

ON THE REACTION OF ALCOHOLS WITH HALOCARBENES.
ARE CARBOCATIONS INTERMEDIATES?¹

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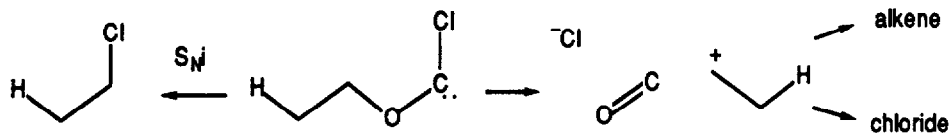
Abstract: There is no evidence for hydride shift in the reaction of alcohols 1 and 2 with dichlorocarbene.

Accordingly, the intermediate cannot be a *free* carbocation. It is suggested that the products are formed through a combination of S_Ni and direct displacement reactions in which tight ion pairs are involved.

JACK HINE and his coworkers, in 1953, suggested that chloroalkoxycarbenes were intermediates in the reactions of alcohols with alkali and haloforms.² They favored a β elimination giving the observed alkene, carbon monoxide and halide.

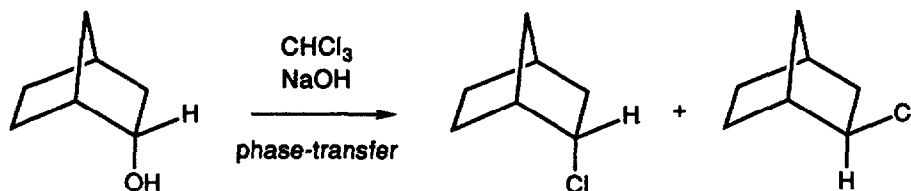


Since 1953, the phase-transfer method of generating dihalocarbenes has taken over from the simple hydrolysis of haloforms,³ but the notion that alkoxy-carbenes are intermediates in the reaction with alcohols has met with widespread approval. Most impressive are the demonstrations by Moss^{4d} and Stevens^{4b} that alkoxyhalocarbenes generated from diazirines undergo appropriate fragmentation reactions in the absence of carbene traps. However, the mechanistic hypothesis for the reaction has expanded to include an S_Ni pathway to account for the formation of halides from alcohols. Fragmentation to a carbocation has supplanted Hine's earlier concerted elimination reaction, even in cases in which an unstabilized primary cation would be required.^{3,4c}

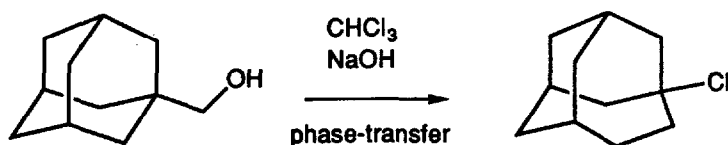


It seems to us that the evidence for *free* cations⁵ is meagre, and we supply here some new data which suggest that Hine's mechanistic ideas may have been close to the mark.

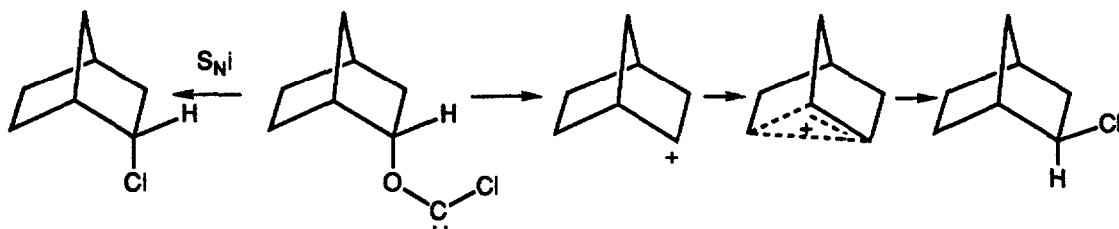
Evidence that carbocations are active ingredients in this reaction rests on general plausibility (although one might certainly worry about those primary ions!) and, more important, on a few reactions in which isomerization is found. Thus, Tabushi and his coworkers found that *l*-menthol partially racemized under the reaction conditions and that *endo*-2-norbornyl alcohol gave a nearly equal mixture of *exo*- and *endo*-2-chloronorbornane. The *exo* alcohol gave only *exo* chloride.^{4c}



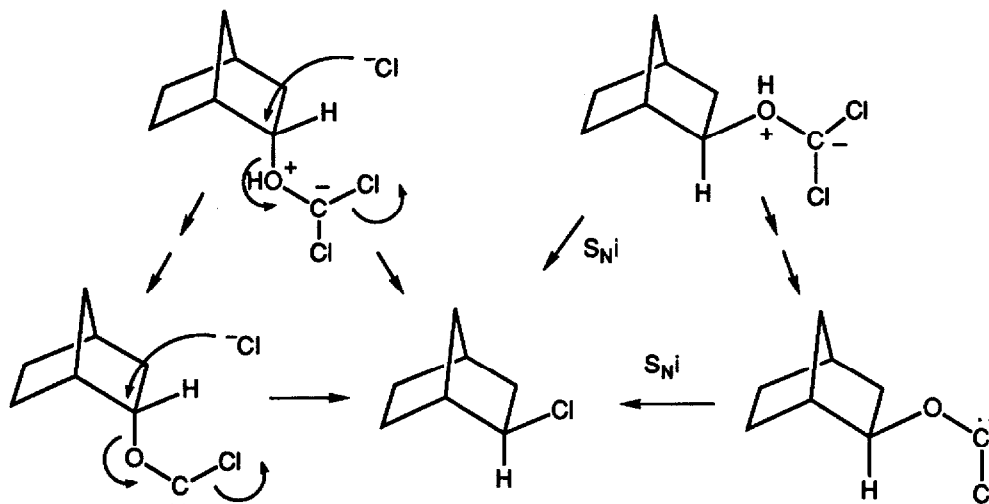
The Tabushi group also found that (1-adamantyl)methyl alcohol gave 13% of the rearranged homoadamantyl chloride.^{4c}



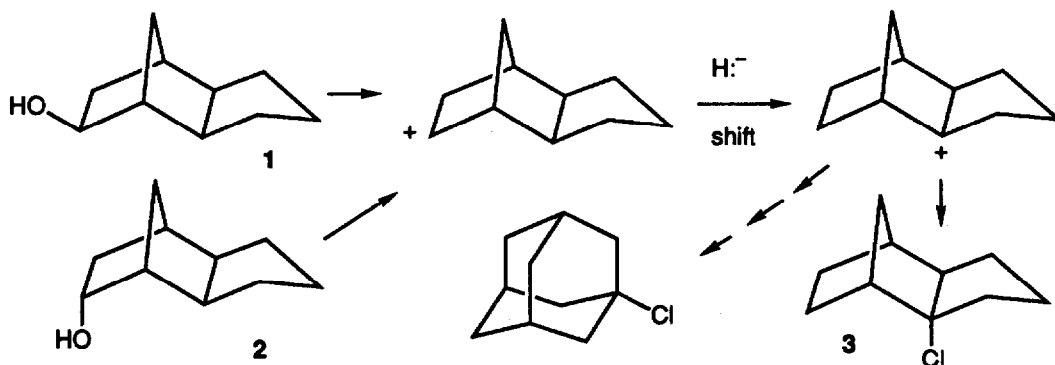
The adamantyl case surely need not involve a primary cation, as ring expansion to the homoadamantyl cation could accompany fragmentation of the alkoxy carbene intermediate. Alternately, an S_N1 process in which a free cation was never present could be the source of homoadamantyl chloride. The strongest evidence for cations would seem to be the isomerization of the *endo* norbornyl system to the *exo*.^{4a,4b} Does this not imply leakage from an initially formed open cation to the bridged 2-norbornyl cation which must give *exo* chloride? The mixture of products would come from a combination of S_N1 (retention) and carbocationic (net inversion in the 2-norbornyl system) pathways. For the *exo* alcohol, the product from S_N1 and cationic paths must be the same, the observed *exo* chloride. In support of this mechanistic picture, it is known that the reactions of the epimeric 2-norbornyl alcohols with thionyl chloride do involve carbocations capable of internal rearrangement.⁶



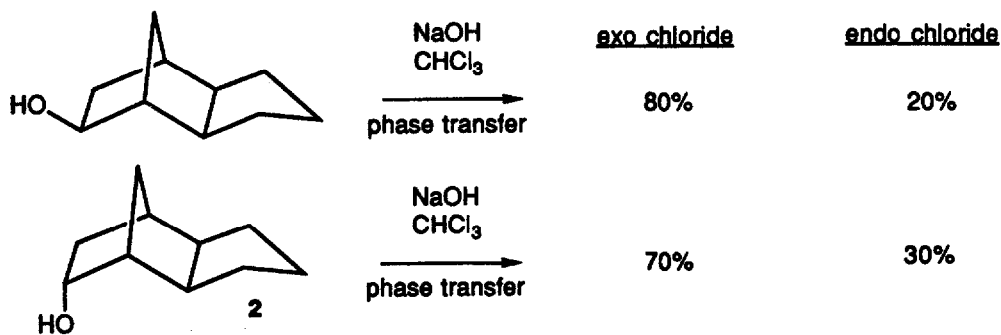
However, a Hine-like concerted mechanism, involving a transformation of the alkoxychlorocarbene or, perhaps more likely, of its ylide precursor, would also explain the inversion component found in the reaction of the *endo* chloride, but not require a carbocation. In this formulation, the *exo* compound, less prone to attack from the rear⁷ would give *exo* chloride entirely through the S_N1 mechanism.



We investigated the reaction of a pair of bicyclic alcohols related to the norbornyl alcohols, but more sensitive, we thought, to the presence of cations. Were a free cation to be formed from either of the isomeric alcohols 1 and 2, rearrangement to the adamantyl system might occur⁸ and at a minimum the extraordinarily rapid⁹ 2,6-hydride shift should give an ion which would produce a chloride (3) we had already obtained from the related alcohol, and thus could readily detect.



In each case we did observe formation of the epimeric chloride, but neither adamantyl chloride nor 3 could be found.¹⁰



Under conditions where isomerization is easy to detect - we see 70% isomerization from the endo alcohol to the exo chloride, and even detect 20% isomerization from the exo alcohol to the endo chloride - none of the anticipated products of the cation can be found.^{10,11}

We doubt that a free cation can be involved, and suggest that this reaction can best be described as a combination of an S_N1 reaction leading to retention and a displacement on the intermediate ylide (or the alkoxyhalocarbene) leading to inversion, much as suggested by Hine 36 years ago.

The paper by Moss, Ho, and Wilk reaches similar conclusions from an investigation of cyclopropylmethoxychlorocarbene formed from the related diazirine.¹² Cyclopropyl carbinol, when treated with phase transfer-generated dichlorocarbene gives 80% cyclopropylcarbinyl chloride, 18% cyclobutyl chloride, and 15% homoallyl chloride.¹³ These results are very similar to those reported by the Moss group.¹²

References and Notes:

1. We are grateful to the National Science Foundation for support through grant No. 8800448-AO1. IRL was the recipient of a Fellowship from IREX.
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5. The distinction between intimate ion pairs, which certainly contain a carbocation, and free carbocations must be kept clear. For example, the S_N1 reaction of alcohols with thionyl chloride is thought to involve a carbocation which is committed to chloride formation through intramolecular capture with retention. We are speaking here of uncommitted cations, as are often written as intermediates in this reaction.³
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10. We could easily detect 1-2% of **3**, and much less of 1-adamantyl chloride.
11. Our conditions seem to produce more rearrangement than those of Tabushi.^{4c} For example, we see 95% rearranged chloride in the reaction with (1-adamantyl)methyl alcohol rather than the 13% reported by Tabushi.^{4c}
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