

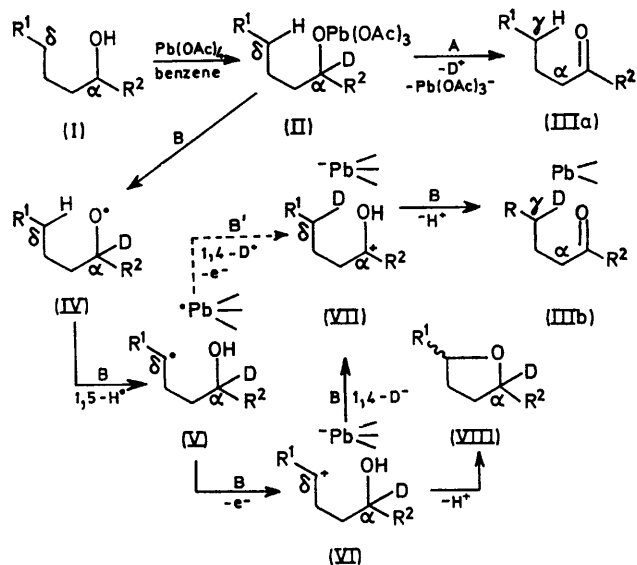
1,4-Shift of Hydrogen from Carbon to Carbon in the Lead Tetra-acetate Oxidation of Monocyclic and Acyclic Alcohols

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Summary The use of α -deuteriated substrates has established that in the lead tetra-acetate oxidation of certain secondary alicyclic and open-chain alcohols, ketone formation proceeds, in part, by 1,4-transfer of hydrogen from the carbinol (α) carbon atom to the δ -carbon atom.

In the reaction of secondary alcohols (I) with lead tetra-acetate in non-polar solvents, intramolecular cyclization to tetrahydrofuran-type ethers (VIII) is usually the major process, whereas oxidation to ketones (III) proceeds in relatively low yields (Table),^{1,2} although cycloalkanols containing a medium-sized ring and cyclododecanol afford the corresponding ketones in appreciably higher yields (Table).^{2,3,4} It was at first considered that in this reaction ketones (III) arise exclusively by simple direct removal of the α -hydrogen, predominantly as a proton in the heterolytic decomposition (type A, Scheme) of the initially formed alkoxylead(IV) acetate (II), and to a minor extent, if at all, as a hydrogen atom in homolytic processes involving intermediate (II) or the subsequently generated alkoxy-radical (IV).³

However, we have recently found that in the thermal lead tetra-acetate reaction of cyclodecanol (in benzene), oxida-



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tion to cyclodecanone proceeds also by an alternative route (Scheme, pathway B),⁴ corresponding in its first stages to the mechanism proposed for cyclic ether (VIII) formation [Scheme, (II) \rightarrow (IV) \rightarrow (V) \rightarrow (VI)],² and followed by intramolecular 1,4-transfer of hydrogen from the carbinol α -carbon atom to the electron deficient δ -carbon atom to give the α -carbonium ion (VII) [this rearrangement process being probably heterolytic and involving 1,4-hydride ion shift, *i.e.* VI \rightarrow VII(\rightarrow IIIb), rather than homolytic 1,4-hydrogen atom transfer, *i.e.* V \rightarrow VII(\rightarrow IIIb)]. In the special case of cyclodecanol, 1,5-hydrogen shift (from α -carbon to ϵ -carbon) was also observed (see Table). Further studies have now shown that this 1,4-transfer of hydrogen in the thermal lead tetra-acetate oxidation of alcohols (in benzene) to ketones is not limited to medium-sized cycloalkanol (cyclodecanol and cyclo-octanol), but occurs also,

the presence of MeCO₂D and other control experiments have shown that deuteration at the electron deficient δ -carbon atom in the intermediate species (V) or (VI) does not take place by an intermolecular transfer.

A prerequisite for the observed 1,4-hydrogen shift, leading through the α -carbonium ion (VII) to ketone (IIIb), is the intramolecular homolytic 1,5-hydrogen abstraction of hydrogen from the δ -carbon by the alkoxy radical (IV \rightarrow V), since α -deuteriated alcohols which do not undergo this rearrangement [and therefore cyclic ether (VIII) formation²], such as [1-²H₁]cyclohexanol, afford only ketones without deuterium (pathway A, Scheme). However, even from alcohols which cyclize readily, such as [1-²H₁] 2-butylcyclohexanol,^{2,4} [2-²H₁] 1-cyclohexylbutan-2-ol,⁶ and [α -²H₁]- α -methylbicyclo[2,2,2]octane-2-methanol,⁶ the ketones obtained did not contain deuterium, which indicates that 1,5-hydrogen

TABLE

Alcohol (I) oxidized	From (I) (α -H) Yield (%) (III)	Ketone product (III) From (I) (α -D)	
		Yield (%) (IIIa) + (IIIb)	Percentage of (IIIb) (D on γ -C)
Cyclohexanol	7	2.7	0
Cycloheptanol	12	5.5	0
Cyclo-octanol	23	10	50
Cyclodecanol	37	12	38
			(+22 D on δ -C)
Cyclododecanol	33	12	60
Cyclopentadecanol	6	2	50
Cyclohexadecanol	8	3	50
Cycloheptadecanol	9	4	50
2-Butylcyclohexanol ^a	8	3	0
1-Cyclohexyl-butan-2-ol	7.5	3	0
α -Methylbicyclo[2,2,2]octane-2-methanol	3.5	1.5	0
Hexan-2-ol	8	3	5
Heptan-2-ol	7	2.5	13
Octan-2-ol	4	1.5	18
Decan-2-ol	4	1.5	31
Dodecan-2-ol	5.5	2.5	35.5
Tetradecan-2-ol	5.5	2.5	37
5-Methylhexan-2-ol	^b	^b	16
6-Methylheptan-2-ol	7.5	3.5	10
5-Phenylpentan-2-ol	11	4	12.5

^a Mixture of *cis* (35–37%) and *trans* (65–63%) diastereomer.

^b Not determined.

to a greater or lesser extent, with secondary alcohols containing large rings or flexible aliphatic chains as substrates (see Table). In contrast to 1,5-shifts, 1,4-migrations of hydrogen (as hydride ions or atoms) in conformationally mobile large-ring monocyclic and acyclic systems (as described here), although reported in certain cases, have not been so far reliably ascertained.⁵

In the present study, the occurrence of 1,4-hydrogen transfer has been established by performing the lead tetraacetate oxidations (in refluxing benzene) on non-deuteriated and the corresponding α -deuteriated secondary alcohols (I); the ketonic products (III), were isolated or separated by g.l.c. and the characteristic fragment peaks in their respective mass spectra were compared.

Crossover oxidations (using mixtures of an α -deuteriated alcohol and a different non-deuteriated alcohol), reactions in

abstraction by the alkoxy radical [(IV) \rightarrow (V)] is not the only and sufficient condition for ketone formation via 1,4-transfer of hydrogen (pathway B, Scheme), and that other factors are also of importance, such as the stability of the intermediately formed electron deficient δ -carbon species (V) and (VI), and particularly the steric requirements in the cyclic five-membered transition state for 1,4-hydrogen transfer [(VI) \rightarrow (VII) or (V) \rightarrow (VII)], involving the relative spatial positions and orientations of the attacking electron deficient δ -carbon site and the C $_{\alpha}$ -H bond attacked.

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