The Wittig Rearrangement of Some Allyl Ethers

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Summary The products and stereochemistry in the Wittig rearrangement of some allyl ethers are in accord with a highly ordered cyclic mechanism; dissociation and recombination can significantly compete with this process.

THE WITTIG,[1] Stevens,[2] and Meisenheimer[3] rearrangements of allyl systems, the Sommelet rearrangement,[4] the rearrangement of allyl sulphonium ylides,[1e,5] sulphenates[1e,6] and many similar hetero-systems[1e,7] can be considered as [2,3]-sigmatropic changes.[1e,f,†]

We have studied products and stereochemistry in some Wittig rearrangements in the light of this interpretation.

Benzyl $\gamma\gamma$-dimethylallyl ether (I; R = H) should be lithiated‡ in the benzyl position[8] to give (I; R = Li). [2,3]-Sigmatropic change could then occur *via* a four-centre transition state which can be viewed as a benzaldehyde anion radical interacting with a $\gamma\gamma$-dimethylallyl radical to give lithium 1-phenyl-2,2-dimethylbut-3-en-1-oxide (II; R = Li).

Alternatively, rearrangement could proceed *via* the radical-pair mechanism demonstrated in the Wittig rearrangement of non-allylic ethers,[9] (I;R = Li) dissociating to form a $\gamma\gamma$-dimethylallyl radical–benzaldehyde anion-radical pair which would recombine to yield (II; R = Li) and lithium 1-phenyl-4-methylpent-3-en-1-oxide (III; R = Li).

Lithiation of (I; R = H) at −80° and subsequent hydrolysis afforded a *ca.* 8 : 1 mixture of (II; R = H) and (III;R = H). When the temperature was raised, more of

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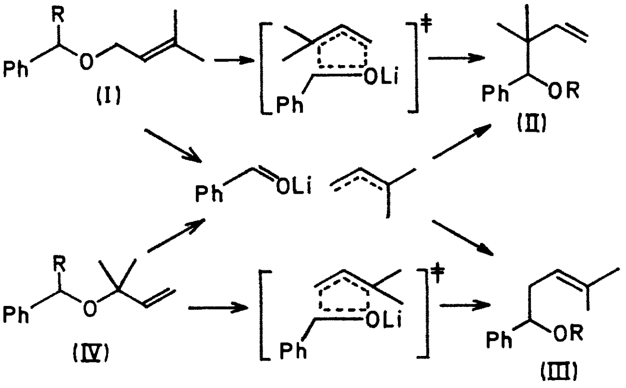
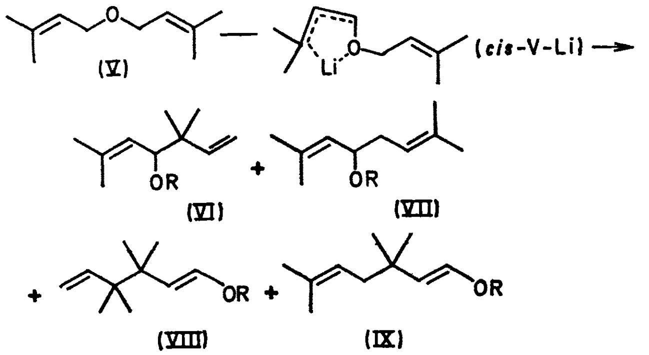
† The all-carbon [2,3]-sigmatropic change, the transition state of which can be viewed as an ethylene anion-radical interacting with an allyl radical, has not been observed. For an all-carbon [3,4]-sigmatropic analogue, see ref. 1f.

(III; R = H) was formed [(II; R = H): (III; R = H) *ca.* 7·5 at −25° and *ca.* 6 at +23°]. Lithiation of αα-dimethylallyl benzyl ether (IV; R = H) at −25° and subsequent hydrolysis furnished a *ca.* 1 : 1·4 mixture of (II; R = H) and (III; R = H).

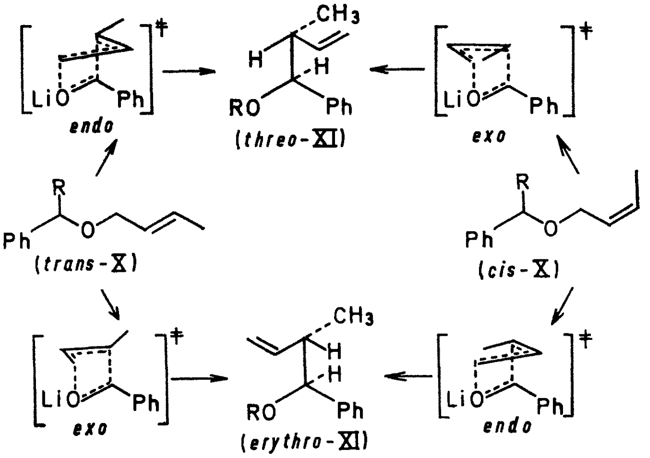


Accordingly, in these systems and under the conditions used, rearrangement with allylic "inversion," which we assume to be a [2,3]-sigmatropic process and dissociation–recombination have very similar $\Delta F^{\ddagger}$. These are about 13 kcal/mole only (see below); at lower temperatures, the sigmatropic route would probably become dominant.

Similar behaviour was observed in the rearrangement of bis-γγ-dimethylallyl ether (V). Lithiation should lead to the *cis*-allyloxy allyl lithium compound (*cis*-V-Li),[10] which could then undergo sigmatropic change to give lithium 3,3,6-trimethylhepta-1,5-diene-4-oxide (VI; R = Li). Dissociation and recombination should in addition yield lithium 2,7-dimethylocta-2,6-diene-4-oxide (VII; R = Li) and the lithium enolates of the two aldehydes 3,3,4,4-tetramethylhex-5-en-1-al (VIII; R = Li) and 3,3,6-trimethylhept-5-en-1-al (IX; R = Li). Reaction at −25° and subsequent hydrolysis gave a mixture of *ca.* 67% of (VI; R = H) ("artemisia alcohol"),[11] *ca.* 14% of (VII; R = H), *ca.* 10% of (VIII; R = H) and *ca.* 8% of (IX; R = H).[12]



The allyl and aldehyde anion radical fragments interacting in the postulated four-centre transition states can do so in an *exo*- or *endo*-arrangement. In suitable cases, products formed *via* these two alternative transition states are diastereomers. Thus *trans*-crotyl benzyl ether (*trans*-X) on lithiation in the benzyl position, can either rearrange *via* the *endo*-transition state to yield *threo*-lithium 1-phenyl-2-methylbut-3-ene-1-oxide (*threo*-XI; R = Li) or *via* the *exo*-transition state to yield the *erythro*-isomer (*erythro*-XI; R = Li). Conversely, in the rearrangement of *cis*-crotyl benzyl ether (*cis*-X; R = H), the *exo*-transition state leads to (*threo*-XI; R = H) and the *endo*- one to (*erythro*-XI; R = H).



The highly hindered *endo*-arrangements should be less favourable than the *exo*-ones and the rearrangements may therefore be stereoselective. In the *cis*-crotyl case both transition states are more highly hindered than in the *trans*-crotyl case.

Lithiation of (*cis*-X; R = H) at −80° and subsequent hydrolysis did indeed afford one diastereomer of structure (XI; R = H) only, which we therefore identify as *threo*. However, under the same conditions (*trans*-X; R = H) gave a *ca.* 1 : 1 mixture of (*threo*-XI; R = H) and (*erythro*-XI; R = H). The two isomers have different n.m.r. spectra and can be separated by g.l.c. on a capillary column.

Stereoselectivity in the *trans*-crotyl case might reveal itself at lower temperatures.

Stereoselective rearrangement was also observed in the case of α-methylallyl benzyl ether (XII).[1a,b] Lithiation at −80° and subsequent hydrolysis yielded *trans*-1-phenylhex-3-en-1-ol (XIII); none of the corresponding *cis*-isomer could be detected. This indicates that folding towards the *exo*- or *endo*-transition state occurs in such a way that the methyl group is in a quasi-equatorial rather than a quasi-axial position.

In contrast to the dimethylallyl cases, no products arising from dissociation and recombination could be detected in the three methylallyl cases. One further methyl group apparently stabilises allyl radicals to such an extent that dissociation can compete with sigmatropic change.

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‡ Lithiation was effected by reaction with n-butyl-lithium in ether–hexane in the presence of tetramethylethylene diamine at −80° to −25°.

The lithiated ethers could not be trapped by hydrolysis with deuterium oxide.[9b] Lithiation is therefore the rate-determining step in these rearrangements. From the fastest reaction [of (I; R = H)], an upper limit for the rate constant k of rearrangement of the lithiated ether of *ca.* 10^{-3} sec^{-1} at -80° ($\Delta F^{\ddagger}$ = *ca.* 13 kcal/mole) can be estimated. This rate constant is *ca.* three times larger than the corresponding one in the Wittig rearrangement of t-butyl benzyl ether at -74°.[9b]

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Note added in proof. I have learned that Professor J. E. Baldwin has also studied this subject. I thank him for communicating his results.

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