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STEREOCHEMISTRY OF BERTYADIONOL AND RELATED COMPOUNDS

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Abstract—Two new diterpenes related to bertyadionol have been isolated and their structure determined. Degradation of bertyadionol to 2*R*-methylsuccinic acid provided the configuration at C-2 for this compound. The absolute stereochemistry of bertyadionol and its congeners was established by application of INDOR and NOE techniques.

INTRODUCTION

In previous publications[1] evidence was presented for the structure of bertyadionol (**1**), a novel diterpene isolated from *Bertya cuppressoidea* (Euphorbiaceae). The absolute configuration of the cyclopropane ring was obtained by degradation of **1** to (−)-*cis*-homocaronic acid. With this result and by application of NMDR techniques it was possible to determine the absolute stereochemistry of the product (**3**) obtained by pyridine isomerisation of **1**, and, with the exception of the chirality at C-2, the stereochemistry of the reductive acetylation product (**5**). Adoption of these techniques for the determination of the absolute stereochemistry of bertyadionol (**1**) was precluded by the presence of a double bond at the ring fusion (C-4, C-15) and the overlap of the resonance signals of the 5-H and 12-H in the NMR spectrum of **1** or its acetate derivative (**2**).

The elucidation of the structure and absolute stereochemistry of two related diterpenes from *B. cuppressoidea* as well as NMDR results on the trifluoracetate derivative of **1**, have provided information which allows the stereochemistry of the two trisubstituted double bonds in **1** to be assigned the *E*-configuration. These results together with the determination of the stereochemistry at C-2 in bertyadionol, by degradation to 2*R*-methyl succinic acid, provide the absolute stereochemistry of **1**. Attempts to elucidate the structure and stereochemistry of bertyadionol by X-ray crystallographic methods were unsuccessful and only crystal data could be obtained.

RESULTS AND DISCUSSION

As previously reported[1] an ethereal solution of the neutral residues of *Bertya cuppressoidea* deposited crystals of bertyadionol (**1**). Chromatography of the mother liquors afforded, in order of increasing polarity, two new diterpenes designated diterpene B (**6**) and diterpene D (**9**).

Structure of diterpene B (**6**). The crystalline diterpene B (**6**), $C_{20}H_{26}O_4$, was characterised as the mono- and diacetoxy derivatives identifying two of the oxygen functions as OH groups. The IR spectrum of **6** showed OH absorption at 3580, CO bands at 1720 and 1705 as well as bands at 1645 and 1601 cm^{-1} attributed to non-conjugated and conjugated double bond absorptions respectively. Comparison of the UV and NMR spectra of the monoacetate (**7**) with those obtained from the acetate of the pyridine product (**4**) suggested a close similarity between the two structures, although diterpene B contains an extra tertiary OH group. The location of this group at C-15 was suggested by the following observations. Comparison of the NMR spectrum of **4** with that of the monoacetate (**7**) (Table 1) showed that the latter lacked the signal for the 15-H and that the 4-H appeared as a doublet at δ 2·95 (*J* 10·6 Hz) replacing the doublet of doublets at δ 2·89 (*J* 10·8, 5 Hz) for the same proton in **4**. The MS of **6** showed a base peak at *m/e* 151 attributed to the fragment arising from cleavage of the C-7, 8 and C-14, 15 bonds. Similar fragmentations have been observed in the MS of other bertyadionol derivatives but in general appear less important. In the case of **6** the greater ease of fission is consistent with the presence of an α-ketol group.

Confirmation of the structure proposed for diterpene B (**6**) was obtained by conversion of its monoacetate (**7**) to **4**. Attempts to achieve reduction of the α-ketol group by the conventional method with Zn dust in AcOH failed. However the conversion was achieved smoothly by treating *in situ* the trifluoroacetate derivative of **7** with Zn dust at room temperature.[2] The product obtained was identical with a sample of **4**.

Structure of diterpene D(**9**). Diterpene D(**9**) was obtained as an amorphous solid and was characterised as the crystalline monoacetoxy derivative (**10**), $C_{22}H_{30}O_5$. A comparison of the spectral properties of **10** with those of the reductive acetylation pro-

Table 1. NMR data* for some compounds related to bertyadionol (1) (chemical shifts (δ) and coupling constants (Hz))

Compounds	1-H[a]	4-H	5-H[a]	7-H[b]	12-H[a]	15-H	18-H_3	19-H_3	20-H_3[c]	Others
Pyridine product acetate (4)	7·41 (1·1, 0·5)	2·89[b] (10·8, 5)	5·49 (10·8, 1·2)	4·95 (10·7, 2·5)	6·15 (11·3, 1·2)	3·92[e] (0·5, 2·0, 5)	1·88[c] (1·2)	1·84[b] (1·1, 2·0)	1·65 (1·2)	(1·09) 16-, 17-H_3 (1·22) 2·05—$COCH_3$
Diterpene B monoacetate (7)	7·52 (1·2)	2·95[c] (10·6)	5·74 (10·6, 1·2)	4·94 (10·5, 2·4)	7·35 (11·4, 1·2)	—	1·83 br.s.	1·83 br.s.	1·63 (1·2)	(1·08) 16-, 17-H_3 (1·22) 2·04—$COCH_3$
Reductive acetylation product (5)	—	2·66[c] (11·0)	5·40 (11·0, 1·5)	4·87 (11, 3)	6·09 (11·5, 1·5)	3·33 m	1·87[c] (1·5)	1·18[c] (7·0)	1·52 (1·5)	(1·13) 16, 17-H_3 (1·21) 2·01—$COCH_3$
Diterpene D monoacetate (10)	—	2·79[c] (10·0)	5·64 (10·0, 1·2)	4·84 (11·0, 2·6)	7·32 (11·8, 1·2)	—	1·81[c] (1·2)	1·17 m	1·52 (1·2)	(1·08) 16-, 17-H_3 (1·21) 2·03—$COCH_3$

*Obtained at 90 MHz for $CDCl_3$ solutions.
[a]doublet of quartets; [b]doublet of doublets; [c]doublet; [d]triplet; [e]doublet of doublets of quartets.

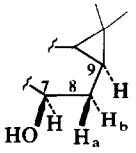
duct (**5**) suggested the same relationship between these two compounds as that observed for **7** and **4** (Table 1). Confirmation of the structure (**9**) assigned to diterpene D was obtained by dehydration of **9** on silicic acid. The resulting compound was identical in all respects with an authentic sample of bertyadionol (**1**).

Stereochemistry of diterpene B and D

Since the absolute stereochemistry of the products of pyridine isomerisation (**3**) and of reductive acetylation (**5**) of bertyadionol are known the interrelation of diterpene B (**6**) and D (**9**) respectively with these compounds immediately establishes the stereochemistry of the cyclopropane ring and of C-7 in these new diterpenes. For diterpene B diacetate (**8**) significant NOE's were observed between the C-6Me protons, 7-H and the 4-H only. Also, the presence of the 15-OH in **6** and **7** causes a marked deshielding of both the 12-H and 5-H. These results are only compatible if both the 5- and 12-ene have the *E*- configurations and if the C-6Me, 7-H and 4-H are on the opposite face of the molecule to the 5-H, 12-H and 15-OH groups.

INDOR measurements monitoring the 7-H and 12-H of **7** and **8** yielded coupling constants (Table 2)

Table 2. Summary of coupling constants obtained by INDOR and decoupling



	Coupling constants (Hz)											
Compound[a]	7-8a	7-8b	8a-8b	8a-9	8b-9	11-9	11-12	4-15	4-5	12-18	5-20	1-19
Pyridine product (**3**)	~9	~2	~14				11·0	4·9	11·2	~1		2
Pyridine product acetate (**4**)	10·7	2·5	13·2	~11·5	~4		11·3	5	10·8	1·2	1·2	1·1
Reductive acetylation product (**5**)	11	3	13·5	12·5	4	8	11·5	11	10	1·5	1·5	
Diterpene B (**6**)	10·6	2·9					11·1		11·0	1·2	1·2	1·2
B monoacetate (**7**)	10·5	2·4	13·3	12·3	3·9	7·6	11·4		10·6	1·2	1·2	1·2
B diacetate (**8**)	11·0	2·6					11·2		10·6	1·2	1·2	1·2
Diterpene D (**9**)	10·6	2·8				8	11·6		10		1·2	
D monoacetate (**10**)	11	2·6	13·2	11·9	4·3	7·6	11·8		10	1·2	1·2	
Bertyadionyl (**2**) acetate	9·6	2·1	14·9	11·4	5·0		11·8	—		1·2	1·5	
Bertyadionyl Trifluoroacetate (**12**)	9·5	2·3	14·9	11·1	5·2		11·0			1·2	1·2	

[a] In $CDCl_3$.

Table 3. NOE measurements on **8**, **10** and **12**

Sample	Protons irradiated		Protons showing NOE (% increase)
Monoacetate of diterpene D (**10**)	C-6Me	H-4(11)	H-7(12)
	OH-15	H-12(6)	H-5(4)
Diacetate of diterpene B (**8**)	C-2Me	H-1(22)	
	C-6Me	H-4(19)	H-7(11)
Trifluoroacetate of bertyadionol (**12**)	C-6Me		H-7(10)

similar to those observed for the pyridine isomerisation product (**3**) and its acetate (**4**). The limitations imposed by these results lead to the absolute stereochemistry for diterpene B as shown in **6**.

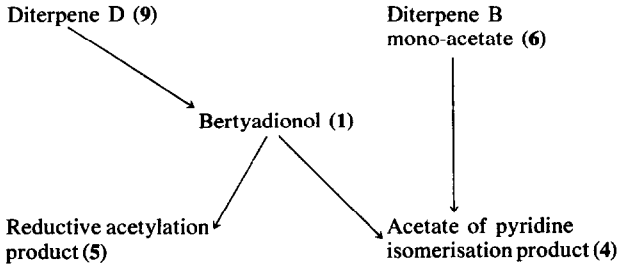
Similar arguments for the data in Tables 1–3 reveal the absolute stereochemistry of diterpene D with the exception of the configuration at C-2, which on the basis of the following results can be assigned the *R*-configuration.

Absolute stereochemistry of bertyadionol

Previous work on bertyadionol had clarified the configuration of the cyclopropane ring and of the C-7 OH. The remaining stereochemical points to be elucidated were (a) the configuration of the C-2 secondary Me and (b) the configuration of the trisubstituted double bonds. A decision on (a) was sought by degradation of bertyadionol to methyl succinic acid which would contain the 1,2,3 and 19-C atoms of bertyadionol. Ozonolysis of **1** followed by oxidative work-up and recovery of the acid fraction yielded 2-methylsuccinic acid identical to an authentic sample. The optical rotation of the sample derived from **1** ($[\alpha]_D + 13{\cdot}6°$) clearly indicated the *R*-enantiomer (**11**) of known absolute configuration.[3,4] Consequently the configuration of C-2 in bertyadionol (**1**) and diterpene D (**9**) is designated *R*.

The transformations (Scheme 1) achieved between the compounds described above indicated that bertyadionol contains the 12-ene in the *E*-configuration, since it is unlikely that a double isomerisation of the 12-ene could occur in the transformation of **9** to **1** and **1** to **4**. Consistent with this, no significant solvent induced shift was observed for the 12-H and the 18-H_3 in the NMR spectrum of **1** in benzene relative to CCl_4 (12-H deshielded by 0·07 ppm, 18-H_3 shielded by 0·09 ppm). An examination of a Dreiding model of **1** and consideration of possible conformations suggests that for the 12(*Z*)-configuration a significant shielding effect on both groups would be predicted.[6] Furthermore, no NOE effect was observed between the C-13Me and the 12-H in the NMR spectrum of bertyadionyl trifluoroacetate (**12**) (see below).

Although indirect evidence was available in support of the *E*-configuration for the 5-ene, isomerisation of this double bond in the transformations **9** to **1** and **1** to **4** or **5** is possible since participation of the 5-ene in resonance stabilization of the probable intermediates in the transformations cannot be excluded. More direct evidence was obtained by the use of NMDR techniques on bertyadionyl trifluoroacetate (**12**). The NMR spectrum showed resonances for the 5-H and 12-H at δ 6·13 and 5·99 respectively and INDOR measurements indicated (Table 2) that the conformation of the macrocyclic ring in **12** is similar to that of **1** and not significantly different to the conformation deduced for compounds **4**, **5**, **6** and **10**. Irradiation of the resonance signal for the C-6Me resulted in a 10% increase of the integral for 7-H whereas no increase was observed for the 5-H. Similarly no NOE effect was observed between the C-13Me and the 12-H. The positive NOE between the C-6Me and the 7-H places these groups in proximity. A similar relationship for these two groups is observed for compounds **8** and **10**. (Table 3). From an examination of a Dreiding model of **12** the NOE results and the coupling constants between 7-H, 8-H_2 and 9-H are compatible only for an *E*-configuration of the 5-ene. For the alternative *Z*- configuration accommodation of these results cannot be achieved from a consideration of the likely conformations. The two double bonds in bertyadionol are therefore assigned the *E*-configuration and the absolute stereochemistry of this novel diterpene is as depicted in **1**.



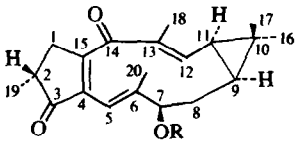
SCHEME 1. Summary of interrelationships.

EXPERIMENTAL

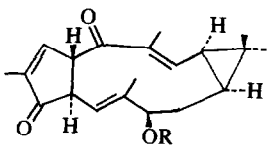
General experimental details are as described previously.[1]

Bertyadionol (**1**). Crystal data: Triclinic probable space group, P_1, (on the basis of intensity statistics), $Z = 2$. Cell dimensions: $a = 8{\cdot}92 \pm 0{\cdot}01$; $b = 12{\cdot}87 \pm 0{\cdot}01$; $c = 8{\cdot}37 \pm 0{\cdot}01$ Å. $\alpha = 92{\cdot}5 \pm 0{\cdot}1°$, $\beta = 90{\cdot}5 \pm 0{\cdot}1°$, $\lambda = 100{\cdot}5 \pm 0{\cdot}1°$.

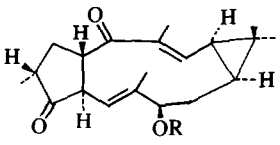
Isolation of diterpene B (**6**) *and D* (**9**). The extraction of *Bertya cuppressoidea* and the recovery of bertyadionol have been described.[1] Chromatography of the mother liquors (156 g) yielded further amounts of **1**, the more polar diterpenes B (800 mg) and diterpene D (200 mg). The yields of the latter were found to vary. A similar extrac-



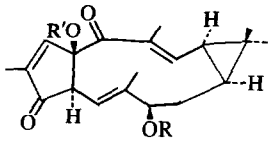
1: R = H
2: R = Ac
12: R = $COCF_3$



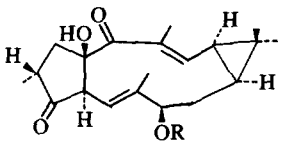
3: R = H
4: R = Ac



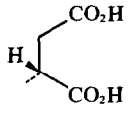
5: R = Ac



	R	R'
6:	H	H
7:	Ac	H
8:	Ac	Ac



9: R = H
10: R = Ac



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tion of *B. cuppressoidea* collected at a different time yielded a neutral extract which afforded bertyadionol (1·5 g) and diterpene D (18 g) *Diterpene B* (**6**) was recrystallized from acetone–ether as needles, m.p. 203°–204°, $[\alpha]_D$ − 105° (*c*, 1·1). (Found: C, 72·36; H, 8·03. $C_{20}H_{26}O_4$ requires: C, 72·70; H, 7·93%). $\nu_{max}^{CHCl_3}$ 1720, 1705, 1645, 1601 cm^{-1}; λ_{max}: 213 (ϵ 11,600), 284 nm (ϵ, 15,000) MS: *m/e* 330 (M^+, 16%), 312, (10), 243 (13), 180 (24), 161 (21), 162 (21), 163 (21), 151 (100), 136 (63), 123 (48). NMR (C_5D_5N; 90 MHz) δ: 8·61 (1-H, br.s); 7·80 (12-H, br.d, J_{11-12} = 11·1 H); 6·47 (5-H, d of q, J_{4-5} = 11·0 Hz, J_{5-20} = 1·2 Hz) 4·23 (7-H, d of d, J_{7-8a} = 10·6 Hz, J_{7-8b} = 2·9 Hz); 3·20 (4-H, d, J_{4-5} = 11·0 Hz); 1·93 (18-H_3, J_{12-18} = 1·2 Hz); 1·66 (19-H_3, d, J_{1-19} = 1·2 Hz), 1·52 (20-H_3, d, J_{5-20} = 1·2 Hz); 0·98 and 1·09 (16- and 17-H_3, s). *Diterpene D* (**9**): $[\alpha]_D$ + 20·7° (*c*, 2·6), $\nu_{max}^{CCl_4}$ 3600, 3430, 1745, 1710, 1645 cm^{-1}, λ_{max} 212 (ϵ 3200), 280 nm (ϵ 5200) MS: M^+ obsd 332·198131 ($C_{20}H_{28}O_4$ requires 332·198747), *m/e* 332 (33%), 296 (16), 253 (21), 245 (28), 151 (35), 136 (57), 123 (46), 122 (40), 121 (63), 109 (85), 108 (65), 107 (100). NMR ($CDCl_3$: 90 MHz) δ: 7·31 (12-H, br.d, J_{11-12} = 11·6 Hz); 5·72 (5-H, d of q, J_{4-5} = 10·0 Hz, J_{5-20} = 1·2 Hz); 3·97 (7-H, d of d, J_{7-8a} = 10 Hz; J_{7-8b} = 2·8 Hz); 2·78 (4-H, d J_{4-5} = 10·0 Hz); 1·79 (18-H_3, br.s); 1·49 (20-H_3, br.d, J_{5-20} = 1·2 Hz); 1·14 (19-H_3, m); 1·07 and 1·23 (16 and 17-H_3, s).

Acetylation of diterpene B (**6**). The compound (50 mg) in pyridine and Ac_2O was left at 0° for 6 h. Recovery of the reaction product with ether afforded an oil which crystallized from n-pentane–ether as needles of the *monoacetate* (**7**; 48 mg), m.p. 198–199°, $[\alpha]_D$ − 17·6° (*c*, 4·9). (Found: C, 71·15; H, 7·96. $C_{22}H_{28}O_5$ requires: C, 70·94; H, 7·58%). $\nu_{max}^{CCl_4}$ 3580, 3425, 1740, 1723, 1645, 1605 cm^{-1}, λ_{max} 219 (ϵ 8600), 282 nm (ϵ 10,000). MS: *m/e* 372 (12%), 312 (15), 202 (35), 151 (35), 136 (100). NMR as described in Table 1.

If the reaction was allowed to proceed for 16 h at room temp the oily *diacetate* (**8**) was obtained. The diacetate could not be crystallized after purification by preparative TLC and had the following parameters. $[\alpha]_D$ − 130·3° (*c* 3·9), $\nu_{max}^{CCl_4}$ 1750, 1730, 1650, 1605 cm^{-1}. MS: M^+ obsd 414·204370. $C_{24}H_{30}O_6$ requires 414·204224, *m/e* 414 (11%) 372 (6) 354 (9), 312 (20), 136 (100). NMR ($CDCl_3$, 90 MHz δ: 7·81 (1-H, br.q, J_{1-19} = 1·2 Hz), 6·73 (12-H, d of q, J_{11-12} = 11·2 Hz, J_{12-18} = 1·2 Hz), 5·77 (5-H, d of q, J_{4-5} = 10·6 Hz, J_{5-20} = 1·2 Hz) 5·77 (5-H, d of q, J_{4-5} = 10·6 Hz J_{5-20} = 1·2 Hz) 4·93 (7-H, d of d, J_{7-8a} = 11·0 Hz, J_{7-8b} = 2·6 Hz); 3·05 (4-H, d, J_{4-5} = 10·6 Hz); 2·09 and 2·0 (—$COCH_3$, s) 1·87 (19-H_3, d, J_{1-19} = 1·2 Hz); 1·85 (18-H_3, d J_{12-18} = 1·2 Hz); 1·60 (20-H_3, d, J_{5-20} = 1·2 Hz); 1·08 and 1·23 (16- and 17-H_3, s).

Reduction of diterpene B monoacetate (**7**). The compound 7 (48 mg) in pyridine (1 ml), THF (3 ml) and $(CF_3CO)_2O$ (0·1 ml) was stirred for 3 h at room temp. Zn dust (0·25 g) was then added and the mixture stirred for 1 h. Addition of ice water followed by normal work-up yielded an oil which was purified by preparative TLC to give a compound (30 mg), identical with that obtained from the pyridine isomerisation product of bertyadionol acetate prepared as described previously. MS: M^+ obsd 356·198504 ($C_{22}H_{28}O_4$ requires 356·198747); *m/e* 35 (11%) 296 (28), 123 (100). $\nu_{max}^{CCl_4}$ 1740, 1720, 1655, 1615 cm^{-1} NMR as described for **4** in Table 1.

The identity of the two samples was determined by comparison of their MS, NMR, IR and mixed TLC.

Acetylation of diterpene D (**9**). The compound (100 mg in pyridine (5 ml) and Ac_2O (2 ml) was left at room temp

for 4 h. The product recovered was crystallized from n-pentane–ether as prisms of the *mono-acetate* (**10**); (70 mg), m.p. 182–183°, $[\alpha]_D + 88{\cdot}7°$ (*c*, 2·3). (Found: C, 70·73; H, 8·00. $C_{22}H_{30}O_5$ requires: C, 70·56; H, 8·08%). $\nu_{max}^{CCl_4}$ 3580, 3480, 1740, 1640, λ_{max} 211 (ϵ 4700), 278 nm (ϵ 10400). MS: *m/e* 374 (M^+; 48%), 314 (44), 253 (44), 136 (100). NMR as described in Table 1.

Dehydration of diterpene D (**9**). The compound (50 mg) in $CHCl_3$ was absorbed on silica gel and allowed to stand at room temp in the dark for 3 weeks. Elution with $CHCl_3$ gave a compound (30 mg) which crystallized from ether as bright yellow needles of bertyadionol m.p. 150–151°, $[\alpha]_D - 380{\cdot}1°$ (*c*, 2·1). The m.p. was undepressed on admixture with an authentic sample, m.p. 150–151°, $[\alpha]_D - 389°$ (*c*, 7·1). Comparison of their MS, NMR and IR confirmed their identity.

Ozonolysis of bertyadionol (**c**). The compound (220 mg) was dissolved in acetone (30 ml), cooled to −60° and ozone passed into the soln for 3 h. Jones' reagent was added to the cold soln and the excess reagent was destroyed by the addition of MeOH. The soln was diluted with water and extracted with 8% $NaHCO_3$ aq. The $NaHCO_3$ extract was acidified to congo red and exhaustively extracted with ether. Evaporation of the ether afforded the crude acid fraction (84 mg). Preparative TLC yielded a compound which crystallized from benzene as prims of 2*R*-methyl succinic acid (**11**, 22 mg) m.p. 108·5–109·5°, $[\alpha]_D^{CHCl_3} + 13{\cdot}62°$ (lit.[5] values for 2*S*-methylsuccinic acid[4]: m.p. 111°, $[\alpha]_D^{Acetone} - 11{\cdot}78°$.) Comparisons of the NMR and MS with those of an authentic sample of 2-methylsuccinic acid confirmed their identity. The corresponding dimethyl esters were identical with respect to mobility and retention time on a 5% UCON-50-HB-2000/NAW Chromosorb W 80/100, at 100° (alone or on mixed injection). MS (diacid) at *m/e* 114 (54%, $M^+ - 18$), 86 (81), 73 (94), 45 (100). NMR (dimethylester; $CHCl_3$: 60 MHz) δ: 1·23 (2-Me, d, $J = 7$ Hz), 2·49–3·09 (2-H, 3-H, m) 3·69 (CO_2 Me, s).

Bertyadionyl trifluoroacetate (**12**). Trifluoroacetic anhydride (0·5 ml) was added dropwise to bertyadionol (300 mg) in pyridine (2 ml). The mixture was allowed to stand for 5 min then diluted with ice water and extracted with ether (30 ml). The ether extract was washed with 1N HCl (10 ml × 2), H_2O (10 ml) and dried over $MgSO_4$. Evaporation of the ether gave the trifluoroacetate (**12**) which crystallized from $CHCl_3$-pentane as needles, m.p. 154–155°. $[\alpha]_D - 280°$ (*c*, 7·4). (Found: C, 64·54; H, 6·24. $C_{22}H_{25}O_4F_3$ requires: C, 64·38; H, 6·13%). NMR ($CDCl_3$; 90 MHz) δ 6·13 (5-H, m); 5·99 (12-H, d of q, $J_{11\text{-}12} = 11{\cdot}5$ Hz, $J_{12\text{-}18} = 1{\cdot}5$ Hz), 5·37 (7-H, d of d, $J_{7\text{-}8a} = 9{\cdot}5$ Hz, $J_{7\text{-}8b} = 2$ Hz, 1·85 (18-H_3, d, $J_{12\text{-}18} = 1{\cdot}5$Hz), 1·57 (20-$H_3$, d, $J_{5\text{-}20} = 1{\cdot}5$ Hz), 1·26 (19-H_3, d, $J_{2\text{-}19} = 7$ Hz), 1·21 and 1·14 (16-, 17-H_3, s).

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REFERENCES

[1]E. L. Ghisalberti, P. R. Jefferies, T. G. Payne and G. K. Worth, *Tetrahedron* **29**, 403 (1973); *Tetrahedron Letters* 4599 (1970)

[2]E. J. Corey, T. M. Brennan and R. L. Carney, *J. Am. Chem. Soc.* **93**, 7316 (1971)

[3]A. Fredga, *Tetrahedron* **8**, 126 (1960); A. Fredga, J. P. Jennings, W. Klyne, P. M. Scopes, B. Sjöberg and S. Sjöberg, *J. Chem. Soc.* 3928 (1965)

[4]A. T. McPhail, G. A. Sim, J. D. M. Asher, J. Monteath Robertson and J. V. Silverton, *Ibid.* (B), 18 (1966)

[5]J. W. ApSimon, J. A. Corran, N. G. Creasey, K. Y. Sim and W. B. Whalley, *Ibid.* 4130 (1965)

[6]F. H. Cottee and C. J. Timmons, *Ibid.* (B), 326 (1968)