MARTINEZ-RIPOLL, M. & CANO, F. H. (1975). *PESOS*. Unpublished program.
NAGAI, S., ODA, N., ITO, I. & KUDO, Y. (1979). *Chem. Pharm. Bull.* **27**, 1771–1778.
NARDELLI, M. (1983). *Comput. Chem.* **7**, 95–98.
SMITH, J. A. S., WEHRLE, B., AGUILAR-PARRILLA, F., LIMBACH, H., FOCES-FOCES, C., CANO, F. H., ELGUERO, J., BALDY, A., PIERROT, M., KHUSHID, M. M. T. & LARCOMBE-MCDOUALL, J. B. (1989). *J. Am. Chem. Soc.* **111**, 7304–7312.
STEEL, P. J. (1983). *Acta Cryst.* C**39**, 1623–1625.
STEWART, J. M., MACHIN, P. A., DICKINSON, C. W., AMMON, H. L., HECK, H. & FLACK, H. (1976). The *XRAY* system. Tech. Rep. TR-446. Computer Science Center, Univ. of Maryland, College Park, Maryland, USA.
SZEVERINYI, N. M., SULLIVAN, M. J. & MACIEL, G. E. (1982). *J. Magn. Reson.* **47**, 462–475.
WATSON, A. A., HOUSE, D. A. & STEEL, P. J. (1986). *J. Organomet. Chem.* **311**, 387–397.
WATSON, A. A., HOUSE, D. A. & STEEL, P. J. (1989). *Polyhedron*, **8**, 1345–1350.

Acta Cryst. (1993). C**49**, 729–731

Structure of (4α)-13-Hydroxykaur-16-en-18-oic Acid (Steviol) Methanol Solvate

BY A. M. G. DIAS RODRIGUES, R. H. DE ALMEIDA SANTOS AND J. R. LECHAT

Universidade de São Paulo, Instituto de Física e Química de São Carlos, CP 369, 13560 *São Carlos, SP, Brazil*

(*Received* 4 *February* 1992; *accepted* 27 *August* 1992)

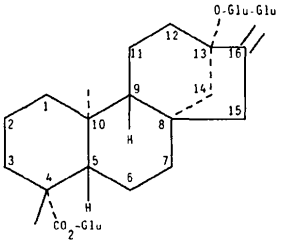
Abstract. $C_{20}H_{30}O_3.CH_4O$, $M_r = 350.50$, orthorhombic, $P2_12_12_1$, $a = 7.407$ (2), $b = 14.442$ (3), $c = 17.696$ (3) Å, $V = 1893$ (1) Å^3, $Z = 4$, D_m(flotation) = 1.20 g cm^{-3}, $D_x = 1.230$ g cm^{-3}, λ(Cu $K\alpha$) = 1.54056 Å, $\mu = 6.3$ cm^{-1}, $F(000) = 768$, $T = 298$ (1) K, final $R = 0.058$ for 1675 observed reflections. The hydrogen-bonding scheme consists of head-to-tail associated steviol molecules forming a ribbon in the **a** direction. The methanol molecule is hydrogen bonded to the carbonyl of the carboxyl group (acceptor) and to the hydroxyl group (donor) of associated steviol molecules.

Introduction. As a result of the banning of cyclamate for use as a non-nutritive sweetener and of the question raised regarding the possible carcinogenicity of saccharin, a great deal of work has been carried out recently directed toward the development of alternative sweeteners.

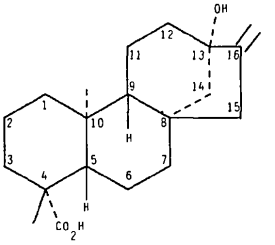
Stevioside (I), the extremely sweet diterpenoid glycoside found in the South American shrub *Stevia rebaudiana*, has been valued as a sweetener by the indigenous population. More recently, the plant source has been cultivated quite intensively in Japan where the product is approved for use in food.

Enzymatic hydrolysis of the diterpenoid glycoside stevioside by the gastric juices of the snail, *Helix pomatia* (Bridel & Lavieille, 1931), pectinase (Ruddat, Heftmann & Lang, 1965) or hesperidinase (Mizukami, Shiba & Ohashi, 1982), affords the aglycone steviol (II). Studies of the sweeteners of stevioside analogue compounds suggest that all of the functionality involved in receptor binding is located in the aglycon diterpenoid (Dubois, Dietrich, Lee, McGarraugh & Stephenson, 1981).

The differences in the structural features of diterpenes have an important role in their biological activity. Thus the following structure determination was undertaken.



(I)



(II)

Experimental. Colorless crystals of the title compound were prepared by Dr Mauro Alvarez (Departamento de Farmácia e Bioquímica, Universidade Estadual de Maringá).

A crystal of dimensions 0.75 × 0.25 × 0.20 mm was used for data collection. Cell dimensions were refined by a least-squares fit to the setting angles of 25 reflections ($7 < \theta < 12°$) on a CAD-4 automatic diffractometer. Intensity measurements were carried out up to 68° in θ with graphite-monochromated Cu $K\alpha$ radiation and employing the ω–2θ scan technique. Reflections were collected in the range 0 to 8 for h, 0 to 17 for k and 0 to 21 for l. Lorentz and polarization corrections were applied but no absorption correction was made. Two standard reflections

0108-2701/93/040729-03$06.00

(161, 154) were monitored every 50 reflections; maximum intensity variation ± 1.2% over 19.4 h. Of the 1979 measured unique reflections, 1675 were considered observed [$I > 3\sigma(I)$, where $\sigma(I)$ was calculated from counting statistics] and used in the structure determination and refinement. The structure was solved by direct methods using the program *MULTAN*80 (Main, Fiske, Hull, Lessinger, Germain, Declercq & Woolfson, 1980). All non-H atoms appeared clearly on the *E* map corresponding to the best figures of merit. The previously proposed absolute configuration was assumed (Mosettig, Beglinger, Dolder, Lichti, Quitt & Waters, 1963).

Refinement was carried out by full-matrix least-squares method minimizing $\sum w_i(k|F_o| - |F_c|)^2$ with $w_i^{-1} = \sigma(F)^2 + 0.00052F^2$ for observed and $w_i = 0$ for unobserved reflections, until all the atomic parameter shifts were smaller than each standard deviation (*SHELX*76; Sheldrick, 1976). The atomic scattering factors used were those of Cromer & Waber (1974).

Anisotropic temperature factors were assigned to all non-H atoms. H atoms ($B = 6.0$ Å^2) were included in calculated positions except for the O—H H atoms which were located from difference Fourier syntheses and their positions refined (O—H = 0.97 Å). Final *R* and *wR* factors, omitting unobserved reflections and refining 235 parameters, were 0.058 and 0.066; $S = 2.56$. Maximum and minimum heights in the final difference Fourier synthesis were 0.220 and -0.272 e Å^{-3} respectively. The final atomic parameters are given in Table 1.* An *ORTEP* (Johnson, 1965) representation of the steviol and methanol molecules with identified atoms is given in Fig. 1.

Table 1. *Fractional atomic coordinates and equivalent isotropic thermal parameters (Hamilton, 1959) with e.s.d.'s in parentheses*

$B_{eq} = (8\pi^2/3)\sum_i\sum_j U_{ij}a_i^*a_j^*\mathbf{a}_i.\mathbf{a}_j$.

	x	*y*	*z*	B_{eq}(Å^2)
C(1)	0.2447 (7)	0.5078 (3)	0.5118 (3)	4.6 (1)
C(2)	0.2619 (7)	0.4606 (3)	0.4353 (3)	4.8 (2)
C(3)	0.4160 (6)	0.3921 (3)	0.4342 (3)	4.7 (2)
C(4)	0.5991 (6)	0.4338 (3)	0.4575 (2)	3.6 (1)
C(5)	0.5746 (6)	0.4857 (3)	0.5341 (2)	3.6 (1)
C(6)	0.7476 (6)	0.5250 (3)	0.5684 (2)	3.9 (1)
C(7)	0.7174 (6)	0.5464 (3)	0.6511 (2)	4.3 (1)
C(8)	0.5663 (5)	0.6150 (3)	0.6637 (3)	3.6 (1)
C(9)	0.3949 (5)	0.5851 (3)	0.6209 (2)	3.6 (1)
C(10)	0.4176 (5)	0.5570 (3)	0.5371 (2)	3.5 (1)
C(11)	0.2399 (6)	0.6537 (3)	0.6370 (3)	4.2 (1)
C(12)	0.2951 (6)	0.7552 (3)	0.6411 (3)	4.2 (1)
C(13)	0.4684 (6)	0.7691 (2)	0.6856 (2)	3.7 (1)
C(14)	0.6180 (6)	0.7154 (3)	0.6465 (2)	3.6 (1)
C(15)	0.5229 (7)	0.6240 (3)	0.7496 (2)	4.3 (1)
C(16)	0.4585 (6)	0.7212 (3)	0.7610 (2)	3.8 (1)
C(17)	0.4093 (8)	0.7607 (3)	0.8248 (3)	5.0 (2)
C(18)	0.7317 (7)	0.3532 (3)	0.4671 (3)	4.8 (2)
C(19)	0.6729 (6)	0.4930 (3)	0.3945 (2)	3.7 (1)
C(20)	0.4506 (6)	0.6391 (3)	0.4841 (2)	3.8 (1)
O(21)	0.4967 (4)	0.8660 (2)	0.6905 (2)	4.5 (1)
O(22)	0.8358 (4)	0.5256 (2)	0.4089 (2)	4.3 (1)
O(23)	0.5989 (5)	0.5062 (2)	0.3346 (2)	5.2 (1)
O(*M*)	0.8321 (5)	0.9047 (3)	0.7477 (3)	6.8 (2)
C(*M*)	0.9145 (8)	0.8504 (5)	0.8021 (3)	6.7 (2)

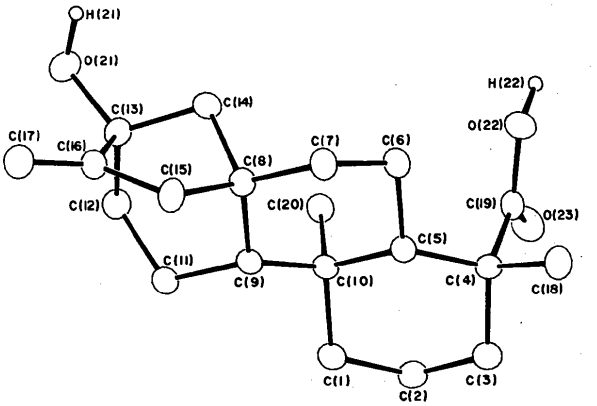


Fig. 1. An *ORTEP* (Johnson, 1965) representation of steviol.

Discussion. The previously deduced molecular skeleton of steviol (Dolder, Lichti, Mosettig & Quitt, 1960) has been confirmed by this X-ray diffraction study. The structural parameters of the carboxyl group correspond to the typical geometry of a —COOH group (Borthwick, 1980). The torsion angles around the C(5)—C(10) bond denote a *trans* fusion and those around the C(9)—C(8) bond denote a *cis* fusion. So, the stereochemistry of the tricyclic system perhydrophenanthrene, that is part of the steviol skeleton, is *cis-anti-trans* (Eliel, 1962).

The most common motif observed in the solid state for carboxylic acids consists of pairs of molecules forming a cyclic hydrogen-bonded dimer (Leiserowitz, 1976). Isosteviol exhibits this kind of association (Dias Rodrigues & Lechat, 1988). In the case of the title compound, molecules related by the twofold screw axis parallel to **a** associate head-to-tail through a hydrogen bond between the carboxyl and hydroxyl groups. The carbonyl of the carboxyl group, which is not involved in this type of hydrogen bonding, is hydrogen bonded to the methanol molecule. The hydrogen-bonding scheme is completed by the hydroxyl group acting as a proton donor in a hydrogen bond with the methanol molecule; this explains the presence of the solvent in the structure. The strength of the hydrogen bond between steviol molecules may be classified as intermediate and that between steviol and methanol molecules as weak (Novak, 1974). Table 2 gives the interatomic distances and angles for the hydrogen bonding.

* Lists of structure factors, anisotropic thermal parameters and H-atom parameters have been deposited with the British Library Document Supply Centre as Supplementary Publication No. SUP 55781 (17 pp.). Copies may be obtained through The Technical Editor, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England. [CIF reference: CD1002]

Table 2. *Hydrogen-bonding distances* (Å) *and angles* (°) *with e.s.d.'s in parentheses*

X—H···*Y*	*X*—H	H···*Y*	*X*···*Y*	*X*—H···*Y*
O(21)—H(21)···O(*M*)	0.97 (2)	1.78 (3)	2.740 (5)	168 (4)
O(22)—H(22)···O(21)^{i}	0.97 (2)	1.67 (4)	2.639 (4)	171 (4)
O(*M*)—H(*M*)···O(23)^{i}	0.97 (4)	2.12 (4)	2.772 (5)	123 (4)

Symmetry code: (i) $\frac{1}{2}+x, \frac{3}{2}-y, 1-z$.

This work has received the support of FAPESP, CNPq and FINEP, which is hereby gratefully acknowledged.

References

BORTHWICK, P. W. (1980). *Acta Cryst.* B**36**, 628–632.

BRIDEL, M. & LAVIEILLE, R. (1931). *Bull. Soc. Chim. Biol.* **13**, 781–791.

CROMER, D. T. & WABER, J. T. (1974). *International Tables for X-ray Crystallography*, Vol. IV, pp. 71–98. Birmingham: Kynoch Press. (Present distributor Kluwer Academic Publishers, Dordrecht.)

DIAS RODRIGUES, A. M. G. & LECHAT, J. R. (1988). *Acta Cryst.* C**44**, 1963–1965.

DOLDER, F., LICHTI, H., MOSETTIG, E. & QUITT, P. (1960). *J. Am. Chem. Soc.* **82**, 246–247.

DUBOIS, G. E., DIETRICH, P. S., LEE, J. F., MCGARRAUGH, G. V. & STEPHENSON, R. A. (1981). *J. Med. Chem.* **24**, 1269–1271.

ELIEL, E. (1962). *Stereochemistry of Carbon Compounds*. New York: McGraw-Hill.

HAMILTON, W. C. (1959). *Acta Cryst.* **12**, 609–610.

JOHNSON, C. K. (1965). *ORTEP*. Report ORNL-3794. Oak Ridge National Laboratory, Tennessee, USA.

LEISEROWITZ, L. V. (1976). *Acta Cryst.* B**32**, 775–802.

MAIN, P., FISKE, S. J., HULL, S. E., LESSINGER, L., GERMAIN, G., DECLERCQ, J.-P. & WOOLFSON, M. M. (1980). *MULTAN80. A System of Computer Programs for the Automatic Solution of Crystal Structures from X-ray Diffraction Data*. Univs. of York, England, and Louvain, Belgium.

MIZUKAMI, H., SHIBA, L. & OHASHI, H. (1982). *Phytochemistry*, **21**, 1927–1930.

MOSETTIG, E., BEGLINGER, U., DOLDER, F., LICHTI, H., QUITT, P. & WATERS, J. A. (1963). *J. Am. Chem. Soc.* **85**, 2305–2309.

NOVAK, A. (1974). *Struct. Bonding (Berlin)*, **18**, 177–216.

RUDDAT, M., HEFTMANN, E. & LANG, A. (1965). *Arch. Biochem. Biophys.* **110**, 496–499.

SHELDRICK, G. M. (1976). *SHELX76*. Program for crystal structure determination. Univ. of Cambridge, England.

Acta Cryst. (1993). C**49**, 731–735

Structures of Diels–Alder Mono-Adducts of 4-Phenyl- or 4-Methyl-1,2,4-triazolidine-3,5-dione with 11-Substituted-1,6-methano[10]annulene

BY P. ASHKENAZI AND M. KAFTORY*

Department of Chemistry, Technion-Israel Institute of Technology, Haifa 32000, *Israel*

(*Received* 3 *June* 1992; *accepted* 20 *November* 1992)

Abstract. 1*H*,2*H*,5*H*,10*H*-5a,9a-Dihydro-2-phenyl-5,10-etheno-5a,9a-methano[1,2,4]triazolo[1,2-*b*]phthalazine-1,3-dione (1), $C_{19}H_{15}N_3O_2$, $M_r = 317.35$, monoclinic, $P2_1/c$, $a = 8.500$ (4), $b = 14.271$ (7), $c = 12.758$ (6) Å, $\beta = 91.97$ (2)°, $V = 1546.67$ Å^3, $Z = 4$, $D_x = 1.363$ g cm^{-3}, λ(Cu $K\alpha$) = 1.5418 Å, $\mu = 0.696$ cm^{-1}, $F(000) = 664$, $R = 0.053$ for 2329 reflections. Methyl 1*H*,5*H*,10*H*-2,3,5a,9a-tetrahydro-2-methyl-1,3-dioxo-5,10-etheno-5a,9a-methano[1,2,4]-triazolo[1,2-*b*]phthalazine-14-acetate (2), $C_{16}H_{15}N_3O_4$, $M_r = 313.31$, monoclinic, $P2_1$, $a = 6.421$ (3), $b = 10.872$ (5), $c = 10.564$ (5) Å, $\beta = 91.05$ (2)°, $V = 737.34$ Å^3, $Z = 2$, $D_x = 1.412$ g cm^{-3}, λ(Mo $K\alpha$) = 0.71069 Å, $\mu = 0.097$ cm^{-1}, $F(000) = 328$, $R = 0.042$ for 1262 reflections. 1*H*,2*H*,5*H*,10*H*-5a,9a-Dihydro-14-methyl-2-phenyl-5,10-etheno-5a,9a-imino[1,2,4]-triazolo[1,2-*b*]phthalazine-1,3-dione (3), $C_{19}H_{16}N_4O_2$, $M_r = 332.36$, triclinic, $P\bar{1}$, $a = 26.027$ (13), $b = 10.155$ (5), $c = 6.147$ (3) Å, $\alpha = 96.99$ (3), $\beta = 93.58$ (3), $\gamma = 92.64$ (3)°, $V = 1607.09$ Å^3, $Z = 4$, $D_x = 1.374$ g cm^{-3}, λ(Mo $K\alpha$) = 0.71069 Å, $\mu = 0.086$ cm^{-1}, $F(000) = 696$, $R = 0.088$ for 3526 reflections. Crystal structures of the Diels–Alder adducts of 4-phenyl- or 4-methyl-1,2,4-triazolidine-3,5-dione with 11-substituted bridged [10]annulenes show that the mono-adduct has the Alder *endo* configuration. The triazolidinedione ring in each case is *anti* to the three-membered ring and to its substituent.

Introduction. Many Diels–Alder reactions between propellanes containing one or two cyclohexadiene rings and bridged [10]annulenes with triazolidinediones have been conducted by Kalo, Vogel & Ginsburg (1977*a*,*b*), Kalo, Bloomfield & Ginsburg (1978), Kalo & Ginsburg (1978), Ashkenazi, Kalo, Ruttimann & Ginsburg (1978), Ashkenazi, Vogel &

* To whom all correspondence should be addressed.

0108-2701/93/040731-05$06.00