

tween C(4) and its neighbors. We have interpreted this peak as a bromine atom in a site which is occupied in approximately one-sixth of the molecules, and conclude that we are dealing here with an example of cocrystallization of isomers I and II in the approximate ratio of 5:1. As the scale factor between the observed and calculated structure amplitudes in a molecule of this size is largely determined by the bromine atom, an overrepresentation of the occupancy of this atom would be expected to result in negative temperature factors for the lighter atoms. Refinement, with the appropriate partial occupancy of the two bromine atoms, has reduced the *R* factor to 0.144. As the assumption that all the other atoms occupy exactly the same positions in the crystal for the two isomers is probably not quite valid, we feel that this stage of refinement corresponds to the best information that can be obtained about the molecular geometry from an analysis on this crystal.

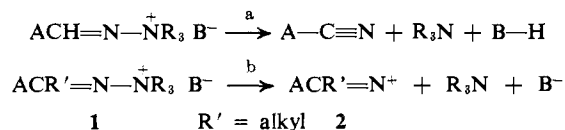
This study emphasizes several important general points. While a sharply melting organic solid containing some 16% of an isomeric structure is rare, its present detection serves to stress a need for caution in applying the classic criterion for the purity of solids. Furthermore, the possible dangers of accepting information from structural models containing physically unacceptable thermal parameters are clearly indicated, however reasonable the structural results or assuring the *R* value. It is extremely doubtful if this cocrystallization would have been detected had it not been that the heaviest atom occupied different positions in the two isomers.

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Received April 30, 1966

2,6-Diarylpyridines from the Pyrolyses of Phenone Hydrazonium Fluoroborates

Sir:

Potential N-N cleavage reactions of N,N,N-trimethylhydrazonium derivatives of carbonyl compounds **1** are either analogous to Hofmann elimination (route a) or should give the incipient cationic intermediate **2** (route b), expected to undergo skeletal rearrangement. Route a has been demonstrated by



syntheses of nitriles from the base-catalyzed decomposition of aldehyde N,N,N-trimethylhydrazonium iodides or *p*-toluenesulfonates.¹

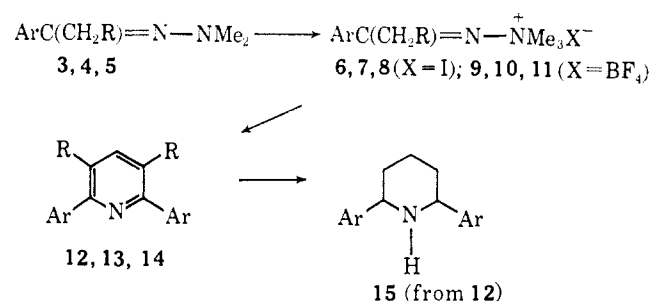
The latter potential reaction course, although apparently similar to well-known C-N rearrangements,² has been reported not to occur in the pyrolyses of ketone N,N,N-trimethylhydrazonium iodides.³ Reaction with base under anhydrous conditions, however, gives a variant of the Neber rearrangement.^{3,4}

- (1) R. F. Smith and L. E. Walker, *J. Org. Chem.*, **27**, 4372 (1962).
- (2) P. A. S. Smith in "Molecular Rearrangements," P. De Mayo, Ed., Interscience Publishers, Inc., New York, N. Y., 1963, Chapter 8.
- (3) P. A. S. Smith and E. E. Most, Jr., *J. Org. Chem.*, **22**, 358 (1957).

We have pyrolyzed ketone N,N,N-trimethylhydrazonium fluoroborates in an attempt to demonstrate the cationic intermediate **2**. Fluoroborate, as counterion, is less nucleophilic and is a much poorer reducing agent than iodide.

Pyrolysis of anhydrous acetophenone N,N,N-trimethylhydrazonium fluoroborate (**9**), either as a crystalline solid heated to its decomposition point (~200°) or as a suspension in refluxing cumene (~150°), gave 2,6-diphenylpyridine (**12**) and trimethylamine as the major isolable organic products (40–50%). Structural variations of the ketone N,N,N-trimethylhydrazonium fluoroborate gave upon pyrolysis the analogous pyridine derivatives.

Acetophenone N,N-dimethylhydrazone⁵ (**3**) with methyl iodide gave acetophenone N,N,N-trimethylhydrazonium iodide³ (**6**). Treatment of a hot aqueous solution of **6** with aqueous sodium fluoroborate resulted in high yields of acetophenone N,N,N-trimethylhydrazonium fluoroborate (**9**), mp 153–154° dec.



R = CH₃ in **5, 8, 11, 14**, otherwise R = H; Ar = *p*-tolyl in **4, 7, 10, 13**, otherwise Ar = phenyl.

4'-Methylacetophenone N,N,N-trimethylhydrazonium fluoroborate (**10**), mp 159–160° dec, and propiophenone N,N,N-trimethylhydrazonium fluoroborate (**11**), mp 110–111°, dec point ~180°, were prepared in high yields in an analogous manner.

Pyrolysis of **9, 10**, or **11** at ~200°, either under a slow stream of nitrogen or *in vacuo*, afforded a tarry residue, which was extracted, then purified by elution chromatography on neutral alumina with petroleum ether. **9** gave 2,6-diphenylpyridine (**12**), mp 82–83° (lit.⁶ mp 82°), **10** yielded 2,6-di-*p*-tolylpyridine (**13**), mp 165–165.5° (lit.⁷ mp 162°), and **11** afforded 2,6-diphenyl-3,5-dimethylpyridine (**14**), mp 136–137° (lit.⁸ 134–135°); nmr (CCl₄) displayed a doublet at τ 2.74 (C_{aromatic}-CH₃) with a coupling constant of *J* = 0.5 cps and a multiplet at τ 2.6 (aromatic protons) with relative intensities 6:11, respectively; mol wt, 259 (mass spectroscopy).

Reduction of **12** with sodium and ethanol gave 2,6-diphenylpiperidine (**15**), characterized as its picrate, mp 204° (lit.⁹ mp 198°).

The elemental analyses and spectral data of all the compounds agree with the assigned structures.

Isolation of **14** from pyrolysis of **11**, in which the methyl groups are at positions 3 and 5 of the pyridine

- (4) R. F. Parcell, *Chem. Ind. (London)*, 1396 (1963), and references therein.
- (5) G. R. Newkome and D. L. Fishel, *J. Org. Chem.*, **31**, 677 (1966).
- (6) D. Bryce-Smith and A. C. Skinner, *J. Chem. Soc.*, 577 (1963). A mixture melting point with an authentic sample, supplied by Dr. A. C. Skinner, showed no depression; the spectral properties were identical.
- (7) M. Scholtz and A. Wiedemann, *Ber.*, **36**, 852 (1903).
- (8) V. Balick and A. Ekambarom, *J. Indian Chem. Soc.*, **32**, 274 (1955).
- (9) M. Scholtz, *Ber.*, **28**, 1726 (1895).

ring, indicated that the three-carbon chain of propiophenone remained intact during pyrolysis. Labeling of one of the N-methyl groups of **9** with ^{14}C , followed by pyrolysis, gave **12**, in which one-third of the original activity was retained. Thus, the γ carbon (4C) of the pyridine nucleus must be derived from the trimethylamine moiety of the quaternary fluoroborate.

Phenylazirine, which has been isolated during studies of the Neber rearrangement,⁴ was not detected nor was its expected dimerization product, 2,5-diphenylpyrazine.¹⁰ Products arising from C-N skeletal rearrangement were not detected, which implies that either the incipient intermediate **2** does not form or, if formed, it does not undergo rearrangement under the conditions used.

Investigations of the synthetic utility and mechanism of these pyrolysis reactions are being continued.

Acknowledgment. Mass spectroscopic analyses were performed by Nathan M. Ingber in the laboratories of The Standard Oil Co., Cleveland, Ohio.

(10) L. Horner, A. Christmann, and A. Gross, *Ber.*, **96**, 399 (1963).

(11) To whom inquiries should be addressed.

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An Unequivocal Ozonide Stereoisomer Assignment

Sir:

The formation of both *cis*- and *trans*-ozonides upon ozonolysis of olefinic materials has now been reported by a number of workers.¹⁻⁸ In those cases where individual ozonide stereoisomer assignments have been reported they have been based upon some combination of infrared, nmr, glpc, and chemical reactivity data. Such a combination of data has permitted some reasonable stereoisomer designations to be made. However, it should be noted that in many cases the significant finding is a dependence of ozonide^{1,2,5-7,9} or cross-ozonide⁹ *cis*-*trans* ratio on olefin geometry rather than the specific assignments made. Such assignments are, nevertheless, equivocal, and a more exact method becomes essential in several important cases.

The surprising results reported by Schröder, for example, that *trans*-di-*t*-butylethylene gives 100% *trans*-ozonide while the *cis* isomer gives a 70:30 (*cis*:*trans*) ratio, are based, in part, on the difference in rate of reduction of the ozonides with lithium aluminum hydride, the reasonable assumption being made that the *cis* isomer is more rapidly reduced. A similar difference in rate of reaction of ozonides, this time with triphenylphosphine, was used by Lorenz and

- (1) G. Schröder, *Chem. Ber.*, **95**, 733 (1962).
- (2) R. Criegee, S. S. Bath, and B. V. Bornhaupt, *ibid.*, **93**, 2891 (1960).
- (3) O. S. Privett and E. C. Nickell, *J. Lipid Res.*, **4**, 208 (1963).
- (4) G. Riezebos, J. C. Grimmelikhuyzen, and D. A. Van Dorp, *Rec. Trav. Chim.*, **82**, 1234 (1963).
- (5) P. Kolsaker, *Acta Chem. Scand.*, **19**, 223 (1965).
- (6) F. L. Greenwood and B. J. Haske, *Tetrahedron Letters*, 631 (1965).
- (7) O. Lorenz and C. R. Parks, *J. Org. Chem.*, **30**, 1976 (1965).
- (8) L. D. Loan, R. W. Murray, and P. R. Story, *J. Am. Chem. Soc.*, **87**, 737 (1965).
- (9) R. W. Murray, R. D. Youssefyeh, and P. R. Story, *ibid.*, **88**, 3143 (1966).

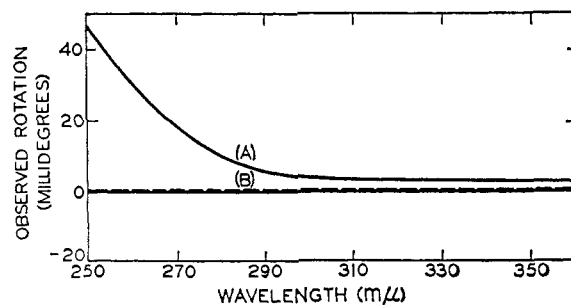


Figure 1. Optical rotatory dispersion curves of the isomeric ozonides of 2,5-dimethylhexene-3 after reaction with brucine. Isomer A is necessarily assigned the *trans* configuration, and B the *cis* configuration.

Parks⁷ to distinguish between the diisopropyl ozonide isomers. Again the underlying assumption is that the *cis*-ozonide will react faster. In the diisopropyl ozonide case the assignment based on chemical reactivity correlated with the glpc data.⁷ In the case of the butene-2 ozonides, however, the isomer with the longer glpc retention time, *i.e.*, the alleged *cis* isomer, reacted more slowly with triphenylphosphine. Existing stereoisomer assignments must be regarded as tentative, therefore, with a consequent reduction in their value to the ozonolysis mechanism problem.

With increasing attention being given to the use of ozonide *cis*:*trans* ratios as a means of investigating the mechanism of ozonolysis,^{9,10} it has become necessary to be able to make this stereochemical assignment on an unequivocal basis. We wish to report an unequivocal assignment of ozonide stereoisomers. The method takes advantage of the fact that the *trans* isomer of a symmetrical ozonide must be a *dl* pair.

Based on our earlier observations¹¹ that ozonides react rapidly with amines, we have treated each isomer of 2,5-dimethylhexene-3 ozonide (diisopropyl ozonide, I)¹² with less than the anticipated¹³ stoichiometric amount of brucine in an attempt at kinetic resolution of the true *trans* isomer. In a typical reaction 100 mg of ozonide was treated with 70 mg of brucine in dichloromethane at -70° for *ca.* 10 min. The reaction mixture was allowed to warm to room temperature and stand for 16 hr. Pentane was then added and the precipitated material filtered off. The unreacted ozonides were isolated from their mother liquors by glpc, identified by comparison with authentic samples, and investigated for optical activity. In order to magnify any optical activity developed we have run ORD curves¹⁴ on both of the recovered ozonides. The results from a typical run are shown in Figure 1. One of the ozonide isomers (isomer A) develops a strong rotation with the beginning of a positive Cotton effect lobe while the other (isomer B) has no rotation. Isomer A is, therefore, unequivocally assigned the

(10) P. R. Story, R. W. Murray, and R. D. Youssefyeh, *ibid.*, **88**, 3144 (1966).

(11) R. W. Murray, P. R. Story, L. D. Loan, and R. D. Youssefyeh, unpublished results.

(12) For details of the ozonolysis and isomer separation procedures see ref 9.

(13) The mechanism of the reaction between ozonides and amines is still not completely clear. Work on this aspect of the problem is in progress.

(14) The ORD spectra were measured on a Durrum-Jasco Model ORD/UV-5 spectrophotometer and ORD recorder using a 0.5 M solution of ozonide in hexane.