Phytochemistry, 1978, Vol. 17, pp. 1995–1999 ©Pergamon Press Ltd. Printed in England. 0031-9422/78/1101-1995 $02.00/0

LIMONOID EXTRACTIVES FROM *APHANAMIXIS POLYSTACHA*

DULCIE A. BROWN and DAVID A. H. TAYLOR
Department of Chemistry, University of Natal, Durban 4001, Republic of South Africa

(*Revised received* 23 *March* 1978)

Key Word Index—*Aphanamixis polystacha*; Meliaceae; limonoids; ^{1}H NMR spectra; ^{13}C NMR spectra.

Abstract—The seed of *Aphanamixis polystacha* has been found to contain a number of limonoids. Eight of these are now described; they are all of the ring A-lactone, ring B-cleaved, meliacan group and are closely related to the known prieurianin.

INTRODUCTION

The seed of *Aphanamixis polystacha* (Wall.) J. N. Parker [synonyms, *Amoora rohituka* Wight et Arn, *Aphanamixis rohituka* (Roxb.) Pierre], Meliaceae, is a rich source of complex limonoids. We have already described the isolation of the main crystalline component, rohitukin [1]; we now describe the isolation of eight related substances from the mother liquors. One of these crystallized, while the other seven remained amorphous; the structures of all were elucidated by Fourier transform magnetic resonance spectroscopy.

RESULTS AND DISCUSSION

Extraction of the seed with refluxing hexane gave a resin, sparingly soluble in hexane, which crystallized readily to give impure rohitukin and mother liquor A. Recrystallization of the crude rohitukin gave a pure sample and mother liquor B. ^{1}H NMR spectroscopy of these mother liquors showed that they contained different mixtures of substances, since each showed several different bands in the δ 8 region of the spectrum, provisionally assigned to the proton in formate esters in different compounds.

Because of their association with rohitukin, it was expected that these compounds would belong to the ring A-lactone, ring B-cleaved meliacan group of limonoids. Previous experience with rohutikin and prieurianin had shown that these are difficult to handle; mild alkaline hydrolysis leads to opening of the ring A-lactone, followed by a variety of further changes, producing a complex mixture of products difficult to resolve [2]. No other reaction, apart from the trivial acylation of the side chain hydroxyl in prieurianin, has yet given a pure product.

Initial experiments aimed at purifying rohitukin by PLC converted it into a complex mixture, as has also been noticed with prieurianin [2]. This does not always happen, but we have not been able to define the conditions under which it does happen. Our first attempts at separating the mother liquors were unsuccessful, but eventually we found that column chromatography on Merck Kieselgel 60, combined with the use of Merck F245 silica gel on aluminium sheets gave a separation without, so far as we could tell, producing any changes in our material, Separation was still difficult; in several cases it was found that fractions were more easily purified after acetylation.

In this way we obtained from mother liquor A six substances which we name rohituka **1–6**, in order of their isolation. None of these crystallized. **1**, **2** and **4** appeared to be pure as judged by TLC and by the sharpness of a ^{1}H NMR spectrum. **3** and **5** were not obtained pure, but gave acetates which were obtained apparently pure; **6** was only obtained in very small amount and neither it nor its acetate has been obtained quite pure.

From mother liquor B we obtained mainly a crystalline material, **7**, mp 239–242°, $[\alpha]_D$ −32°, and smaller amounts of **8** and **9**. **8** remained amorphous, but was apparently pure, while **9** was not obtained pure and was not in sufficient quantity for acetylation.

We have recorded ^{1}H NMR spectra of all these compounds on a CFT 20 Fourier transform spectrometer fitted with a proton probe and homodecoupler. ^{13}C NMR spectra were also obtained of **1**, **2** and **7**, but no chemical transformation products of any of these compounds have yet been obtained. All spectra were recorded at 60° to obviate the difficulties noted in prieurianin **11** [3] due to restricted rotation of the molecule about the C-9, C-10 bond at lower temperatures.

We now consider the spectra obtained for each substance. **2** was obtained as a gum which gave a gummy acetate. Both these retained solvent tenaciously; they were evaporated several times *in vacuo* with $CDCl_3$, which effectively removed other solvents, before recording the spectra. The ^{1}H and ^{13}C NMR spectra of **2** were similar to those of prieurianin. The differences were that in the ^{13}C NMR spectrum the resonance due to the ketonic carbonyl group of prieurianin was absent, being replaced by an extra resonance in the C—O region of the spectrum, while the ^{1}H NMR spectrum showed an additional one proton multiplet at δ 5.70. This suggests that **2** differs from prieurianin in that the C-15 carbonyl group of the latter is replaced in **2** by an acyl group. This suggestion is supported by double resonance experiments which show the δ 5.70 multiplet to be coupled to a multiplet at δ 2.32, which is coupled to the characteristic wide H-17 triplet [3] at δ 4.05 ($w/2 = 20$ Hz). In addition to this the ^{1}H NMR spectrum of **2** shows resonances which can be attributed to a methoxy carbonyl group, two acetates, a formate group and to the same acid, 2-hydroxy-3-methylvaleric acid, as is present in prieurian-

in. There are also 1-H multiplets at δ 5.85 and 5.47, a doublet at δ 6.15 and a broad 2-H singlet at δ 3.92 which is replaced by a doublet of doublets (δ 4.56, 4.07, J = 13 Hz) in the spectrum of the acetate. This latter shows two new acetyl groups, the second of these being associated with the appearance of a doublet at δ 4.72 (J = 4.5 Hz) which is typical of H-2′ in the acetylated hydroxy acid. Double resonance experiments show a small coupling between the formate resonance and the multiplet at δ 5.4, which is further coupled to the doublet at δ 6.15 and a doublet at δ 3.23. This is consistent with the location of the formate at C-11 as in prieurianin; by analogy with prieurianin we place the hydroxy ester at C-12 and an acetate at C-1, while the hydroxy methyl group is located at C-29. We therefore assign **2** the structure 15-dihydro-29-deactylprieurianin 15-acetate. The ^{13}C NMR spectrum of **2** and its acetate are consistent with this structure. The problem of the orientation of the 15-acyl group will be considered later.

1 gives only a monoacetate, in which the new acetate is on a hydroxymethyl group. The spectra of this compound are almost identical to those of **2**, differing only in the loss of the resonances assigned to the hydroxy acid at C-12, in place of these appeared resonances which we assign to a 3-methylbutyric acid residue, as in rohitukin. We therefore assign **1** a structure differing from **2** only in the substitution at C-12.

3 was also an impure gum, giving an apparently pure monoacetate, the ^{1}H NMR spectrum of which shows the characteristic H-2′ doublet at δ 4.82 (J = 4.5 Hz). We therefore consider that **3** is an ester of 2-hydroxy-3-methylvaleric acid, like prieurianin. The spectra of **3** acetate are very different from those of **1**. The ^{13}C NMR spectrum shows the presence of a ketone, similar to that in rohitukin. The ^{1}H NMR spectrum shows no carbomethoxy group and only one acetate, not present in **3** itself, though there is a doublet of doublets (δ 4.35, 4.03, J = 12 Hz) suggesting an acylated C-29. We therefore consider **3** to belong to the 7-29 lactone group, like rohitukin (**10**), rather than the ring opened group, like prieurianin or **1**. There is no formate, and only one other resonance (*d*, δ 5.84) which can be attributed to a proton vicinal to an acyloxy group. We consider provisionally that this is due to H-12, on account of the presence in the molecule of the characteristic C-12 hydroxy acid. This assignment is supported by double resonance experiments, which show the doublet to be coupled to a multiplet (δ 3.79), further coupled to a doublet (δ 3.22), which is consistent with the usual H-12, H-11, H-9 chain, with the formate at C-11 replaced by some other group, probably an oxide. The spectrum also shows a multiplet (δ 3.98), coupled to a two proton resonance near δ 2.5 which is not further coupled. This we consider to represent the other end of an oxide bridge, which we locate at C-1. On this basis, we assign **3** its structure. Mild hydrolysis of prieurianin, dregeanin and rohitukin has been shown to give products with a similar 1-11 oxide bridge [2], although in these the ring A-lactone has also been opened.

4 gave a ^{1}H NMR spectrum which was extremely similar to that of prieurianin, the only difference being the absence of the bands attributed to the hydroxymethylvaleric acid residue and the presence instead of bands which we attribute to 3-methylbutyric acid. We therefore consider that it is the 3-methylbutyrate ester corresponding to prieurianin. **4** did not give an acetate.

5 was not obtained pure but gave an apparently pure acetate. The spectrum of this was very similar to that of **3**, except that it showed the presence of two acetate groups, only one introduced by acetylation, and an additional one proton multiplet at δ 5.57, ($w/2$ = 16 Hz). There was insufficient of this material for double resonance experiments, but the similarity of the multiplet to that due to H-15 in substance **1** (δ 5.71, $w/2$ = 16 Hz) leads us to propose that this compound is the 15-acetate corresponding to **3**, and has the structure shown.

6 was also not obtained pure, it gave a ^{1}H NMR spectrum which was very similar to that of **3** except that it showed a methyl ester, and lacked the doublet of doublets due to 2H-29 in the lactone ring of **3**. We therefore suggest that **6** is similar to **3**, except that it contains the ring opened form of the 7-29 lactone, as in **1**. Acetylation gave a slightly impure acetate, which did not show the characteristic H-2′ resonance of the acetylated hydroxy acid residue. We therefore suggest that **6** belongs to the 12(3-methylbutyrate) series. In view of the small amount available, we have not been able to carry out double resonance experiments or determine a ^{13}C NMR spectrum to confirm this structure.

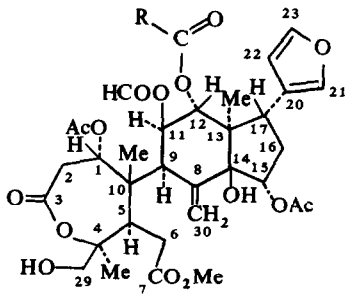
Mother liquor B, from the recrystallization of crude rohitukin (**10**), gave the crystalline **7**, and two non-crystalline compounds **8** and **9**. The ^{1}H NMR spectra of **7** showed no carbomethoxy group; a doublet of doublets (δ 4.37, 4.10, J = 12 Hz) suggested the presence of 2H-29 in a C-7:C-29 lactone ring as in rohitukin. There was a formate, irradiation of the formate proton resonance at δ 7.97, led to the identification of H-11, H-9 and H-12 as in the case of **2**. There was also evidence of the presence of an α,β-unsaturated lactone as in obacunone; a pair of coupled doublets at δ 7.58 and 6.11 (J = 12 Hz) representing H-1 and H-2 in this system. Further double resonance experiments showed the 2H-6 multiplet (δ 2.62) coupled to a triplet (H-5, δ 4.0); and H-2′ (δ 3.30) coupled to H-3′ (δ 1.65), which was further coupled to a methyl doublet at δ 0.90. The complete structure of **7** is therefore revealed by decoupling in this way. Acetylation gave the expected monoacetate, which remained amorphous. The ^{13}C NMR spectrum was in agreement with this structure.

8 was obtained as an apparently pure gum, but the amount was too small to allow acetylation or decoupling. The ^{1}H NMR spectrum was similar to that of **7**, except that it showed the presence of a carbomethoxy group and a second acetate, at C-29 (δ 4.72, 4.35, J = 11 Hz). We therefore suppose it to be the methyl ester acetate (**8**) corresponding to the lactone (**7**). It is noteworthy that in this compound H-1 resonated at δ 7.05, considerably upfield of its position in **7**.

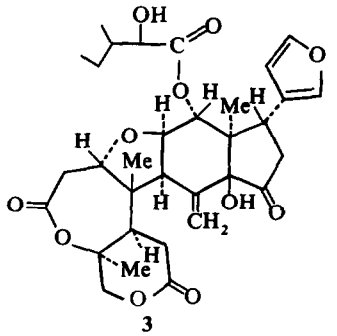
9 was not obtained pure; the ^{1}H NMR spectrum was however very similar to that of **7** and we consider it is probably a different ester; in view of the other compounds isolated we suggest it is the corresponding 12(3-methylbutyrate) ester.

A further compound obtained from the initial mother liquors also appeared to be an unsaturated lactone, since it differed from **7** in the absence of the resonances we ascribe to H-15, it may be the 1,2-unsaturated 15-ketone corresponding to rohitukin, but insufficient material was available to investigate this proposal either by decoupling or by examination of the ^{13}C NMR spectra.

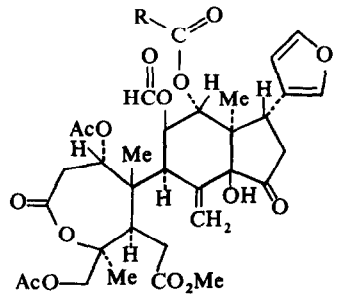
We now return to the problem of the stereochemistry



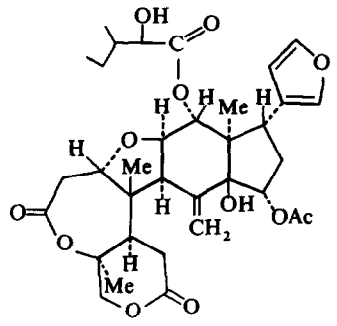
1 R = CH_2CHMe_2
2 R = CHOHCHMeEt



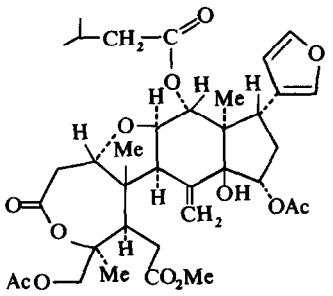
3



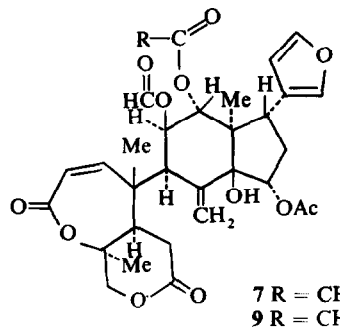
4 R = CH_2CHMe_2
11 R = CHOHCHMeEt



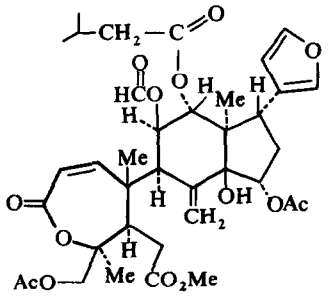
5



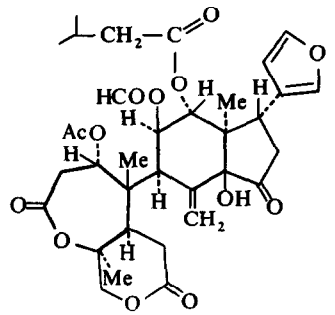
6



7 R = CHOHCHMeEt
9 R = CH_2CHMe_2



8



10 Rohitukin

at C-15 in the 15-acetoxy compounds. The sum of the coupling constants between H-17, which is known [3] to be β, and 2H-16 in 1 is 20 Hz; examination of a model, using this value as a guide to the conformation of ring D, leads to the prediction that the sum of the couplings between H-15α and 2H-16 should have approximately the same value, while with H-15β, the expected value is less than half this [4]. Since the observed value in 1 is 16 Hz, we propose that the 15-acetate in the compounds we have studied is α-oriented, as shown in the formulae.

This conclusion is in line with the probable biosynthesis. By analogy with proposals for other limonoids [5–7] we expect the ring D oxidation pattern to arise from a 14,15β-oxide (found in dregeanin [1] and in *Guarea*

thompsonii root bark substances [2], which is ring-opened to a 14,15-glycol that is acetylated or oxidized to the ketone. Mechanistically, ring opening of the epoxide would be expected to occur by fission of the C-14, O bond, but this would lead to the formation of a 15-ketone, or to rearrangement [8]. We therefore suggest that in this case ring opening occurs for steric reasons at C-15 (cf. the opening of a steroidal 5,6α oxide [9]), leading to the observed 14β-hydroxy group and, by inversion at C-15, to a 15α-acetoxy group. It would then seem reasonable to suggest that the 14β-hydroxy-15-ketones are derived by oxidation of an intermediate 14β,15α-glycol.

From TLC experiments on the crude mixture, it appears that rohitukin and **1** and **2** are the main limonoids of the extract, probably in comparable amounts. We do not know if the other substances are present in the seed, or whether they are artefacts of isolation. Similar substances are produced by mild hydrolysis of rohitukin or prieurianin, [2] but in these the first change to occur is the opening of the seven membered lactone in ring A, which does not recyclize. Since all our compounds have the intact ring A-lactone, we believe that they are not artefacts, but are true natural products. Analogues to the 1-acetoxy and 1,2-unsaturated lactone ring compounds are found in nomilin and obacunone; an analogue to the 1, 11 ether type of compound has been isolated by Halsall from *Khaya anthotheca* [10].

The quantities of the substances isolated depends not only on the amount present, but also on the ease of separation. The quantities of **1** and **2** present are considerable, of the order of 0.1%, though isolation is tedious. We have little idea how much of the other substances are actually present in the extract; the isolation of 50 mg was adequate for a ^{13}C NMR spectrum, 10–15 mg for a study of the double resonance ^1H NMR spectrum, and a few mg for simple determination of a ^1H NMR spectrum.

EXPERIMENTAL

The seeds of *Aphanamixis polystacha* (2.5 kg, gathered from a tree in the Durban Botanical Garden) were extracted with refluxing isohexane. Evaporation of the solvent gave an oil (*ca* 1 l.), not further investigated) and a resinous solid (24 g).

Table 1. ^1H NMR spectra of *Aphanamixis polystacha* compounds.

Proton	10*	1	1* acetate	2*	2 acetate	3* acetate	4	5 acetate	6 acetate	7*	7 acetate	8	9
1	5.25		5.78	5.85	5.75	3.98	5.26	4.16		7.58		7.05	7.62
	m.		*m*8	*m* 6	*m*	*m* 10	*m*	*m*		*d* 12		*d* 12	*d* 12
2	3.24		2.98			2.50				6.11		6.12	6.11
	bs		*m*			*m*				*d* 12		*d* 12	*d* 12
9	3.72		3.25	3.23		3.22				3.16			
	d 7		*d* 6	*d* 5		*d* 6.3				*d* 10			
11	5.49		5.40	5.47	5.55	3.79	5.5	4.06		5.70		5.67	
	m 19		*m*17	*m* 16	*m*	*m* 15	*m* 19	*m*		*m*		*m*	
12	6.06		6.12	6.15	5.97	5.84	6.25	5.75		6.25		6.12	
	d 11		*d* 11	*d* 11	*d* 11	*d* 9	*d* 12	*d* 8		*d* 11		*d* 12	
15	NA		5.71	5.70	5.70	NA	NA	5.57		5.75			
			m 16	*m* 13	*m*			*m* 16		*m*			
16	2.4		2.38	2.32						2.37			
	m		*m*	*m*						*m*			
17	3.98		4.0	4.05				3.85		4.01			
	m 18		*m* 20	*m* 20				*m*		*m* 10			
29A	4.18	3.86	4.61	3.92	4.56	4.35		4.35		4.37		4.72	
	s	*bs*	*d* 13	*bs*	*d* 13	*d* 12		*d* 12		*d* 12		*d* 11	
29B	4.18	3.86	4.15	3.92	4.07	4.03		4.05		4.10		4.35	
	s	*bs*	*d* 13	*bs*	*d* 13	*d* 12		*d* 12		*d* 12		*d* 11	
30A	5.92	5.36	5.23	5.40		5.42	5.98	5.25		5.32		5.35	
30B	5.58	5.22	5.18	5.27		5.42	5.74	5.17		5.27		5.35	
α furan A	7.36	7.4	7.4	7.37	7.35	7.37	7.38	7.37		7.4	7.37	7.35	7.37
α furan B	7.24	7.26	7.26	7.25	7.35	7.37	7.28	7.37		7.25	7.37	7.20	7.25
β furan	6.28	6.30	6.30	6.32	6.3	6.3	6.44	6.35		6.32	6.32	6.27	6.32
CO_2Me	NA	3.75	3.74	3.77	3.70	NA	3.69	NA	3.80	NA	NA	3.85	NA
Ac	2.1	2.24	2.28	2.31	2.27	2.21	2.22	2.25	2.22	2.2	2.2	2.2	2.2
		2.07	2.2	2.15	2.14		2.15	2.22			2.09	2.12	
			2.16		2.14								
					2.11								
CMe	1.83		1.70	1.70	1.73	1.92	1.81	1.78	1.67	1.75	1.75	1.61	
	1.75		1.47	1.56	1.51	1.27	1.66	1.3	1.36	1.27	1.27	1.36	
	0.98		1.02	1.10	1.33	1.05	1.03	1.10	1.15	1.12	1.12	1.13	
2′					4.72	4.82		4.86		3.30	4.68		
					d 4.5	*d* 4.5		*d* 3.5			*d* 4		
Formate	7.85	8.06	8.06	8.07	8.06	NA	8.04	NA	NA	7.97	7.97	7.97	8.0

Determined in $CDCl_3$ at 60°, on a CFT 20 spectrophotometer at 80 MHz, in ppm from internal TMS. Couplings, J for doublets, $J_{AX} + J_{BX}$ for ABX systems, are given in Hz.
NA = Not applicable. * = Investigation by double resonance.

Crystallization of this from MeOH–CH_2Cl_2 gave crude rohitukin (2.09 g) and a residue termed mother liquor A. The solid was fractionally crystallized from the same solvent to give a residue termed mother liquor B, and rohitukin (**10**) (1.25 g), mp 275–280°. Later, it was found easier to purify crude rohitukin by chromatography. (Found: C, 62.0; H, 6.8. $C_{34}H_{42}O_{13}$ requires: C, 62.0; H, 6.4%. ^{13}C NMR spectrum: 206.6 *s*, 173.3 *s*, 172.3 *s*, 169.5 *s*, 169.3 *s*, 160.3 *d*, 142.9 *d*, 140.8 *d*, 139.2 *s*, 124.7 *t*, 123.0 *s*, 110.8 *d*, 81.2 *s*, 79.5 *s*, 78.0 *t*, 75.8 *d*, 75.7 *d*, 71.8 *d*, 52.0 *d*, 49.7 *s*, 46.4 *s*, 42.9 *t*, 42.8 *d*, 42.0 *d*, 37.6 *t*, 35.4 *d*, 32.2 *t*, 24.9 *q*, 23.3 *q*, 22.5 *t*, 22.5 *q*, 21.4 *q*, 21.2 *q*, 12.9 *q*.)

Resolution of the mother liquors was achieved by repeated chromatography over silica columns, eluting with EtOAc–hexane, and collecting fractions with an automatic collector. Purity of the fractions was followed by analytical TLC on Merck F-254 Si gel on Al sheets, and by ^1H NMR spectroscopy. In this way we obtained 10 pure or nearly pure fractions, which were finally evaporated *in vacuo* with $CDCl_3$ to obtain spectroscopic samples. The ^1H NMR spectra are collected in Table 1. From mother liquor A we obtained the following:

Substance **1** (*ca* 150 mg), which remained amorphous, and gave an amorphous acetate with Py and Ac_2O [^{13}C NMR spectrum of the acetate: 173.6 *s*, 172.2 *s*, 170.9 *s*, 168.8 *s*, 169.8 *s*, 169.6 *s*, 160.9 *d*, 142.8 *s*, 142.6 *d*, 140.5 *d*, 123.8 *s*, 119.7 *t*, 110.9 *d*, 88.4 *s*, 84.4 *s*, 73.3 *d*, 73.0 *d*, 72.7 *d*, 70.6 *d*, 67.9 *t*, 53.0 *q*, 52.1 *d*, 50.7 *s*, 48.7 *s*, 44.2 *d*, 43.0 *t*, 39.7 *d*, 36.2 *t*, 36.0 *t*, 36.0 *d*, 33.6 *t*, 24.9 *q*, 22.4 *q*, 22.3 *q*, 20.8 *q*, 20.8 *q*, 20.7 *q*, 20.1 *q*, 13.2 *q*].

Substance **2** (*ca* 150 mg) which also remained amorphous and gave an amorphous acetate with Py and Ac_2O [^{13}C NMR spectrum of the alcohol: 175.5 *s*, 175.3 *s*, 171.4 *s*, 170.4 *s*, 168.9 *s*, 161.3 *d*, 142.9 *d*, 142.9 *s*, 140.7 *d*, 123.7 *s*, 120.0 *t*, 110.7 *d*, 92.1 *s*, 84.3 *s*, 75.1 *d*, 74.9 *d*, 73.8 *d*, 72.6 *d*, 69.7 *d*, 66.2 *t*, 52.8 *q*, 52.0 *d*, 50.9 *s*, 48.8 *s*, 41.6 *d*, 39.6 *d*, 38.1 *d*, 36.1 *t*, 35.4 *t*, 35.2 *t*, 34.2 *t*, 22.7 *q*, 20.7 *q*, 20.7 *q*, 19.4 *q*, 15.1 *q*, 13.3 *q*, 11.4 *q*.].

Substance **3** was not obtained pure, the amorphous acetate (*ca* 25 mg) appeared to be pure by TLC and ^1H NMR spectroscopy.

Substance **4** (*ca* 25 mg) appeared pure but remained amorphous.

Substance **5** was not obtained pure, the amorphous acetate (*ca* 10 mg) appeared to be pure.

Substance **6** was obtained as its acetate (*ca* 5 mg), which was still not obtained pure.

From the mother liquor B we obtained the following:

Substance **7** (300 mg) mp 239–242°, $[\alpha]_D$ −32° [Found: C, 62.2; H, 6.6. $C_{35}H_{44}O_{13}$ requires: C, 62.5; H, 6.6%. ^{13}C NMR spectrum: 174.9 *s*, 171.9 *s*, 169.4 *s*, 166.6 *s*, 159.9 *d*, 153.1 *d*, 143.1 *d*, 140.9 *s*, 140.7 *d*, 123.7 *s*, 120.6 *d*, 119.5 *t*, 110.7 *d*, 84.9 *s*, 79,2 *s*, 76.2 *d*, 75.1 *d*, 74.7 *t*, 72.5 *d*, 71.6 *d*, 52.4 *d*, 51.1 *d*, 51.1 *s*, 44.0 *s*, 39.3 *d*, 37.9 *d*, 36.8 *t*, 30.2 *t*, 27.2 *q*, 24.0 *q*, 23.3 *t*, 20.8 *q*, 15.3 *q*, 13.5 *q*, 11.3 *q*.].

The monoacetate remained amorphous.

Substance **8** (*ca* 5 mg) was apparently pure.

Substance **9** (*ca* 5 mg) was not obtained completely pure, but gave a ^1H NMR spectrum which was closely similar to that of **7**.

Acknowledgement—We are grateful to Dr. J. D. Connolly, of Glasgow University, for discussion of these and other related results.

REFERENCES

1. Connolly, J. D., Okorie, D. A., de Wit, L. D. and Taylor, D. A. H. (1976) *J. Chem. Soc. Chem. Commun.* 909.
2. Connolly, J. D., Taylor, D. A. H. *et al.*, unpublished work.
3. Gullo, V. P., Miura, I., Nakanishi, K., Cameron, A. F., Connolly, J. D., Duncanson, F. D., Harding, A. E., McCrindle, R. and Taylor, D. A. H. (1975) *J. Chem. Soc. Chem. Commun.* 345.
4. Jackman, L. M. and Sternhell, S. (1969) in *Applications of NMR Spectroscopy In Organic Chemistry*, 2nd edn, p. 281. Pergamon Press, Oxford.
5. Cotterrell, G. P., Halsall, T. G. and Wriglesworth, M. J. (1970) *J. Chem. Soc. C.* 1503.
6. Buchanan, J. G. St. C. and Halsall, T. G. (1970) *J. Chem. Soc. C.* 2280.
7. Connolly, J. D., Thornton, I. M. S. and Taylor, D. A. H. (1973) *J. Chem. Soc. Perkin Trans. 1*, 2407.
8. Adesogan, E. K., Okorie, D. A. and Taylor, D. A. H. (1970) *J. Chem. Soc. C.* 205.
9. Fieser, L. F. and Fieser, M. (1959) in *Steroids*, p. 194. Reinhold.
10. Halsall, T. G. and Troke, J. A. (1975) *J. Chem. Soc. Perkin Trans. 1*, 1758.