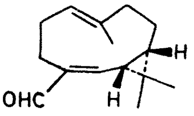
X-Ray Crystal Structure of (+)-Vitrenal, a Sesquiterpenoid Plant-growth Inhibitor containing a Novel Carbon Skeleton isolated from the Liverwort *Lepidozia vitrea*

By AKIHIKO MATSUO*, SEIRYÛ UTO, HIROSHI NOZAKI, and MITSURU NAKAYAMA
(*Department of Chemistry, Faculty of Science, Hiroshima University, Naka-ku, Hiroshima* 730, *Japan*)

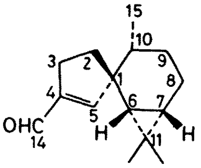
and SHÛICHI HAYASHI
(*Department of Chemistry, Faculty of Science, Okayama University of Science, Okayama* 700, *Japan*)

Summary A sesquiterpenoid containing a novel carbon skeleton (+)-vitrenal, a plant-growth inhibitor, has been isolated from the liverwort *Lepidozia vitrea* and its structure and absolute configuration have been shown to be as in structure (**2**) on the basis of chemical and spectral evidence and *X*-ray analysis

RECENTLY, we reported the isolation, from the liverwort *Lepidozia vitrea* Steph , and structural determination of (—)-isobicyclogermacrenal (**1**), a sesquiterpenoid which has an opposite absolute configuration to that of sesquiterpenoids from higher plants and displays plant-growth inhibiting properties[1] We have now isolated an additional plant-growth inhibitor, which we have named (+)-vitrenal, and its structure and absolute configuration have been determined; it is also an enantiomeric type-sesquiterpenoid (**2**), with a novel carbon skeleton.[†] We report here the chemical and spectroscopic evidence and the result of *X*-ray crystal structure analysis for the proposed structure.



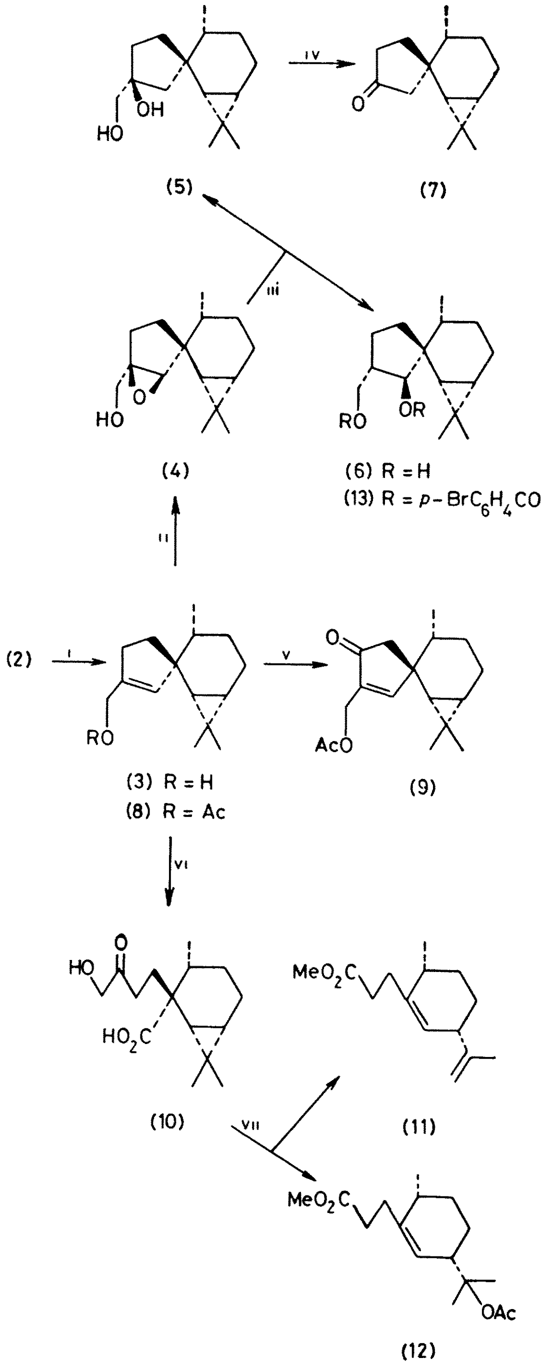
(1)



(2)

(+)-Vitrenal (**2**), $C_{15}H_{22}O$, oil, $[\alpha]_D$ +107°, was characterized as a tricarbocyclic sesquiterpenoid containing a cyclopropane ring [δ 0·7—0·8 (2H, m)], a secondary methyl group [δ 0·78 (3H, d, J 5·5 Hz)], two tertiary methyl groups [δ 0·96 and 1·19 (each 3H, s)], and an α,β-unsaturated aldehyde group conjugated with a trisubstituted double bond [λ 242 nm (ϵ 13,200); ν 1680, 1613, and 853 cm^{-1}; δ 6·85 (1H, t, J 1·5 Hz) and 9·75 (1H, s)].[‡]

On reduction with $LiAlH_4$, (**2**) gave the primary alcohol (**3**) whose off-resonance ^{13}C n.m.r. spectrum showed 3 singlets, 4 doublets, 5 triplets, and 3 quartets. The epoxide (**4**) derived from (**3**) was converted by treatment with Li into the 1,2-diol (**5**) and the 1,3-diol (**6**), in a ratio of 1 : 3. The vicinal diol (**5**) was oxidized with $NaIO_4$ to afford the ketone (**7**), showing a characteristic i.r. band at ν 1740 cm^{-1} assigned to a 5-membered ketone. This chemical transformation (Scheme) suggested that the aldehyde group of (**2**) was attached to the cyclopentene ring. Since the ^1H n.m.r. spectrum of the α,β-unsaturated 5-membered ketone (**9**) [λ 227 nm (ϵ 8860), ν 1710 cm^{-1}] produced by oxidation of the acetate (**8**) exhibited a pair of AB-type signals due to the methylene group adjacent to the carbonyl group at δ 2·39 and 2·75 (J 18·5 Hz), one of the two quaternary carbon atoms was certainly located β to the carbonyl group as a spiro-carbon atom. The primary alcohol (**3**) was, furthermore, ozonolysed to a biscarbocyclic hydroxy-keto-acid (**10**) which, on treatment with $Pb(OAc)_4$ and subsequent methylation, afforded two monocarbocyclic esters, (**11**) and (**12**) in a ratio of 1 : 1, undergoing oxidative cleavage of the 1,2-keto-alcohol moiety and decarboxylation accompanied by ring opening of the cyclopropane.[2] These products had an isopropenyl group [ν 890 cm^{-1}, δ 1·67 (3H, d, J 1·0 Hz) and 4·64 (2H, brs)] and an acetoxyisopropyl group [ν 1735 cm^{-1}, δ 1·38 (6H, s) and 1·94 (3H, s)], together with a trisubstituted double bond [ν 864 cm^{-1}, δ 5·20 (1H, br, $w_{\frac{1}{2}}$ 6·0 Hz) for (**11**); ν 872 cm^{-1}, δ 5·25 (1H, br, $w_{\frac{1}{2}}$ 5·0 Hz) for (**12**)], instead of the cyclopropane ring and two tertiary methyl groups. The full structure was, therefore, deduced to be (**2**) having the cyclopropane ring substituted with a geminal dimethyl group α,β to the spiro-carbon on the 6-membered ring, as well as the spiro[4.5]decane system. However, the position of the secondary methyl group was suggested only by the biogenetic isoprene rule.[3]



SCHEME *Reagents:* i, $LiAlH_4$ in ether, ii, *m*-$ClC_6H_4CO_3H$ in $CHCl_3$, iii, Li in NH_2–$[CH_2]_2$–NH_2; iv, $NaIO_4$, v, CrO_3–pyridine in CH_2Cl_2; vi, O_3 and H_2O_2; vii, $Pb(OAc)_4$ in benzene and CH_2N_2

For confirmation of the structure and establishment of the absolute configuration, *X*-ray crystallographic analysis of the di-*p*-bromobenzoate (**13**) of the diol (**6**) was carried out.

[†] We propose the name vitrane for the new carbon skeleton and suggest the numbering shown in (**2**).

[‡] All new compounds gave satisfactory combustion and/or mass spectrometric analysis and spectroscopic data consistent with the assigned structures.

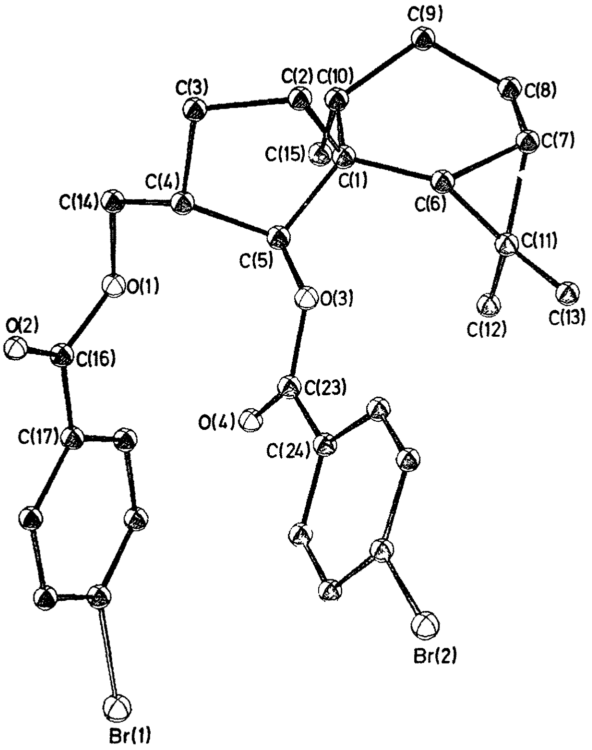


FIGURE A computer-generated perspective drawing of the di-*p*-bromobenzoate (**13**) derived from (+)-vitrenal (**2**) Hydrogen atoms have been omitted for clarity

Crystal data· $C_{29}H_{34}Br_2O_4$, orthorhombic, space group $P2_12_12_1$, a = 9·568(3), b = 11·290(1), c = 24·819(11) Å, D_c = 1·50 g cm^{-3}, Z = 4 The intensity data were collected on a four-circle diffractometer with graphite-monochromated Mo-K_α radiation The positions of the two bromine atoms were determined from a Patterson synthesis and the subsequent electron density synthesis revealed the non-hydrogen atom skeleton, and the thirty-four hydrogen atoms were located using the difference electron density synthesis The refinement by full-matrix least-squares, using anisotropic temperature factors, converged to a current R value of 0 073 At this stage, the anomalous scattering factor corrections for the bromine atoms were introduced into structure-factor calculations to establish the absolute configuration For the configuration (**13**), R was 0 070 whereas for the inverted configuration it was 0 081 [4] Further full-matrix least-squares iterations reduced the R factor to 0 067 for 1170 reflections The Figure shows a perspective drawing of the structure of the benzoate (**13**) § The sesquiterpenoid belongs to the enantiomeric series having the cyclopropane ring in the α-orientation and the secondary methyl group *cis* to the cyclopropane

Accordingly, the structure, including the absolute configuration, of (+)-vitrenal was determined as (**2**) This enantiomeric structure agrees with the result that most of the liverworts produce enantiomeric sesquiterpenoids [5] (+)-Vitrenal (**2**) inhibits completely the growth of leaves and roots of rice seedlings at a concentration of 25 p p m (1·1 × 10^{-4} M) and the concentration for 50% growth inhibition (I_{50}) is 18 p p m It may be acting as allomone,[6] together with (−)-isobicyclogermacrenal (**1**), in ecological systems

We thank Dr Y Kushi, Hiroshima University, for suggesting the X-ray analysis Part of this work was supported by a Grant-in-Aid for Scientific Research from the Ministry of Education

(*Received, 6th August* 1980, *Com* 865)

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§ The atomic co-ordinates for this work are available on request from the Director of the Cambridge Crystallographic Data Centre, University Chemical Laboratory, Lensfield Road, Cambridge CB2 1EW Any request should be accompanied by the full literature citation for this communication

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