mixture of the dried barium salt (9.5 g.) and dilute acid was concentrated to 15 ml. and acidified with concentrated hydrochloric acid to give 2.5 g. of prehnitic acid, m.p. 239–241° dec. (reported 236–238°[9]). The melting point was not depressed by admixture with a sample of prehnitic acid prepared previously.[2]

(B) By Independent Synthesis.—Tertiary amine VI was prepared from 44.5 g. (0.24 mole) of *o*-xylyl bromide which was added during 2 hours to a stirred mixture of 42.7 g. (0.722 mole) of *n*-propylamine, 25.3 g. of sodium bicarbonate and 25 ml. of water. After refluxing 24 hours, water was added and the mixture extracted with petroleum ether to give 17.7 g. (45%) of *o*-xylyl-*n*-propylamine, b.p. 86–88° at 5 mm. (113–114° at 16 mm. on redistillation), and 15.5 g. of presumably di-*o*-xylyl-*n*-propylamine, b.p. 165–166° (discarded). The secondary amine, which appeared to absorb carbon dioxide in air, was identified by its *p*-toluenesulfonamide, m.p. 74.0–74.5°.

Anal. Calcd. for $C_{18}H_{23}NO_2S$: N, 4.41. Found: N, 4.50.

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(8) C. Graebe and M. Leonhardt, *Ann.*, **290**, 221 (1896).

(9) L. I. Smith and E. J. Carlson, THIS JOURNAL, **61**, 291 (1939).

A solution of 12.0 g. of *o*-xylyl-*n*-propylamine in 10.5 g. of 88% formic acid and 8.5 g. of 35% formalin was heated on the steam-bath 2 hours, and then refluxed 2 hours. After adding 25 ml. of 5 *N* sulfuric acid, the volatile material was removed at the water-pump. The resulting sirup was dissolved in water, made alkaline with 50% sodium hydroxide, and the oil taken up in ether to give 11.3 g. (86%) of *o*-xylyl-*n*-propylmethylamine (VI), b.p. 98–99° at 10 mm.; picrate, m.p. 125.5–126°.

The melting point of the picrate of tertiary amine VI from the rearrangement of V was not depressed by admixture with a sample of the picrate of the amine from this independent synthesis.

Tertiary amine VIII was prepared from *o*-ethylaniline (obtained from Monsanto Chemical Company).[6] This amine (1 mole), b.p. 114° at 30 mm., was diazotized and treated with potassium iodide to form *o*-ethyliodobenzene (89%), the Grignard reagent of which was carbonated to give *o*-ethylbenzoic acid (68%), m.p. 62–63.5° and 65–65.5° after two recrystallizations from water (reported m.p. 68°).[10] This acid (0.33 mole, m.p. 62–63.5°) was converted by thionyl chloride to the acid chloride which was stirred with a cold solution of 60 g. of sodium hydroxide in 500 ml. of water while excess dimethylamine was passed in to give *o*-ethyl-N,N-dimethylbenzamide (74%), b.p. 112–114° at 3 mm.

Anal. Calcd. for $C_{11}H_{15}NO$: C, 74.54; H, 8.53; N, 7.90. Found: C, 74.41; H, 8.45; N, 7.82.

A solution of 0.236 mole of *o*-ethyl-N,N-dimethylbenzamide in 200 ml. of ether was added during 1 hour to a stirred suspension of 0.236 mole of lithium aluminum hydride in 300 ml. of ether, and the mixture refluxed 1 hour. After cautiously adding water, followed by a solution of 250 g. of sodium potassium tartrate in 600 ml. of water; there was isolated 36 g. (93%) of *o*-ethylbenzyldimethylamine (VIII), b.p. 94° at 16 mm., $n^{25}\mathrm{D}$ 1.5027 (see note *e*, Table II); picrate, m.p. 140.5–141°.

The melting point of the picrate of tertiary VIII from the rearrangement of VII was not depressed by admixture with a sample of the picrate of the amine from this independent synthesis.

DURHAM, NORTH CAROLINA

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[10] G. Giebe, *Ber.*, **29**, 2534 (1896).

[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF NORTHWESTERN UNIVERSITY]

Allyl Ethers in the Thiophene Series

BY CHARLES D. HURD AND HUGH J. ANDERSON

RECEIVED OCTOBER 17, 1953

The allyl ethers of three nitrothiophenes have been prepared by a modified Williamson procedure. The ethers darkened extensively on heating but did not give rise to allylthienols as products of rearrangement. Nitration of 5-chloro-2-thiophenesulfonyl chloride yielded not only the expected 4-nitro-5-chloro-2-thiophenesulfonyl chloride, but also 2-chloro-3,5-dinitrothiophene, pointing to substitution of chlorosulfonyl by nitro. 5-Nitro-2-thienyl sulfide is formed as a result of interaction of 2-chloro-5-nitrothiophene and sodium ethoxide or sodium allyl oxide.

Certain nitrothienyl alkyl ethers were prepared by Hurd and Kreuz,[1] the alkyl group being methyl and ethyl. They were prepared from nitrohalothiophenes and alcohols by use of alcoholic potassium hydroxide.

It was desired to extend this synthesis to include the allyl ethers so that the latter might be examined for their behavior on heating. If the conventional Claisen rearrangement occurred, as in the change of aryl allyl ethers into allylphenols, this would become a synthesis of allylthienols. Also, it would be a means of testing whether or not neighboring positions on the thiophene ring exhibit an "ortho" effect comparable to that shown in the phenyl ethers.

The procedure used for the preparation of methyl and ethyl ethers[1] using alcoholic potassium hydroxide needed to be modified when applied to allyl ether preparations. It was found that these ethers could be prepared by the addition of the theoretical amount of sodium in an excess of allyl alcohol to a solution of the nitrohalothiophene in benzene. The reaction took place at room temperature over one or two days; any attempt to speed the reaction by heating resulted in a rapid decomposition to a foul smelling black tar.

The three ethers prepared by this method were 5-allyloxy-4-nitro-2-acetothienone, 3-nitro-2-allyloxythiophene and 2-nitro-3-allyloxythiophene. They were all unstable compounds, becoming yellowish to bright yellow within 24 hours. The first of these compounds was the most stable and the second the most unstable. In less than a week the latter had become an oily brown solid with a sharp odor. It was necessary to carry out the elementary analyses of these compounds within 24 hours.

It was found that these allyl ethers did not undergo a smooth thermal rearrangement into allylthienols. Actually no pure products were obtainable from the tarry residues of the pyrolytic procedure.

During the preparation of 3-nitro-2-chlorothiophene by the method of Hurd and Kreuz[2] it was necessary to nitrate 5-chloro-2-thiophenesulfonyl chloride. After treatment of the reaction mixture with boiling 1:1 sulfuric acid to hydrolyze off the chlorosulfonyl group it was found that some 2-chloro-3,5-dinitrothiophene had been formed. This would indicate that the nitro group had replaced the chlorosulfonyl group to a small extent during the nitration. Although replacement of one group by another is fairly common in thiophene reactions, replacement of chlorosulfonyl by nitro under these conditions never has been reported.

All attempts to convert 2-nitro-5-chlorothiophene to the corresponding allyl ether by the above method were unsuccessful. In most trials the starting material was recovered. Heating caused a vigorous reaction to set in with evolution of hydrogen sulfide. From the black tar a yellow solid was extracted which proved to be 5-nitro-2-thienyl sulfide. The same compound was obtained from the reaction with sodium ethoxide, so its formation is independent of the base used.

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[1] C. D. Hurd and K. L. Kreuz, THIS JOURNAL, **74**, 2965 (1952).

[2] C. D. Hurd and K. L. Kreuz, *ibid.*, **72**, 5543 (1950).