Bridgehead Carbocations: Formation of a 1-Bicyclo[2.1.1]hexyl Cation as the Primary Intermediate in the Solvolysis of 3-Methoxycarbonylbicyclo[2.1.1]hexyl Triflate

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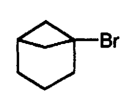
The 3-methoxycarbonylbicyclo[2.1.1]hexyl cation is the primary intermediate in the solvolysis of 3-methoxycarbonylbicyclo[2.1.1]hexyl triflate.

Bicyclic and polycyclic substrates bearing leaving groups at the bridgehead position normally ionise at rates commensurate with the degree of strain engendered at the bridgehead.[1] The 1-halobicyclo[*n*.1.1]alkanes **1**,[2,3] **2**[4] and **3**,[5] however, behave anomalously and solvolyse far more rapidly than predicted on the basis of the strain energies associated with their corresponding cations. It is noteworthy that 1-bromobicyclo[3.1.1]heptane **3** has been shown[5] to react *via* the intermediacy of the cation **6** which, unlike almost all other bridgehead cations, must therefore possess considerable thermodynamic stability. The nature of the mechanism involved in solvolysis of the other two systems has not been established unequivocally. The observation that the products of solvolysis of **1** and **2** are found to consist entirely of ring-opened material suggests that rearrangement and ionization may well be concerted in these cases, thus by-passing the bridgehead cation as intermediate. Recently, however, we presented[6] evidence from a substituent-effect study of 1-bromobicyclo[1.1.1]pentane **1** (X = Br) and its 3-substituted derivatives that solvolysis of **1** is in fact mediated by the 1-bicyclo[1.1.1]pentyl cation **4**.

Compared with the extent to which systems **1** and **3** have attacted attention, little interest has been shown in the homologue **2** since Wiberg's original study[4] over 20 years ago. Our interest in the bicyclo[2.1.1]hexyl system was stimulated by the recent observation[7] that treatment of methyl 3-iodobicyclo[2.1.1]hexane-1-carboxylate **7** with xenon difluoride yields a small quantity of the corresponding fluoroester **8**. Inasmuch as the fluorodeiodination of bridgehead iodides is believed to proceed *via* bridgehead cations, the interconversion **7** → **8** represents a phenomenon of considerable importance because it implicates cation **9** as the precursor to **8**. Although the 1-bicyclo[2.1.1]hexyl cation **5** itself is predicted to rearrange with only a small activation barrier,[8] it seems likely that the activation energy for ring-opening of species **9** will be higher in view of the destabilising effect upon the incipient cation of the ester function attached directly to the site of developing positive charge.

1, X = Br, Cl



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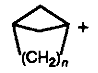
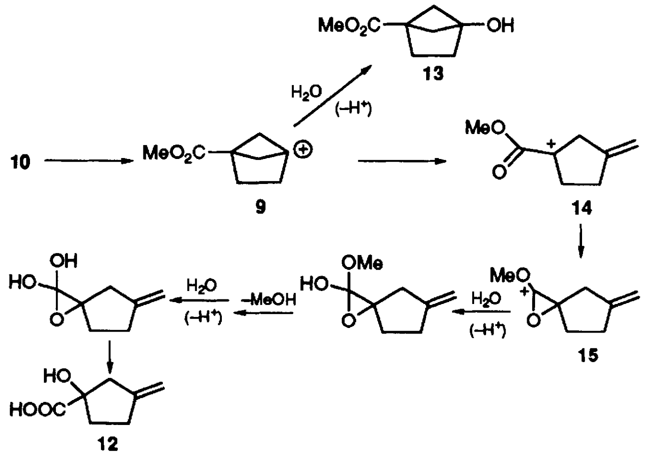
2, R = H, X = Br
7, R = MeO_2C, X = I
8, R = MeO_2C, X = F
10, R = MeO_2C, X = OSO_2CF_3
11, R = X = MeO_2C
16, R = H, X = OSO_2CF_3



4, *n* = 1
5, *n* = 2
6, *n* = 3



Scheme 1

In an attempt to trap the species **9** under solvolytic conditions we decided to synthesise the triflate **10** and to examine its fate upon exposure to protic solvent. In view of the exciting results which have evolved from the study, we now wish to report our preliminary observations.

Synthesis of the triflate **10** from dimethyl bicyclo[2.1.1]hexane-1,4-dicarboxylate **11** was accomplished by application of routine procedures. Treatment of a solution of **10** in 50% aqueous dioxane buffered with one equiv. of triethylamine for 72 hours at 45 °C gave a mixture of products of which 1-hydroxy-3-methylenecyclopentane-1-carboxylic acid **12** predominated (yield 70–80%). Removal of **12** was effected by extraction of the crude product with aqueous sodium hydrogen carbonate; the neutral fraction, which consisted of a mixture of **13** and as yet unidentified unsaturated compounds, was treated with bromine and then distilled. The distillate was shown by GC–MS and ^1H and ^{13}C NMR analysis to consist almost exclusively of methyl 3-hydroxybicyclo[2.1.1]hexane-1-carboxylate **13** (yield *ca.* 10%), which was identified by comparison of its properties with those of authentic material.

Isolation of **13** is highly significant because, in our view, it demonstrates unambiguously that the cation **9** is the primary intermediate formed in the solvolysis of the triflate **10**. Before it can be intercepted by solvent, however, the cation largely rearranges to give the ring-opened species **14** from which the hydroxy acid **12** is produced *via* the cyclic isomer **15**, as depicted in Scheme 1. It is both fortunate and fortuitous that the ring-opened product appears as the hydroxy acid **12** because it facilitates isolation of the bicyclic ester **13**.

The possibility that solvolysis of the triflate **10** does, in fact, proceed by concerted fragmentation to give cation **14** as the primary intermediate, thus by-passing the 1-bicyclo[2.1.1]hexyl cation **9**, should also be considered. Under these circumstances, the bicyclic product **13** would subsequently arise by ring-closure of **14** to give **9** which would then be trapped by water. However, in light of our previous calculations,[8] which predict a very large barrier to this type of cyclisation for the 3-methylenecyclobutylethyl cation, we believe this mechanism to be highly unlikely.

We plan to examine the behaviour of the parent system, 1-bicyclo[2.1.1]hexyl triflate **16**, in order to assess whether the above conditions, which are considerably milder than those employed by Wiberg and Lowry[4] for the solvolysis of the bromide **2**, combined with the use of the much more efficient leaving group are more conducive to the generation of the 1-bicyclo[2.1.1]hexyl cation **5**.†

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Footnote

† *Note added in proof*: de Meijere and Messner (unpublished observations; M. Messner, Dissertation, Universität Göttingen, 1992) have observed products which appear to be derived from a 1-bicyclo[2.1.1]hexyl cation produced from rearrangement of a bridgehead-substituted bicyclo[1.1.1]pentane-1-methanol. (Personal communication with Professor A. de Meijere.)

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