

Isotopic exchange of active methyl hydrogens *

II. Deuteration of diphenylmethylpyrylium and methyltropylium salts

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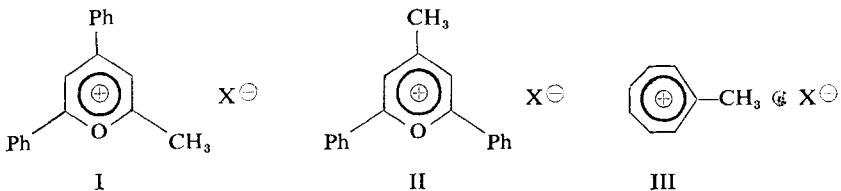
SUMMARY

Methyl groups of 2,6-diphenyl-4-methylpyrylium, 2,4-diphenyl-6-methylpyrylium and methyltropylium salts were deuterated with deuterium oxide and/or acetic acid. The dedeuteration rates of the two diphenylmethylpyrylium salts are contrary to expectations, the 4-methyl group reacting faster than the 2-methyl groups at 50° in acetic acid.

INTRODUCTION.

In previous papers it was shown by means of isotopic analysis ^(1,2), infra-red ⁽³⁾ and nuclear magnetic resonance spectra ⁽⁴⁾ that benzylic hydrogens of alkyl groups in α and γ positions of pyrylium rings are deuterated in mild conditions (in water at 80-100° C for 1-2 hrs with no catalyst added). At pH 5 the isotopic exchange proceeds faster than at pH 1, but even at acidities as high as that, the exchange is fairly rapid. A kinetic study of the dedeuteration of 2,4,6-tri-d₃-methylpyrylium perchlorate ⁽¹⁾ gave a composite kinetic curve which provided evidence for a faster exchange of the α -standing methyl groups than of the γ -methyl.

The present study was undertaken in order to compare the isotopic exchange of : (i) two pyrylium salts with only one methyl group able to undergo exchange, namely 2,4-diphenyl-6-methylpyrylium [I] and 2,6-diphenyl-4-methylpyrylium [II]; and (ii) methyl-substituted pyrylium [I, II] and tropylium salts [III].



* Received on 14 June 1965.

EXPERIMENTAL PART.

2,6-Diphenyl-4-methylpyrylium chloroaluminate [II, X = AlCl₄] was prepared by the dibenzoylation of isobutene ⁽⁶⁾. Into 250 g benzoyl chloride, 133 g powdered anhydrous aluminium chloride were introduced at 10-15° C with external cooling and mechanical stirring, then at 5-10° C, 90 ml t-butyl chloride were added for 1 hr. The mixture was stirred for 3 hrs longer, then left overnight. The next day it was heated at 50° C for 6 hrs and then poured into 1 kg crushed ice with 50 ml hydrochloric acid and 700 ml ether. The suspension was filtered off and the residue was washed with ether. The filtrate was separated and the aqueous layer treated with perchloric acid for recovering the difficultly soluble perchlorate [II, X = ClO₄]. The ethereal layer contains 1-phenyl-3-methyl-2-buten-1-one and 3,3-dimethyl-1-indanone, ⁽⁷⁾ and when it precipitates no more chloroaluminate on dilution with ether, it can be worked up for recovering these ketones. The residue of the filtration contains the chloroaluminate and for purification it is dried, then boiled with small portions of 0.1 N hydrochloric acid and filtered. The filtrate is acidified strongly after cooling with conc. hydrochloric acid, when the chloroaluminate crystallizes as yellow needles. In the filtrates, perchloric acid can precipitate the last traces of II.

The chloroaluminate in 0.1 N hydrochloric acid yielded the fluoborate [II, X = BF₄] by treatment with fluoboric acid.

2,4-diphenyl-6-methylpyrylium sulphoacetate [I, X = AcOSO₃] was prepared from acetophenone and suphoacetic acid ^(8,9) and then recrystallized from ethanol. Perchloric acid precipitates the perchlorate [I, X = ClO₄] from an acetic acid solution of the suphoacetate.

Methyltropylium perchlorate was prepared from methyltropyliene (obtained photochemically from diazomethane and toluene ^(10,11) and triphenylmethyl perchlorate ⁽¹²⁾ in equivalent amounts in acetonitrile at room temperature. After evaporating the solvent in vacuum and removing with ether the triphenylmethane formed by hydride uptake, the sensitive ⁽¹³⁾ methyltropylium perchlorate ⁽¹⁴⁾ was obtained.

Carboxyl-deuterated acetic acid was prepared ⁽¹⁵⁾ by refluxing for 1 hr 1.1 moles acetic anhydride with one mole 99.8 % deuterium oxide, followed by fractionation.

Isotopic analyses were carried out on the basis of the thermal conductivity of hydrogen-deuterium mixtures, by combustion of 0.2 g samples, condensing the water at -70° C, reducing it on zinc at 400° C and determining the deuterium content by injecting the gas into a gas chromatograph equipped with a catharometer and a charcoal column for separation of other gases. The height of the hydrogen peak depends on the deuterium content and this is read off from a calibration curve established with standard samples of deuterium oxide of various concentrations. The results are reproducible within 2 %.

Deuterations and dedeuterations were carried out by heating rapidly in a thermostated bath the organic salt in acetic acid (AcOD or AcOH, respectively) for a specified time (Table I) in a flask with reflux condenser protected against atmospheric moisture. After rapid cooling, ether was added and the precipitated salt filtered off and washed with ether. The solubility of sulphoacetate I, chloroaluminate II and perchlorate III allowed concentrations as high as 20 %, but the fluoborate II and the perchlorate I required larger amounts of acetic acid for having a homogenous solution (approx. 2 %).

The exchange of tropylium perchlorate was performed similarly, but the work-up was different. After heating 10 % solutions of the perchlorate in AcOD or AcOH, the solution was chilled and hexachloroplatinic acid was added. The precipitated methyltropylium hexachloroplatinate was collected on a filter, dried, and analyzed for deuterium.

RESULTS.

The deuteration of diphenylmethyl perchlorates [I and II, X = ClO₄], was difficult because they are difficultly soluble. Therefore the more soluble 2,4-diphenyl-6-methylpyrylium sulphoacetate [I, X = AcOSO₃] and 2,6-diphenyl-4-methylpyrylium fluoborate or chloroaluminate [II, X = BF₄ or AlCl₄] were tested. Refluxing in D₂O showed that II is indeed deuterated, but I and III are resinified in these conditions. Recourse was therefore had to deuteration by heating in carboxyl-deuterated acetic acid AcOD.

All three compounds I, II and III are indeed deuterated by hot acetic acid. The results of the deuteration are shown in the upper half of Table I. The deuteration of perchlorate I and of fluoborate II are not included in the table. The values from the last two columns in Table I were calculated after the following procedure. The uncorrected values (for infinite dilution) of a compound with x exchangeable and y non-exchangeable hydrogens are given by the expression:

$$100 \frac{20x}{1.105} : \left(\frac{20x}{1.105} + 18y \right)$$

(x and y are for [I]⊕ AcOSO₃⊖, 3 and 15; for [II]⊕ AlCl₄⊖, 3 and 12; for [III]⊕ ClO₄⊖, 3 and 6).

The corrected values (for the actual concentration and for the distribution coefficient at equilibrium

$$\alpha = \left(\frac{[D]}{[H]} \right)_{\text{subst}} : \left(\frac{[D]}{[H]} \right)_{\text{water}} = 0.83^{(16)}$$

are found from the previous values by multiplication with the correction factor

$$f = \alpha \frac{1.05V}{61} : \left(\frac{3m}{M} + \frac{1.05V}{61} \right)$$

TABLE I. Deuterations and deduterations of methyl-substituted cations I, II and III.

Expe- rience No	Compound			Solvent		Temp. (°C)	Time (min)	Volume % D ₂ O in condensed water			
	Cation	Anion X	m (g)	V (ml)	Initial			Final		Corr.	
								Found	Calculated		
1	I	AcOSO ₃	1.5	AcOD	7.5	100	240	0	13	16.7	12.7
2	II	AlCl ₄	3.0	AcOD	7.0	100	240	0	13	20.1	14.8
3	II	AlCl ₄	3.0	AcOD	15.0	100	120	0	15	20.1	15.3
4	III	ClO ₄	0.5	AcOD	5.0	100	120	0	20	33.4	28.0
5	III	ClO ₄	0.5	AcOD	5.0	100	120	13	28	33.4	28.0
6	I	AcOSO ₃	0.5	AcOH	30.0	80	10	13	4	0	
7	I	AcOSO ₃	0.8	AcOH	40.0	50	10	13	13	0	
8	II	AlCl ₄	0.5	AcOH	30.0	80	10	13	3.5	0	
9	II	AlCl ₄	0.8	AcOH	40.0	50	10	13	1	0	

where 1.105 and 1.05 are the densities of D_2O and $AcOD$, while 20, 18, 61 and M are the molecular weights of D_2O , H_2O , $AcOD$ and of the salts undergoing deuteration.

A comparison between the two pyrylium salts I and II can be made on the basis of dedeuteration experiments shown in the lower half of Table I. It can be seen that at $50^\circ C$ only the 4- d_3 -methyl derivative II is markedly dedeuterated in 10 minutes. At $80^\circ C$ both compounds are dedeuterated relatively fast.

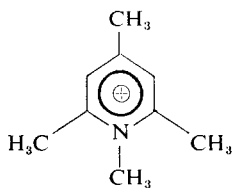
Taking into account that the deuterations were carried at higher temperatures ($100^\circ C$), longer times (2-4 hrs) and that they proceed about three times as fast as dedeuterations owing to the kinetic isotopic effect, the deuterations of I and II in the upper half of Table I must have reached equilibrium: the data for experiments 1-3 confirm this expectation. Experiments 4 and 5 suggest that in comparable conditions, methyltropylium salts are deuterated much more slowly than diphenylmethylpyrylium salts.

The faster dedeuteration of II relatively to I is unexpected and contrary to the analogy with 2,4,6-trimethylpyrylium where methyl groups in positions 2 and 6 are more reactive than the methyl in position 4.

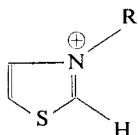
An attempt to deuterate 1,2,4,6-tetramethylpyridinium perchlorate [IV] by refluxation in deuterium oxide showed that this compound does not react.

DISCUSSION.

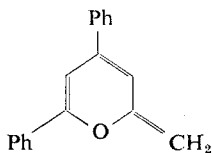
The above experiments show that methyl groups adjacent to tropylium rings or to 2 or 4 positions of pyrylium rings undergo hydrogen exchange in mild and comparable conditions (temperatures under $100^\circ C$ and pH range 1-7). The only compounds so far reported to behave similarly are N-alkylthiazolium salts [V], which exchange the 2-proton in comparable conditions⁽¹⁷⁾; however, this is not an exchange of alkyl hydrogens. The deuteration of pyridines, and probably of pyridinium salts [IV], requires strong bases^(18,20).



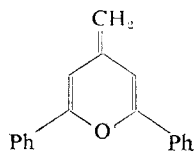
IV



V



VI

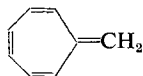


VII

The mechanism of the deuterium exchange of pyrylium salts can involve either the anhydrobases (methylenepyrans VI and VII) or the pseudobases

(1,5-enediones). Since only methyl groups are deuterated, as shown by the nuclear magnetic resonance spectra of deuterated alkylpyrylium salts ⁽⁴⁾, the latter intermediates are excluded in the case of alkyl-substituted pyrylium salts, because they would lead to ring-deuteration as well.

The deuteration of methyltropylium [III] can involve only the « anhydrobase » heptafulvene [VIII]. Its formation (in very small concentrations, taking into account the rapidity of protolytic equilibria) is interesting because of its reported ^(21,22) instability when pure.



VIII

The implication of anhydrobases as intermediates explains why only benzylic hydrogens of alkyl groups in positions 2,4 and 6 of the pyrylium ring undergo exchange : no anhydrobase of 3-methylpyrylium is possible.

The absence of exchange with IV is due to the higher electron density at the ring carbon atoms bearing the methyl groups leading to lower pK_a values, relatively to I, II and III which can undergo exchange. We are at present investigating the deuteration of pyridinium salts with electron-attracting nitrogen substituents; determinations of pK_a values are also under way.

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