# Strained Eliminations: Bicyclobutane and Methylenecyclopropane Formation *versus* Substitution

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In reactions of a cyclopropylmethyl methanesulphonate with alkoxides, competition between formation of bicyclobutane, methylenecyclopropane and substitution products is critically dependent upon the base and the solvent.

Formation of even very strained rings by intramolecular substitution is familiar with carbon nucleophiles[1] but the role of strain in such reactions is not yet clear.[2] The enthalpy of activation for cyclopropane relative to cyclopentane formation is only slightly unfavourable and is more than compensated for by a favourable entropy of activation.[3] Additionally, a linear trajectory is clearly unattainable for intramolecular nucleophilic substitution[4] leading to cyclopropanes and the considerable enthalpic price of such deviations has been calculated.[5]

Such considerations raise the general question as to how much the strain of a product is reflected in its $\Delta G^{\ddagger}$ of formation. We have, therefore, turned our attention to reactivity in reactions leading to bicyclobutanes.

In pioneering work, Gaoni[6] has shown that mesylate (methanesulphonate) **1** with butyllithium in tetrahydrofuran (THF) gives the bicyclobutane **2**. The strain energy (excess enthalpy[2]) of bicyclobutane[7] is 278 kJ mol$^{-1}$ against that of cyclopropane[7] at 115 kJ mol$^{-1}$. This system was clearly a promising candidate to provide answers to our question. It has provided interesting and surprising results but only partial answers.

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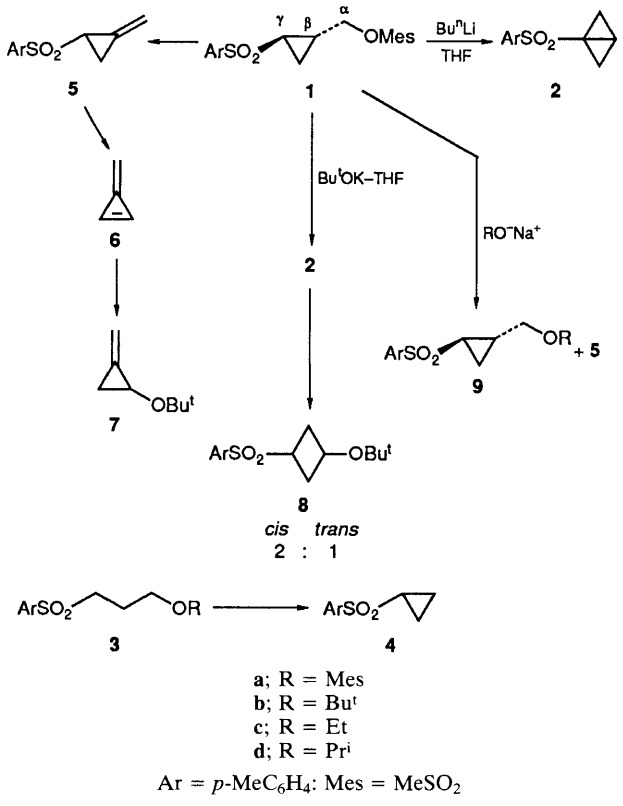
Treatment of **1** with potassium *tert*-butoxide in *tert*-butyl alcohol gave, in quantitative yield, a mixture of the sulphone **5** and the ether **7** in proportions that depended upon reaction time and temperature. The ether **7** is clearly derived from **5** *via* **6** and the same product pattern is obtained starting from **5**.[8] Related elimination–addition reactions in cyclopropyl halides are known.[9] Under forcing conditions (1 mol dm$^{-3}$ base at reflux) two additional products were obtained from the mesylate **1**. These were the cyclobutyl ethers **8** (2%), derived by ring fission of the bicyclobutane **2**, and the cyclopropylmethyl ether **9b** derived (presumably) by direct substitution of the mesyloxy group from **1**.

It is significant that unactivated 1,2-elimination to form such a strained product as **5** occurs readily; when the reaction was carried out in THF as solvent, **8** was very rapidly and quantitatively formed. We think that this product arises from bicyclobutane **2** and separate treatment of **2** with potassium *tert*-butoxide in THF also gives **8** quantitatively. This type of electrophilic behaviour is known for bicyclobutanes bearing electron-acceptive conjugative groups.[10]

We think that this striking change of pathway is occasioned by the change in conditions that determine the effective basicity of the base–solvent system. In THF, the *tert*-butoxide ion is very basic and only reaction *via* the γ-carbanion is seen. In *tert*-butyl alcohol, the *tert*-butoxide ion is less basic and chooses the less acidic β-proton in preference to the severely




**Scheme 1**

hindered γ-proton,[11] for what is almost certainly a concerted reaction‡ to give **5**. With more nucleophilic and less basic bases, we have found a further competing pathway. With sodium 2-propoxide–propan-2-ol, **1** gave substitution product **9d** (69%) as well as elimination product **5** (31%)§ found with potassium *tert*-butoxide–*tert*-butyl alcohol. In the least basic, most nucleophilic system examined, sodium ethoxide–ethanol, **1** gave only substitution product **9c**, and the acyclic substrate **3a** also gave only substitution product **3c**.

Development of strain in the products of these reactions clearly presents little impediment to their formation but choice of pathway is crucially dependent on the nature of the base–nucleophile in the solvent used. We are examining the activation parameters for these competing processes and results will be reported in a subsequent publication.

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‡ A referee pertinently enquired about H–D exchange at $C_\beta$ and $C_\gamma$. After submission of the Communication and before receiving the referees' reports, we established that in Bu$^t$OK–Bu$^t$OD, exchange at $C_\gamma$ but not $C_\beta$ occurred in partial reactions of **1**. This strengthens our belief that 1,3-elimination is stepwise and 1,2-elimination is concerted.

§ Total product yields determined by $^1$H NMR analysis of total products obtained quantitatively.