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The Conformation of Non-Aromatic Ring Compounds. LXXVIII. The Crystal and Molecular Structure of the 3,20-Bis(ethylenedioxy) Analogue of Provitamin D

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Crystals of 3,20-bis(ethylenedioxy)-pregna-5,7-diene are monoclinic, space group $P2_1$. The lattice constants are $a=12{\cdot}22$, $b=6{\cdot}02$, $c=15{\cdot}77$ Å, $\beta=111{\cdot}9°$ and $Z=2$. Owing to pseudo-symmetry the solution of the structure, carried out by Patterson image-seeking methods, was difficult. The refinement, using photographic data, resulted in an R value of 13·1 %. Rings A and C have distorted chair conformations, while ring B is an irregular half chair with C(10) above and C(9) below the planar moiety of atoms 5, 6, 7 and 8. In terms of torsion angles, the five-membered rings (the two dioxolane rings) have a half-chair conformation and ring D a form halfway between a half-chair and an envelope with C(14) as flap.

Introduction

This paper is part of structural study of steroids in the calciferol series. In a previous paper (Knobler, Romers, Braun & Hornstra, 1972) the crystal structure of an analogue of ergocalciferol (hereafter ECF) was described.

The present report deals with its isomer the 3,20-bis-(ethylenedioxy) analogue of ergosterol (provitamin D_2, Fig. 1) with the systematic name (IUPAC–IUB, 1969) 3,20-bis(ethylenedioxy)-pregna-5,7-diene (hereafter EPD). Except for the dioxolane rings A' and D' the atoms are numbered according to chemical convention.

Because we did not succeed in obtaining proper crystals of the mother compound, ergosterol, we investigated an analogue. The omission of the side group and the introduction of dioxolane rings are, indeed, serious handicaps in the evaluation of the conformational properties of provitamin D_2. Nevertheless the eludication of the structure of the chosen analogue is a useful addition to our knowledge of this class of compounds.

Another steroid also having a 5,7-diene system is lumisterol. The structure of its *m*-bromobenzoate ester has been analysed by Hodgkin & Sayre (1952), but the authors gave no information concerning bond lengths and valency angles in the molecule. The structure of lumisterol itself is now being investigated in this laboratory.

Experimental

As reported earlier (Knobler *et al.*, 1972), it is very difficult to obtain proper crystals of vitamin D and its analogues. The crystals of EPD were smaller and less stable to X-radiation than those of ECF and therefore less suitable for extended measurements by diffractometer-counter techniques. The compound crystallizes in colourless rectangular plates (001). The lattice constants (Table 1) were determined at room temperature from oscillation and zero-layer Weissenberg photographs using copper radiation. If the unit cell is assumed to contain two molecules, a density of $d_x=1{\cdot}23$ g cm^{-3} is calculated, a reasonable number compared with the observed value $d_{\text{obs}}=1{\cdot}20$ g cm^{-3} obtained for the vitamin D analogue.

The reflexions of a crystal with dimensions 0·05, 0·4 and 0·6 mm were recorded at room temperature with non-integrated equi-inclination Weissenberg photographs, using Cu $K\alpha$ radiation and multiple film-technique. Collected were six reciprocal layers with $k=0,1,\ldots.5$ and three layers with $h=0,1,2$ in orientations of the crystal about [010] and [100]. The exposures showed a heavy diffuse background. The crystal used was not single, but consisted of two individuals which gradually became more misaligned and which, moreover, slowly decomposed during the exposures.

Table 1. *Crystallographic data of EPD at* 20 °C

Quoted errors are estimated standard deviations.

3,20-Bis(ethylenedioxy)-pregna-5,7-diene, $C_{25}O_4H_{36}$ $M=400{\cdot}5$ g mol^{-1}, space group $P2_1$, 2 molecules per unit cell

$a=12{\cdot}22\ (3)$ Å	$\beta=111{\cdot}9\ (3)°$
$b=6{\cdot}02\ (2)$	$d_x=1{\cdot}23$ g cm^{-3}
$c=15{\cdot}77\ (4)$	

Cu $K\alpha$ radiation, $\lambda=1{\cdot}54178$ Å, μ(Cu $K\alpha$)$=2{\cdot}7$ cm^{-1}

The visually estimated intensities were reduced to structure factors in the usual way and put on a common scale according to the procedure of Rae (1965). No

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absorption correction was applied. Altogether 1854 reflexions were observed in the *b*-axis set of data and 520 reflexions in the *a*-axis set. An average set from these data was used for computation of the Patterson function, but separate sets were used during the initial stages of the refinement. The *a*-axis set was discarded during the final stages of refinement (see below).

Solution of the structure by Patterson methods

1. *Direct inspection*

The limited amount and the poor quality of the visually estimated photographic data suggested that an approach with direct methods would not be particularly promising and attempts to solve the structure in this way were indeed unsuccessful. Inspection of the Patterson function indicated that the average plane of the molecule is perpendicular to the screw axis. Two orientations differing by a rotation of 180° about the long axis of the molecule could be derived from the pattern of strong peaks near $y=0$. In other words, it was not clear whether the methyl groups C(18) and C(19) pointed in the direction of the positive or the negative *b* axis. Nor did peaks near $y=0{\cdot}5$ lead to an unambiguous choice of the position of the molecule with respect to the screw axis.

2. *Patterson search by computer*

Two of the authors (P.B.B. & J. H.) calculated a sharpened Patterson function and started their Patterson search program (Braun, Hornstra & Leenhouts, 1969*a*) with the same model of 9 atoms as used for the solution of the structure of ECF (Knobler *et al.*, 1972).

This model consisted of ring *C* and ring *D* of the steroid dydrogesterone (Braun, Hornstra & Leenhouts, 1969*b*). Again, two possible orientations were found and several positions compatible with either orientation were allocated as with the direct inspection of the Patterson function. A starting set of atoms, comprising the former atoms and atoms C(18) and C(20) (with their spatial arrangement derived from ECF) did not lead to better results.

3. *Pseudo-symmetry*

The poor results were obviously due to the special shape and orientation of the molecule, which gives rise to a type of pseudo-symmetry similar to that discussed by Hornstra (1970). For the sake of simplicity this will be explained with a perhydrophenanthrene system of three *trans*-fused cyclohexane rings (Fig. 2). The true screw axis relates ring A to A', ring B to B', ring C to C' and the incomplete ring E to E'. But, because the mean plane of the molecule is nearly perpendicular to the screw-axis, there are pseudo-screw axes relating A to B', A to C', A to E' *etc.* Altogether there are four pairs of pseudo-screw axes, indicated by crosses on the Figure.

The position of the starting model, whose orientation is assumed to be correct, is varied systematically in the translation search. A possible solution is recorded each time the vector set fits a set of Patterson peaks. Taking a six-membered ring as starting model all pseudo-axes give rise to competing solutions. Moreover, if pseudo-symmetry were perfect, all peaks corresponding to those false solutions would have double weight. For instance, the vector set from A to C' coincides with that from C to A'.

No such doubling occurs with the sets* A to A', B to B' and C to C', corresponding to the correct solution. This explains why even imperfect pseudosymmetry and incomplete rings offer competing solutions. In the example of Fig. 2 there are five vector sets leading to false solutions $AC'=CA'=EB'=BE'$, $AB'=BA'$, $BC'=CB'$, $AE'=AE'$. The first has even fourfold weight.

4. *Search with extended models*

As shown by Hornstra (1970), the solution can be obtained by combining all pseudo-symmetry-related parts of the molecule into one model. Such a combination, comprising rings A, B and C and having double bonds at positions 5 and 7, was built from Dreiding (atomic) spokes. The overall dimension was adapted to fit the peaks of the Patterson function. But even this model of 14 atoms suffered from pseudo-symmetry and did not offer a unique solution.

When seven atoms, C(15), C(16), C(17), C(18), C(19) O(26) and O(29), were added to the framework the correct orientation was found with methyl groups C(18) and C(19) in the direction of the negative *b* axis. However, the best solution for the position was hardly

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* In this paragraph the designation A,B,A' *etc.* does not refer to the current nomenclature in steroid chemistry, but solely to a composition of cyclohexane rings.

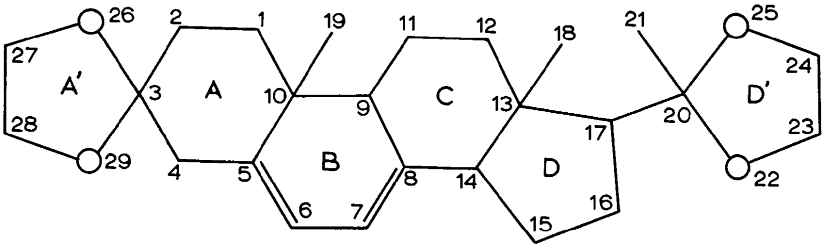

Fig. 1. The numbering of atoms and nomenclature of rings in 3,20-bis(ethylenedioxy)pregna-5,7-diene.

better than several others and this position was not used to find the atoms outside the model, although it proved to be correct later on.

At this moment we looked carefully at the various positions offered by our program. Packing considerations of the two dioxolane rings *A'* and *D'* indicated that several positions could be rejected. All acceptable solutions required that *A'* and *D'* should have their average plane parallel to [010] (see Fig. 5) implying that the configuration of rings *D* and *D'* should be the same as observed in ECF.

We therefore derived a new starting set of 16 atoms comprising rings *C*, *D* and *D'* as well as atoms C(18) and C(21), whose positions were derived from ECF. A search with this model yielded an orientation compatible with the orientation found earlier but no unambiguous position.

The next search was carried out with a combination of the models consisting of 21 and 16 atoms. The combined model was obtained by translating the separate ones (in their proper orientation) until the twelve atoms common to the two models coincided as near as possible and then taking the average. The positional search with this new model of 25 atoms was successful. One position was clearly better than all others and left space for ring *A'*. The atoms still missing were then added in roughly calculated positions.

Refinement

A refinement of the structure with one scale factor, neglect of hydrogen atoms and anisotropic vibrational parameters resulted in $R = 14{\cdot}0\%$. Inspection of a list of observed and calculated structure factors showed that the reciprocal levels were not properly scaled. Moreover, the resulting molecular geometry displayed single-bonded distances between carbon atoms round about 1·60 Å.

For these reasons we decided to apply the procedure of Portheine & Romers (1970) in which separate scale factors are refined for all *a*- and *b*-axis levels. We successively introduced individual isotropic temperature parameters for the heavy atoms, constraints for the hydrogen atoms (at calculated positions with isotropic temperature factors equal to those of the parent carbon atoms) and, finally, anisotropic vibrational parameters for the heavy atoms. Apart from the usual criteria, such as minimization of *R* index and standard deviations of parameters, the geometry of the molecule resulting from each cycle was used as a guide for proper convergence.

When refinement with isotropic individual temperature factors was completed, the *a*-axis data were discarded and the relative scale factors of the *b*-axis levels were fixed. During the following anisotropic refinement, variation of only one scale factor was allowed for. The weighting scheme used during the final cycles was that used by Portheine & Romers (1970). The scattering factors were the same as those employed during the refinement of ECF. A list of cal-

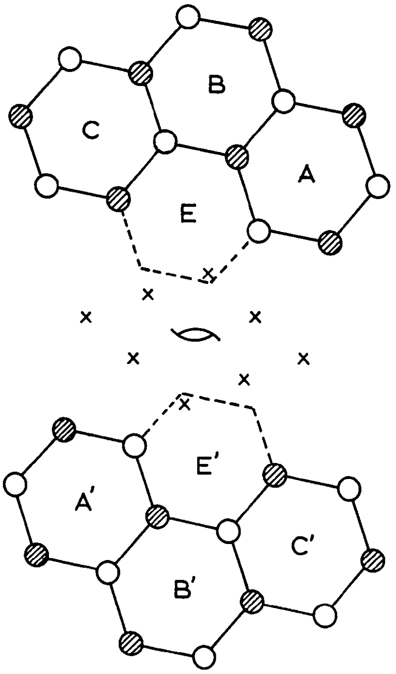

Fig. 2. The perhydrophenanthrene system in relation to the twofold screw axis. The positions of the pseudo-screw axes are indicated by crosses.

Table 2. *Fractional coordinates of EPD chosen in conformity with the accepted absolute configuration and with respect to a right-handed reference system*

The estimated standard deviations (in units of 10^{-3} Å) are given in parentheses.

	x	*y*	*z*
C(1)	0·0824 (9)	0·1140	−0·1968 (9)
C(2)	0·0653 (9)	0·0688 (17)	−0·2979 (9)
C(3)	0·1686 (10)	0·1543 (16)	−0·3179 (9)
C(4)	0·2818 (8)	0·0433 (16)	−0·2563 (8)
C(5)	0·3030 (9)	0·0601 (15)	−0·1560 (8)
C(6)	0·4117 (8)	0·0682 (16)	−0·0918 (8)
C(7)	0·4339 (8)	0·0673 (15)	0·0051 (8)
C(8)	0·3462 (7)	0·0960 (14)	0·0360 (8)
C(9)	0·2218 (8)	0·1366 (14)	−0·0329 (8)
C(10)	0·1975 (8)	0·0247 (15)	−0·1258 (8)
C(11)	0·1232 (8)	0·0908 (17)	0·0046 (9)
C(12)	0·1521 (9)	0·1523 (16)	0·1067 (9)
C(13)	0·2684 (8)	0·0412 (15)	0·1669 (8)
C(14)	0·3660 (8)	0·1391 (14)	0·1341 (8)
C(15)	0·4818 (8)	0·0727 (17)	0·2079 (8)
C(16)	0·4565 (9)	0·0776 (18)	0·2969 (9)
C(17)	0·3209 (8)	0·1155 (15)	0·2686 (7)
C(18)	0·2645 (11)	−0·2124 (17)	0·1559 (10)
C(19)	0·1861 (11)	−0·2310 (17)	−0·1201 (11)
C(20)	0·2717 (9)	0·0273 (15)	0·3351 (9)
C(21)	0·1432 (10)	0·0907 (20)	0·3136 (9)
O(22)	0·2881 (10)	−0·2017 (15)	0·3493 (8)
C(23)	0·3119 (22)	−0·2582 (21)	0·4431 (16)
C(24)	0·3721 (13)	−0·0498 (20)	0·4910 (11)
O(25)	0·3399 (8)	0·1254 (14)	0·4243 (6)
O(26)	0·1760 (9)	0·3935 (14)	−0·3105 (7)
C(27)	0·1838 (19)	0·4803 (17)	−0·3886 (12)
C(28)	0·1339 (15)	0·3140 (19)	−0·4612 (10)
O(29)	0·1515 (8)	0·1060 (14)	−0·4120 (6)

Table 3. *Vibrational parameters U_{ij} of EPD and their standard deviations* (10^{-4} Å^2 units)

The temperature factor is defined as $\exp\left[-2\pi^2 \sum_{ij} h_i h_j a_i^* a_j^* U_{ij}\right]$, $i, j = 1,2,3$.

	U_{11}	U_{22}	U_{33}	$2U_{12}$	$2U_{23}$	$2U_{13}$
C(1)	489 (36)	685 (79)	427 (36)	202 (92)	68 (91)	230 (57)
C(2)	533 (39)	627 (77)	431 (36)	−102 (94)	− 48 (91)	182 (59)
C(3)	657 (44)	428 (63)	377 (34)	12 (89)	−128 (76)	339 (62)
C(4)	522 (36)	626 (72)	366 (32)	87 (82)	30 (79)	418 (56)
C(5)	546 (36)	405 (62)	389 (33)	− 34 (78)	−1 (74)	404 (57)
C(6)	445 (33)	528 (67)	440 (35)	− 24 (77)	16 (80)	342 (55)
C(7)	419 (32)	536 (66)	434 (34)	20 (78)	149 (81)	245 (54)
C(8)	450 (31)	349 (58)	343 (30)	− 47 (68)	− 16 (67)	177 (49)
C(9)	454 (33)	353 (58)	389 (33)	37 (71)	−2 (74)	277 (52)
C(10)	407 (30)	391 (58)	371 (30)	41 (68)	34 (69)	266 (48)
C(11)	457 (37)	773 (85)	426 (35)	− 67 (94)	− 71 (95)	253 (59)
C(12)	504 (37)	725 (78)	438 (38)	− 13 (92)	−231 (92)	462 (61)
C(13)	462 (32)	282 (52)	356 (29)	− 28 (68)	− 40 (64)	296 (50)
C(14)	498 (34)	358 (57)	347 (32)	−234 (73)	−155 (70)	264 (52)
C(15)	430 (33)	844 (85)	377 (33)	− 80 (90)	91 (90)	167 (53)
C(16)	541 (38)	781 (87)	387 (34)	35 (98)	127 (95)	261 (58)
C(17)	508 (35)	421 (61)	352 (32)	− 41 (76)	− 20 (71)	253 (52)
C(18)	731 (51)	508 (74)	507 (43)	−330 (104)	−192 (96)	487 (75)
C(19)	681 (49)	473 (72)	610 (47)	−332 (95)	−294 (98)	636 (79)
C(20)	599 (42)	454 (64)	416 (35)	−2 (85)	0 (78)	406 (63)
C(21)	618 (46)	963 (103)	457 (40)	112 (116)	−115 (110)	462 (70)
O(22)	1131 (53)	514 (56)	600 (37)	303 (92)	137 (79)	826 (73)
C(23)	1811 (162)	661 (121)	846 (87)	91 (201)	484 (168)	1371 (200)
C(24)	859 (68)	988 (110)	476 (45)	220 (136)	569 (119)	224 (86)
O(25)	792 (39)	758 (59)	336 (26)	− 11 (82)	38 (66)	357 (50)
O(26)	969 (44)	410 (52)	433 (29)	−142 (76)	−141 (65)	501 (57)
C(27)	1792 (128)	338 (78)	508 (50)	−333 (152)	−2 (97)	936 (127)
C(28)	1232 (90)	744 (96)	369 (40)	−182 (159)	−105 (105)	429 (94)
O(29)	829 (38)	437 (48)	365 (25)	115 (69)	−174 (59)	353 (49)

culated and observed structure factors from the final cycle ($R = 13{\cdot}3\,\%$, observed reflexions only) is available upon request. The positional parameters and their estimated standard deviations are listed in Table 2; the vibrational parameters, which are in this case artefacts to compensate for systematic errors, are to be found in Table 3. Owing to the limited number of *b*-axis levels the standard deviations of the *y*-parameters are twice as large (0·017 Å) as the corresponding deviations in *x* and *z* (0·009 Å). The molecule (Fig. 5) is oriented perpendicular to [010]. Consequently the average standard error of intramolecular bond lengths is about 0·013 Å, but larger than 0·02 Å for distances C(13)–C(18), C(10)–C(19) and most distances in rings *A'* and *D'* having planes parallel to [010]. The standard deviations in valency and torsion angles are about 0·9° and 1·2°. Evidently these estimates are too low. On the other hand the rather inaccurate cell dimensions do not affect these figures.

Molecular geometry

The geometrical entities of the molecule are depicted in Fig. 3. Apart from rings *A'* and *D'* the distribution of bond lengths is quite normal. The average sp^2–sp^3 single bond length, the average sp^2–sp^2 double-bond length and the sp^2–sp^2 single-bond length, being 1·53, 1·34 and 1·45 Å respectively, are in fair agreement with the values 1·519, 1·348 and 1·465 Å in cyclohexa-1,3-diene (Traetteberg, 1967).

Among the single bonds, the three bonds C(11)–C(12), C(13)–C(17) and C(16)–C(17) are the longest, as in ECF. They occur in the *C*/*D* part of the molecule, which is hardly affected by the ring closure between C(9) and C(10). With the exception of C(17)–C(20), the agreement between the corresponding bond lengths in the *C*/*D* parts of the two molecules (Table 4) is within the standard deviations. The valency angles in the mentioned part of both molecules likewise agree to within one degree. On the other hand the corresponding torsion angles differ slightly and give rise to different conformations (see below).

Table 4. *A number of corresponding bond lengths in EPD and ECF*

Bond	EPD	ECF	Difference
13–14	1·578 (14) Å	1·566 (6) Å	0·012 Å
13–17	1·555 (11)	1·559	−0·004
13–18	1·536 (22)	1·539	−0·003
13–12	1·537 (13)	1·535	0·002
11–12	1·559 (13)	1·551	0·008
14–15	1·514 (10)	1·522	−0·008
15–16	1·545 (13)	1·533	0·012
16–17	1·563 (12)	1·554	0·009
17–20	1·487 (15)	1·520	−0·033
20–21	1·526 (14)	1·514	0·012
8–14	1·497 (11)	1·490	0·007

Owing to larger vibrational parameters and to their specific orientation the bond lengths of rings *A'* and *D'* are less reliable. The distribution of torsion angles indicates that ring *A* is a distorted chair. In agreement with the prediction of Bucourt & Hainaut (1965) and observations of Geise, Altona & Romers (1967), the relatively small torsion angle 1–10–5–4 (−35°) is demanded by the small torsion angle 9–10–5–4 [34°, see Fig. 3(*d*)] and implies rather high torsion angles about the opposite bond C(2)–C(3) and neighbouring bonds C(1)–C(2) and C(3)–C(4). Ring *B* (Fig. 4) is a somewhat irregular half chair. Dallinga & Toneman (1967) established, by means of electron diffraction, that gaseous cyclohexa-1,3-diene has the half-chair conformation with C_2 symmetry.

Ring *C* is also a somewhat distorted chair, the puckering being largest (62°) about C(12) and C(13) and smallest (−32°) about C(8)–C(9). The conformation of ring *D* (Table 5) is about halfway between a half chair and an envelope with C(14) as flap. The conformation about C(17)–C(20) [see Fig. 3(*f*)] is nearly identical with that found for ECF [Knobler *et al.* (1972), Fig. 4(*e*)].

The conformational features of the five-membered rings in EPD and ECF, calculated according to the procedure of Romers, Altona, Buys & Havinga (1969), are listed in Table 5. It is seen that the conformations of the rings *A'*, *D'* and *D* differ largely in the two compounds, the dioxolane rings being half chairs in EPD and envelopes in ECF. The values for the maximum puckering angle φ (max) of the dioxolane

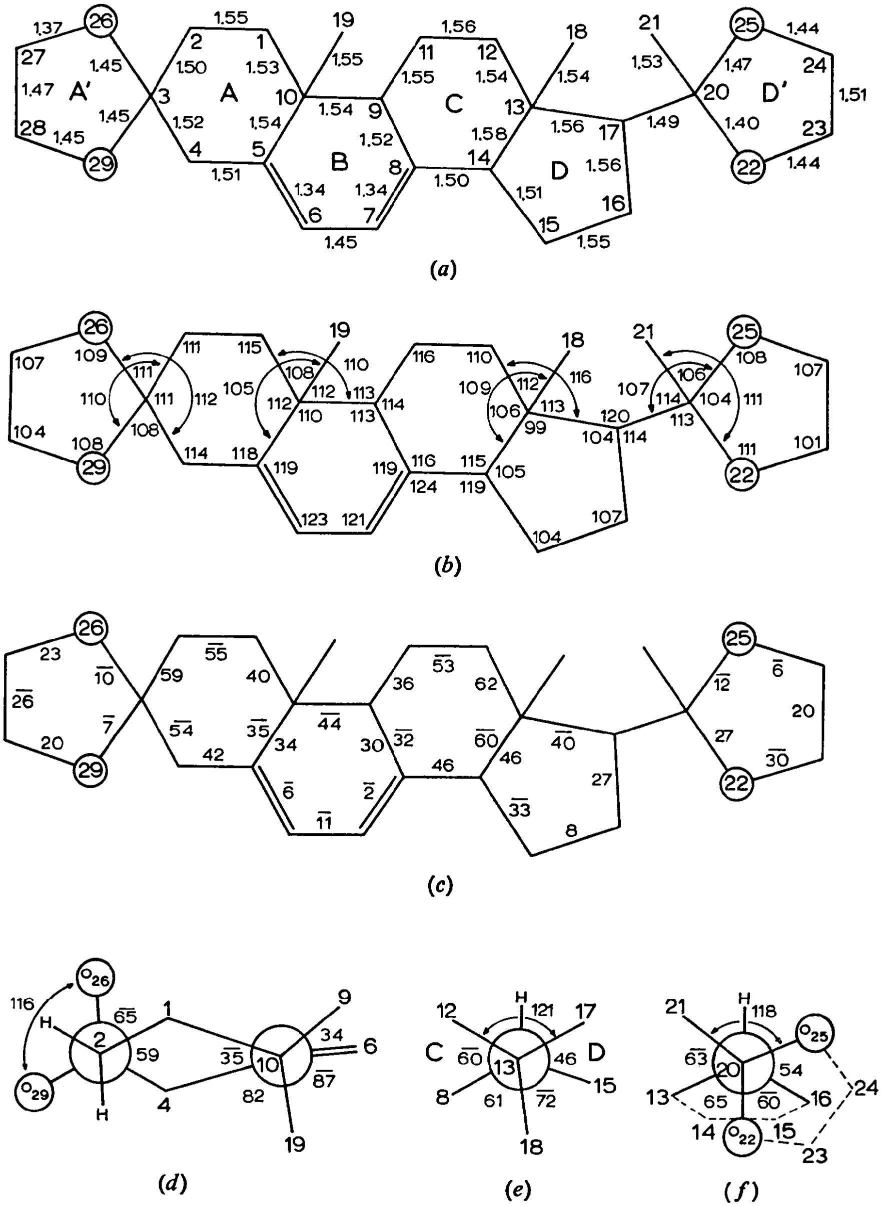

Fig. 3. The molecular geometry of EPD. The bond distances, valency angles and endocyclic torsion angles are to be found in (*a*), (*b*) and (*c*). Newman projections along the bonds 2–3, 10–5, 13–14 and 20–17 are given in (*d*), (*e*) and (*f*).

rings seem to be questionable, since the observed large thermal motion may have a flattening effect. Taking into account the values for ethylene phosphate (31°; Steitz & Lipscomb, 1965) and 2,2′-bis-1,3-dioxolane (21°; Furberg & Hassel, 1950) we arrive at a mean maximum puckering angle of 29°.

Packing

The packing of the molecules is illustrated in a projection along [010] (see Fig. 5). At a maximum distance of 4·0 Å the reference molecule I at x,y,z is surrounded by 12 molecules at

II	x	$1+y$	z
III	x	$-1+y$	z
IV	$-x$	$\frac{1}{2}+y$	$-z$
V	$-x$	$-\frac{1}{2}+y$	$-z$
VI	$1-x$	$\frac{1}{2}+y$	$-z$
VII	$1-x$	$-\frac{1}{2}+y$	$-z$
VIII	x	y	$1+z$
IX	x	y	$-1+z$
X	$1-x$	$\frac{1}{2}+y$	$1-z$
XI	$1-x$	$-\frac{1}{2}+y$	$1-z$
XII	$-1-x$	$\frac{1}{2}+y$	$-z$
XIII	$-1-x$	$-\frac{1}{2}+y$	$-z$

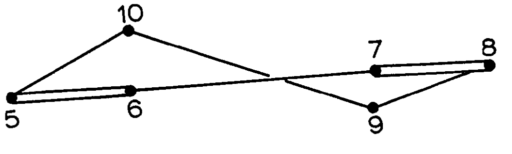

Fig. 4. The conformation of ring *B*. The plane of projection is perpendicular to plane 5,6,7,8 and parallel to bond 6–7.

The calculations performed in Eindhoven were executed on a C.D. 3600 computer, those carried out in Leiden on an IBM 360/65 computer. The third author (C.K.) is indebted to the Netherlands Organization for the advancement of pure research (Z.W.O.) for financial support during her stay in the Netherlands.

Table 5. *Maximum puckering angle φ (max) and phase angle Δ of five-membered rings in EPD and ECF*

	EPD			ECF		
Ring	φ (max)	Δ*	Designation†	φ (max)	Δ	Designation
A′	27·0°	79·6°	$C_2(3)$	37·6°	32·0°	$C_s(28)$
D′	29·5	130·8	$C_2(25)$	30·3	35·4	$C_s(20)$
D	46·2	−15·9	$C_2(16)$–$C_s(14)$	46·5	3·8	$C_2(16)$

* The reference atoms are 29, 25 and 14 for *A′*, *D′* and *D* respectively.

† $C_s(28)$: envelope with 28 as flap; $C_2(3)$: half-chair with twofold axis running through 3; $C_2(16)$–$C_s(14)$: roughly half way between $C_2(16)$ and $C_s(14)$.

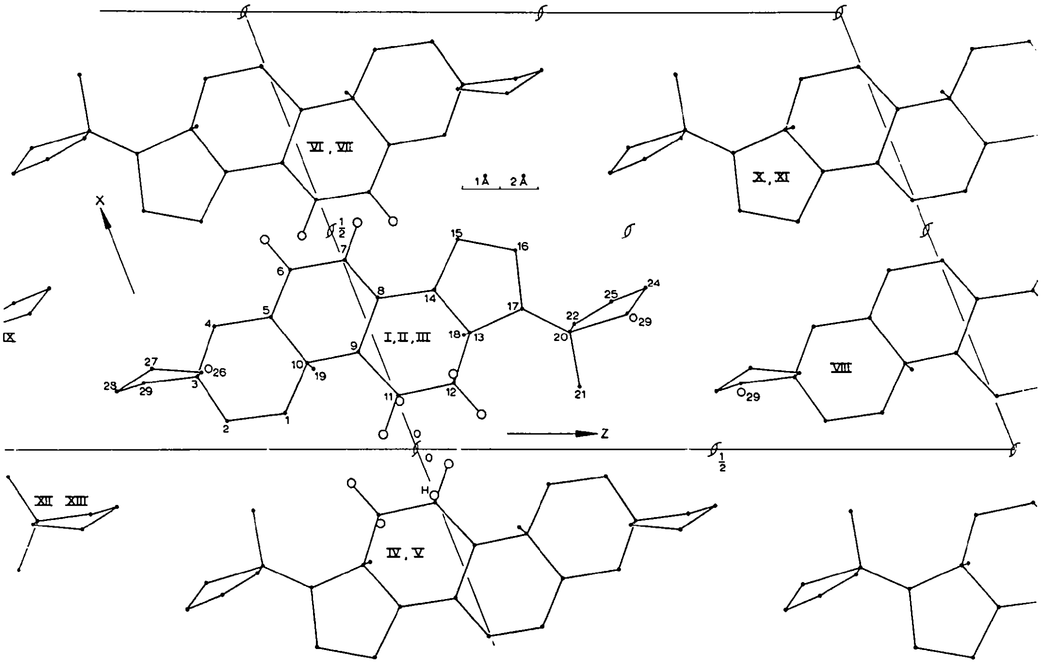

Fig. 5. Projection of a part of the structure along [010]. A few hydrogen atoms bonded to carbon atoms 6, 7, 11 and 12 are indicated by small circles. The roman numbers are explained in the text.

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Structures Cristallines et Conformations Moléculaires de l'*o*-Hydroxyacétylbenchrotrène et de l'*o*-Méthoxyacétylbenchrotrène

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The crystal structures of *o*-hydroxyacetylbenchrotrene (I) and *o*-methoxyacetylbenchrotrene (II) have been determined by X-ray diffraction. The enantiomorphic compound (I) crystallizes in the orthorhombic system with $a=15{\cdot}05\pm0{\cdot}02$, $b=7{\cdot}60\pm0{\cdot}01$, $c=9{\cdot}93\pm0{\cdot}01$ Å; $Z=4$; space group $P2_12_12_1$. The crystals of the racemic compound (II) are orthorhombic with $a=16{\cdot}25\pm0{\cdot}02$, $b=9{\cdot}54\pm0{\cdot}01$, $c=7{\cdot}94\pm0{\cdot}01$ Å; $Z=4$; space group $Pna2_1$. The molecular conformations of the two compounds explain the inversion and the difference of stereoselectivity of these ketones in the Grignard synthesis or the reduction by hydrides.

1. Introduction

Les formes racémiques ou actives de l'*o*-hydroxyacétylbenchrotrène 1 et de l'*o*-méthoxyacétylbenchrotrène 2 (Fig. 1) ont joué un rôle important dans l'étude de divers problèmes stéréochimiques en série métallocénique (Besancon & Tirouflet, 1969).

Ces deux cétones ont servi, tout d'abord, de substrats pour l'étude de l'induction asymétrique en série du benzène chrome tricarbonyle. D'autre part, les propriétés chiroptiques de leurs formes actives ont été discutées.

L'interprétation des phénomènes observés dans ces deux domaines n'apparaît cohérente que si l'on admet, *a priori*, que l'orientation du groupe acétyle par rapport au groupe OR est différente dans la cétone 1 et dans la cétone 2.

En effet, si l'on envisage tout d'abord l'action d'un réactif achiral (KBH_4) sur ces cétones, on observe une inversion de stéréosélectivité lorsqu'on passe de la cétone 1 à la cétone 2. La Fig. 1 indique par exemple les pourcentages relatifs des deux alcools diastéréoisomères que l'on obtient dans chacun des cas en série racémique (une seule chiralité a été représentée pour chacune des espèces).

D'autre part, les courbes de dichroïsme circulaire des formes actives des cétones 1 et 2 présentant la même chiralité ont des morphologies nettement différentes. Notons en particulier que les formes de la cétone 1 et de la cétone 2 qui correspondent à la chiralité représentée sur la Fig. 1 [chiralité 1*R* d'après la systématique de Cahn, Ingold & Prelog (1966), adaptée à la série métallocénique] sont respectivement dextrogyre et lévogyre pour la raie *D*.

L'inversion de stéréosélectivité indique indiscutablement que la configuration de l'état de transition privilégiée est différente dans les deux cas. On peut alors faire l'hypothèse que ceci résulte d'une différence con-