Functionalized Barbaralanes via Ring Expansion of Bicyclo[3.2.1]oct-

6-en-3-ones.   Heteroatom Effects on Degenerate Cope Rearrangements

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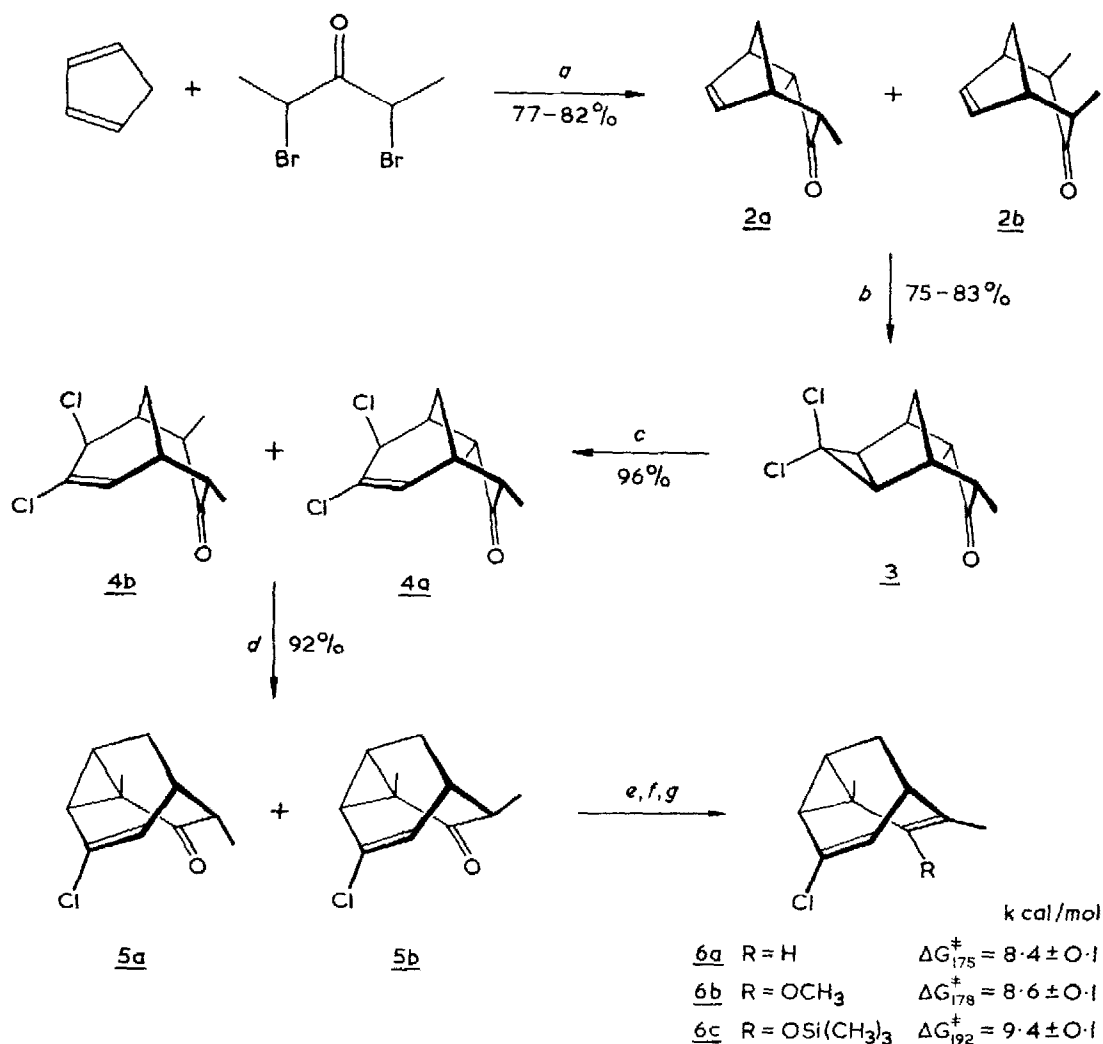
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Doering [1] and Dewar [2] have discussed the possibility that the Cope rearrangement of
the parent 1,5-hexadiene or specifically substituted derivatives such as 2-phenyl and
2,5-diphenyl-1,5-hexadiene [2b] may proceed via 1,4-cyclohexadiyl intermediates, [3] i.e. 1a
in the most simple case, rather than the conventional concerted path with 1b as transition
state.   For an experimental test of the scope of this hypothesis further information is

1a

Intermediate

1b

Transition State
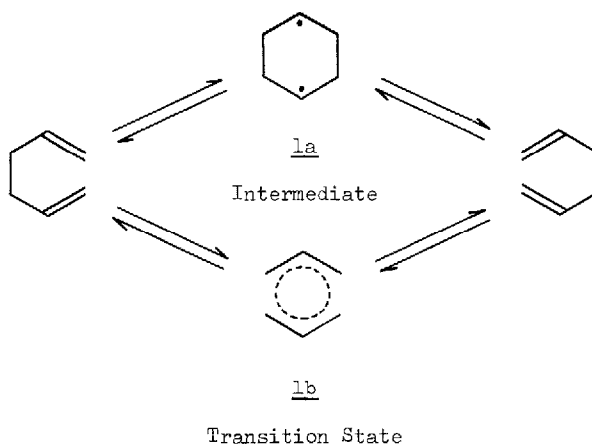
required on how substituents at C-2 and C-5 affect the rate of 3,3-shift.   As yet,
surprisingly few if any additional data are available.

    We have chosen tricyclo[3.3.1.0^{2,8}]nona-3,6-dienes [4] as a system for study, partly
because activation barriers to equilibration of a range of constrained cis-divinylcyclo-
propanes have already been determined, partly because the rigid geometry of the barbaralanes
removes some of the uncertainties inherent in purely kinetic measurements of conformationally
mobile systems where the relative population of the coiled conformer entering into
rearrangement is often unknown.   Furthermore, by specifically investigating 2,4-dimethyl-
barbaralanes the twofold structural degeneracy of the parent compound is maintained, without
the well-known problems of equilibrium displacement [5] and, at the same time, the

6a R = H $\Delta G^{\ddagger}_{175} = 8\cdot4 \pm 0\cdot1$

6b R = OCH$_3$ $\Delta G^{\ddagger}_{178} = 8\cdot6 \pm 0\cdot1$

6c R = OSi(CH$_3$)$_3$ $\Delta G^{\ddagger}_{192} = 9\cdot4 \pm 0\cdot1$

Experimental conditions

a   NaI/Cu, CH$_3$CN solvent, 2hr, 50° (ratio of isomers 2a:2b ~6·4:1)

b   50% NaOH (10 mol equiv), CHCl$_3$; C$_6$H$_5$CH$_2$N$^+$(C$_2$H$_5$)$_3$Cl$^-$ catal., 50hr, 50°

c   o-Dichlorobenzene, 1hr, 170° (4a:4b ~ 5:1)

d   KOC$_4$H$_9^t$ (3mol equiv)/THF, 1hr, 20°, then 1hr, 40° (5a:5b ~3:1)

e   1. LiAlH$_4$ 2. TsCl, pyr.   3. KOC$_4$H$_9^t$/THF (22% yield)

f   KOC$_4$H$_9^t$/CH$_3$OSO$_2$F/HMPA ; 5° (67% yield)

g   (CH$_3$)$_3$SiCN, CDCl$_3$, 3hr, 90° (40% yield); *cf.* also D.A.Evans, G.L.Carroll and L.K.Truesdale, *J.Org.Chem.* **39**, 914 (1974).

interpretation of the pmr spectra is greatly facilitated in that the two methyl groups behave as "flags" appearing as a sharp six proton singlet given the dynamic, fluxional structure and split into a singlet (cyclopropylmethyl group) and a second somewhat broader singlet (olefinic methyl group) below coalescence temperature. As a consequence, the fluxional barriers in our system can be measured with considerable precision.

The synthesis of 2,4-dimethylbarbaralanes started from 2,4-dimethylbicyclo[3.2.1]-oct-6-en-3-one which is readily available as an epimeric mixture 2a + 2b by treating 2,4-dibromo-3-pentanone with sodium iodide and finely divided copper in the presence of cyclopentadiene.[6] Expansion of the five-membered ring using the Makosza variant of the dichlorocarbene addition followed by heating in o-dichlorobenzene gave a mixture of 4a and 4b, which in the presence of potassium tert-butoxide in tetrahydrofuran suffered intramolecular nucleophilic displacement of the labile allylic chlorine anion with introduction of the required 3-membered ring. The isomeric tricyclic monochloroketones 5a and 5b so obtained serve as useful intermediates which allow transformation into a variety of barbaralanes, the nmr spectra of which are indeed temperature dependent. Specifically, the coalescence temperatures of 6a, 6b and 6c are -98.5, -95 and -81°C, respectively.

It will be seen that the degenerate divinylcyclopropane rearrangement of 7-chloro-2,4-dimethylbarbaralane (6a) ($\Delta G^{\ddagger}_{175} = 8.4 \pm 0.1$ kcal/mol) is marginally slower than that of the parent barbaralane ($\Delta G^{\ddagger}_{196} = 7.8$ kcal/mol),[7] the slightly reduced rate of flux being due at least in part to the presence of two methyl groups[8] and perhaps also to chlorine at C-7. Furthermore, replacement of the C_3-H hydrogen by a methoxy group to give 6b has no noticeable effect within experimental error ($\Delta G^{\ddagger}_{178} = 8.6 \pm 0.1$ kcal/mol).

Whilst α-methoxy substitution of hydrogen in an isopropyl radical results in a stabilization of about 4 kcal/mol,[9] one may of course argue that an energy amount of this magnitude does not suffice to promote a biradical path in the barbaralane rearrangement. In any case, still other effects come into play, as seen in 7-chloro-2,4-dimethyl-3-trimethylsilyloxybarbaralane (6c), the fluxional barrier of which is 1 kcal/mol higher than in 6a. Presumably, the bulky trimethylsilyl group, although relatively remote, may impede the molecular reorganization which is required for rearrangement.

In summary, heteroatoms such as chlorine and oxygen seem to cause little if any perturbation of the barbaralane framework, provided they are attached to carbon atoms C-3 and C-7. This negligible effect contrasts with the rate enhancing influence of oxygen in the 3-hydroxy Cope rearrangement of 1,5-hexadienes (estimated energy gain of about 2.4 kcal/mol[10a]) and especially in the 3-oxido Cope rearrangement (energy gain of up to 23.6 kcal/mol[10b]). Finally, the bicyclo[3.2.1]octenone approach represents a new and rather simple route to barbaralanes[11] which also allows diverse functionalization of the tricyclic skeleton. The keto-olefins 2a and 2b which have been used in the present instance, can be made easily in quantities of 120 g per batch.[12,13]

<center>References</center>

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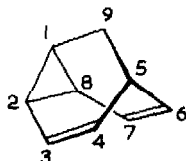
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