

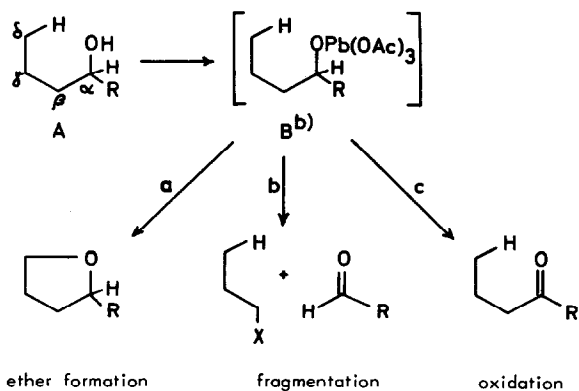
THE DECOMPOSITION OF ALKOXIDES OF TETRAVALENT LEAD

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If an alcohol of type A is treated with lead tetraacetate in an apolar solvent, one or more of the following products may be formed:



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4000 Basel 7, Switzerland.

b) Since lead tetraacetate is used in excess the lead IV-alkoxide is usually formulated as B although the number of acetoxy groups attached to lead in the actual intermediate has never been ascertained.

For preparative purposes it is important to know which factors influence the relative rates of reaction a - c in order to be able to predict the course and the main product of such reactions. Recent publications from other laboratories (1, 2, 3) prompt us to report some experiments which are connected with the above problem.

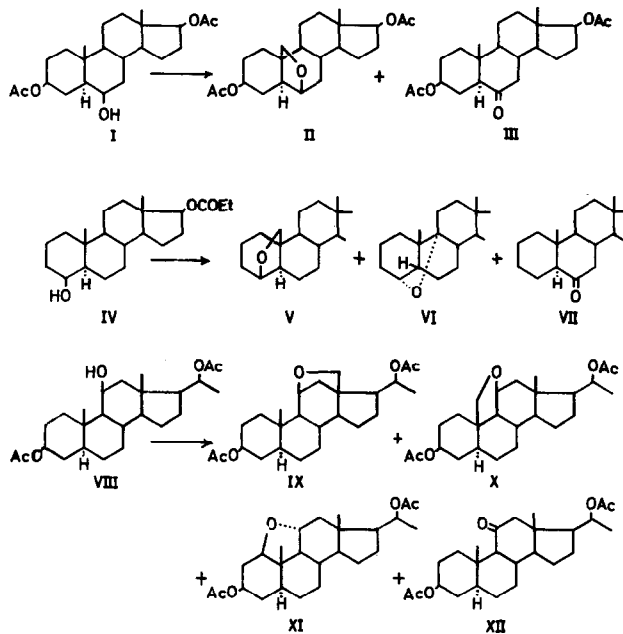
Since the transition state for the ether formation (or  $\delta$ -hydrogen abstraction) requires a rigidly defined steric relationship of the reacting centers (4) the large negative entropy change usually associated with such an arrangement can be minimized by using starting materials in which the required stereochemistry is already present (conformationally fixed system). The influence of the strength of the CH bond attacked on the rate of the ether formation has not yet been investigated in any detail.

The rate  $k_p$  (fragmentation) is mainly dependent upon the stabilisation of a radical on the  $\beta$  carbon atom, other factors being the stability of the carbonyl compound formed, decrease of strain and stabilization or destabilization of polar structures in the transition state (4, 5, 6, 7).

The factors which determine the formation of carbonyl compounds from alcohols with lead tetraacetate have not been investigated until very recently (1, 2).

Rather than determining the effects of structural changes in the substrate on the product composition we have chosen to investigate the influence of changes in reaction conditions (thermal (8) and photolytic (9) decomposition, addition of acid and base) on the relative rates of reactions a - c with three different starting materials, namely with the  $6\beta$ -hydroxysteroid I, the  $4\beta$ -hydroxysteroid IV and the  $11\beta$ -hydroxysteroid VIII. Whereas I gives only products of reactions a and c (II and III)(10), with IV and VIII ether formation (a) (to V, IX and X)(11)

and oxidation (c) (12) (to VII and XII) were observed as well as an epimerisation reaction (to VI and XI) (4, 11) whose first step involves a fragmentation of type b.



The lead tetraacetate reactions were carried out in benzene using about a 4-5 molar excess of oxidant and the results are summarized in Table 1:

TABLE 1

Substrate	Conditions	Products (yields in %)			
		6 $\beta$ , 19-ether II			6-ketone II
I	thermal 47h <sup>a</sup> (+ 8.6m AcOH) <sup>d</sup> photolytic, 30min. <sup>b</sup> (+ 7m pyridine) <sup>e</sup> thermal, 16h <sup>a</sup> (+ 4.9m pyridine)	6 $\beta$ , 19-ether II			6-ketone II
		90 <sup>c</sup>			6.5 <sup>c</sup>
		94 <sup>c</sup>			3 <sup>c</sup>
		3 <sup>c</sup>			95.5 <sup>c</sup>
IV	thermal, 16h <sup>a</sup> (+ 3m AcOH) <sup>d</sup> photolytic, 2h <sup>b</sup> (+4.3m pyridine) <sup>e</sup> thermal, 16h <sup>a</sup> (+4.4m pyridine)	4 $\beta$ , 19-ether V	4 $\alpha$ , 9 $\alpha$ -ether VI		4-ketone II
		74 <sup>c</sup>	7 <sup>c</sup>		8.5 <sup>c</sup>
		75 <sup>c</sup>	6 <sup>c</sup>		1.5 <sup>c</sup>
		9.5 <sup>c</sup>	1 <sup>c</sup>		83 <sup>c</sup>
VIII	thermal, 18h <sup>a, f</sup> photolytic, 2h <sup>b</sup> (+5.2m pyridine) <sup>e</sup>	11 $\beta$ , 18-ether IX	11 $\beta$ , 19-ether X	11 $\alpha$ , 1-ether XI	11-ketone XII
		4.5 <sup>g</sup>	7.5 <sup>g</sup>	23 <sup>g</sup>	54 <sup>g</sup>
		16.5 <sup>g</sup>	30 <sup>g</sup>	42 <sup>g</sup>	4.5 <sup>g</sup>

a) Refluxing benzene. b) Irradiation at 12-15° in pyrex vessel with a high pressure mercury lamp Hanau Q 81. c) Gaschromatographic analysis. d) Molar proportions relative to substrate. Experiments without added acetic acid gave erratic results, apparently depending upon the acetic acid content of the lead tetraacetate used. e) Molar proportion relative to substrate. Pyridine was added in order to ensure a sufficient concentration of lead alkoxide (from alcohol and lead tetraacetate). f) Reaction in boiling cyclohexane. g) Chromatography and thin layer analysis.

These results indicate that the oxidation reaction (c) can easily be separated from reactions a and b (cf. also 1,2). On the other hand the remarkable similarity of the ratio of ether (a) to fragmentation (b) - recyclization products in the thermal and photolytic reactions suggest that these two products have a common precursor and that this precursor has some radical character. It therefore seems that the base catalysed oxidation reaction involves a heterolytic cleavage of the PbO-bond and that the base facilitates the removal of the  $\alpha$ -proton.

A second series of experiments demonstrates the influence of the acyl radicals attached to lead on the decomposition of the lead (IV) alkoxide derived from I. Results are summarized in Table 2. While they confirm the fact that ketone formation is less important in photolytic than in thermal reactions there is clearly an increasing tendency of ketone formation if one goes from acetate to benzoate, propionate and isobutyrate. Since the reactions were always run until complete disappearance of lead-IV-salts the increasing amounts of recovered starting material I reflect the increasing rate of decomposition of the lead tetraacylate (and perhaps to a lesser degree the rate of formation of lead IV-alkoxide).

TABLE 2

Reactions of I with different lead (IV) acylates ( 3 to 4.5 molar equivalents) (yields in % starting material, determined by VPC).

Lead-IV-acylate and reaction time	6 $\beta$ ,19-ether	6-ketone	recovered I
a) thermal reactions <sup>a</sup> (+ 10-20. m of corre- sponding acid) <sup>c</sup>			
Acetate 47 h	90	6.5	-
Benzoate 15 h	80.5	15.0	2.5
Propionate 48 h	24.5	16.5	49.5
Isobutyrate 48 h	3.5	14	79.5
b) photolytic reactions <sup>b</sup> (+ 7 m pyridine) <sup>c</sup>			
Acetate 30 min.	94	3	1
Benzoate 60 "	85	10	1.5
Propionate 60 "	62	14	20
Isobutyrate 15 "	4	12	82

a) Refluxing benzene.

b) Irradiation at 12-15° in benzene with high pressure mercury lamp in pyrex vessel.

c) Molar equivalents relative to substrate.

Although the change in the type of decomposition of the lead IV alkoxide bond could be simply a consequence of steric compression around the lead atom<sup>c)</sup> this view is probably insufficient to explain the position of the benzoate in table 2. The possibility of a simultaneous cleavage of lead acyloxy and lead alkoxy bonds (probably in a more highly associated, perhaps dimeric lead-IV complex) must be considered. Clearly further experimental data are needed for a more detailed understanding of the observed phenomena. For a discussion of further details of the decomposition of lead IV alkoxides see reference 4.

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c) Steric compression seems to favour the heterolytic decomposition of lead (IV) alkoxide, cf. the much higher yield of 11-ketone XII as compared with the 4- and 6-ketone VII and II in table 1 (cf. also 3, 10).

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