Methoxyxanthobilirubinic Acid Methyl Ester (Methyl 3-{5-[(3-Ethyl-5-methoxy-4-methyl-2*H*-pyrrol-2-ylidene)methyl]-2,4-dimethyl-3-pyrrolyl}propanoate), $C_{19}H_{26}N_2O_3$

By J. K. Dattagupta* and E. F. Meyer Jr

Department of Biochemistry and Biophysics, Texas Agricultural Experiment Station, Texas A&M University, College Station, Texas 77843, USA

D. L. Cullen

Department of Chemistry, Connecticut College, New London, Connecticut 06320, USA

and H. Falk and S. Gergely

Department of Organic Chemistry, University of Linz, A-4040 Linz, Austria

Abstract. $M_r = 330.43$, monoclinic, $P2_1/c$, $a = 12.589$ (2), $b = 12.317$ (2), $c = 12.231$ (2) Å, $\beta = 103.53$ (2)°, $V = 1843.9$ Å^3, $Z = 4$, $D_x = 1.190$ Mg m^{-3}, Cu $K\alpha$ radiation, $\lambda = 1.54184$ Å, $\mu = 0.613$ mm^{-1}, $F(000) = 712$, $T = 277$ (1) K, $R = 0.054$, $R_w = 0.084$ for 1420 reflections. The structure was solved by direct methods and refined by full-matrix least-squares calculations. This compound, which can be thought of as a lactim derivative of half a mesobilirubin molecule or alternatively as a substituted pyrromethene, adopts a Z configuration with a syn-periplanar conformation at the methine single bond. While there is no intermolecular hydrogen bonding, there is an $N-H\cdots N$ intramolecular hydrogen bond.

Introduction. The title compound, hereafter referred to as methoxyxanthobilirubinic acid methyl ester, is a derivative of xanthobilirubinic acid and thus can be considered as one half of a molecule of mesobilirubin IXa (rings *A* and *B*). Naturally occurring bile pigments and their derivatives have pyrrolinone rings in the lactam form. In these lactam derivatives hydrogen bonding is generally very important, especially in bilirubin itself where there is extensive intramolecular hydrogen bonding between the lactam oxygens and the peripheral propionic acid groups (Bonnett, Davies, Hursthouse & Sheldrick, 1978). The title compound has the pyrrolinone ring in the lactim form. In addition, since both the propionic acid group and the pyrrolinone O atom are methylated, hydrogen bonding is much less likely. Therefore, an accurate structure determination would be of interest to provide a comparison with bile pigments and their derivatives.
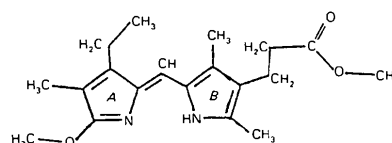
Experimental. Title compound prepared by the method of Fischer & Adler (1931). Single crystals grown by slow evaporation of a saturated solution in methanol at room temperature; light-yellow crystals were transparent and needle-shaped, crystals of suitable size obtained by cutting the needles with a razor blade. Syntex *P*1̄ diffractometer, Cu *K* radiation with a graphite monochromator, monochromator and tube mount in perpendicular mode; degree of mosaicity of the graphite crystal taken as 0.5, $2\theta/\omega$ scan mode, approximate crystal dimensions $0.2 \times 0.2 \times 0.2$ mm. A total of 1795 reflections measured in the range $2\theta \leq 115°$, 1420 unique reflections considered observed with $I > 3\sigma(I)$. Intensities of three standard reflections measured after every 97 reflections; cell dimensions obtained from a least-squares analysis of angle measurements of 15 strong reflections in the range $42° \leq 2\theta \leq 62°$, systematic absences $h0l$ for l odd and $0k0$ for k odd. Corrections for Lorentz and polarization effects and crystal decay (*ca* 3%) applied; no absorption correction. Structure solved by direct methods using the program *MULTAN*78 (Main, Hull Lessinger, Germain, Declercq & Woolfson, 1978), calculations performed on a PDP 11/40 computer using the Enraf–Nonius structure determination package (Frenz, 1978); use was also made of the PDP 11/40 Vector General graphics system (Morimoto & Meyer, 1976; Swanson, Rosenfield & Meyer, 1982). Non-hydrogen atoms were refined by full-matrix least-squares methods, minimizing $\sum w[|F_o| - (1/k)|F_c|]^2$ with $w = 1/\sigma^2(F_o)$, where k is the scale factor. Most of the H atoms (except six which

* Present address: Crystallography and Molecular Biology Division, Saha Institute of Nuclear Physics, 92 APC Road, Calcutta 700009, India.

were idealized with C—H length of 0·95 Å) were located from a difference Fourier synthesis. H atoms were assigned fixed isotropic thermal parameters of 4·0 Å^2 and none were refined except for that attached to N(2) which plays a significant role in the structure. The refinement was stopped when the highest shift/error ratio was 0·41, average shift/error = 0·08, final $R = 0·054$, $R_w = 0·084$, $S = 2·4$. Scattering factors from Cromer & Waber (1974); anomalous-dispersion corrections applied to all non-hydrogen atoms (Cromer, 1974). A difference Fourier calculated at the final stage was featureless, the highest difference peak, 0·15 e Å^{-3}, having no chemical significance. No correction for secondary extinction.

Discussion. The positional parameters along with their e.s.d.'s are given in Table 1.* An *ORTEP* (Johnson, 1965) drawing of the structure is shown in Fig. 1. The numbering scheme used is also given. The molecule assumes a Z configuration with a synperiplanar conformation at the methine single bond. Thus the molecule resembles one-half of a porphyrin ring. The Z synperiplanar arrangement is the one found in both naturally occurring bile pigments such as bilirubin (Bonnett, Davies, Hursthouse & Sheldrick, 1978), their derivatives such as biliverdin dimethyl ester (Sheldrick, 1976), and most synthetic di-, tri-, and tetrapyrroles (*e.g.* Cullen, Pèpe, Meyer, Falk & Grubmayr, 1979, and references therein). Only a few structures with the E configuration have been reported (Sheldrick, Borkenstein, Blacha-Puller & Gossauer, 1977; Hori *et al.*, 1981).

As is found for most of the Z isomers of oxodipyrromethenes previously reported (Cullen, Black, Meyer, Lightner, Quistad & Pak, 1977; Sheldrick *et al.*, 1977; Cullen *et al.*, 1979), the dipyrrolic skeleton is relatively planar. The dihedral angle at the methine single bond is 2·7°. The individual pyrrole rings are planar. The maximum deviation of an atom from the plane of the pyrrole ring to which it belongs is 0·01 Å.

In almost every structure of a bile pigment or their derivatives thus far reported, the pyrrolinone rings are in the lactam form, the exception being dimethoxybilirubin dimethyl ester (Sheldrick & Becker, 1979), which has these rings in the alternative lactim form. The observation that the lactam form is predominant has also been verified by X-ray photoelectron spectroscopy (Falk, Gergely, Grubmayr & Hofer, 1977). In the present case, however, this ring (*A*) is in the lactim form. Bond lengths and angles are shown in Table 2. There is a great deal of bond fixation in ring *A*, the

pyrrolinone ring, so that the form as shown in the introduction predominates for this ring. This is especially apparent from the N(1)—C(1) and N(1)—C(4) distances, which are characteristic of pure C—N double and single bonds respectively. Similarly the C_a—C_b, C_b—C_b and C_a—C_m distances are also what would be expected given the predominance of this form. The C_a—N—C_a angles in rings *A* and *B* are typical of those tabulated for pyrrole rings respectively bearing and lacking an imino H atom (Hoard, 1975). The nomenclature for the various types of C atoms is given in Fig. 1.

Table 1. *Fractional coordinates derived from least-squares refinement*

For non-hydrogen atoms the thermal factor $B_{eq} = \frac{4}{3}\sum_i\sum_j(a_i.a_j)\ \beta_{ij}$. H(N2) was refined isotropically and the value given is the refined isotropic parameter. In this and subsequent tables, the value in parentheses is the e.s.d. of the least significant digits.

|	x	y	z	B_{eq} (Å^2)
O(1)	0·4577 (2)	0·1488 (2)	0·1777 (2)	5·29 (8)
O(2)	−0·0253 (2)	0·6499 (3)	−0·1046 (2)	5·67 (8)
O(3)	0·1220 (3)	0·7481 (3)	−0·0297 (2)	6·48 (9)
N(1)	0·3574 (3)	0·2411 (3)	0·0202 (3)	4·01 (8)
N(2)	0·3131 (3)	0·4423 (3)	−0·0702 (3)	3·81 (8)
C(1)	0·3906 (3)	0·1522 (3)	0·0749 (3)	3·86 (9)
C(2)	0·3483 (3)	0·0533 (3)	0·0184 (3)	4·1 (1)
C(3)	0·2820 (3)	0·0857 (3)	−0·0805 (3)	3·82 (9)
C(4)	0·2884 (3)	0·2046 (3)	−0·0817 (3)	3·87 (9)
C(5)	0·2381 (3)	0·2746 (3)	−0·1632 (3)	3·9 (1)
C(6)	0·2465 (3)	0·3900 (3)	−0·1613 (3)	3·49 (9)
C(7)	0·1953 (3)	0·4696 (3)	−0·2349 (3)	3·52 (9)
C(8)	0·2317 (3)	0·5709 (3)	−0·1872 (3)	3·31 (9)
C(9)	0·3044 (3)	0·5499 (3)	−0·0851 (3)	3·69 (9)
C(10)	0·3691 (4)	0·6257 (4)	0·0019 (3)	4·7 (1)
C(11)	0·1178 (4)	0·4523 (4)	−0·3468 (4)	4·6 (1)
C(12)	0·1967 (3)	0·6811 (3)	−0·2334 (3)	4·0 (1)
C(13)	0·0805 (4)	0·7092 (4)	−0·2259 (3)	4·4 (1)
C(14)	0·0642 (3)	0·7059 (4)	−0·1098 (3)	4·4 (1)
C(15)	−0·0531 (5)	0·6461 (5)	0·0006 (4)	8·2 (2)
C(16)	0·4907 (4)	0·2493 (4)	0·2314 (4)	5·7 (1)
C(17)	0·3751 (4)	−0·0580 (4)	0·0652 (4)	5·4 (1)
C(18)	0·2163 (4)	0·0169 (4)	−0·1711 (4)	4·9 (1)
C(19)	0·2710 (5)	−0·0073 (4)	−0·2645 (4)	6·6 (1)
H(N2)	0·349 (3)	0·386 (3)	−0·003 (3)	4·1 (8)
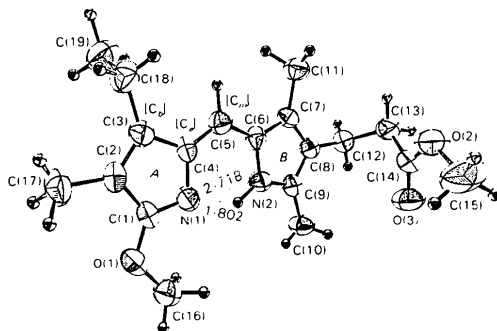
Fig. 1. *ORTEP* (Johnson, 1965) drawing of methoxyxanthobilirubinic acid methyl ester. Thermal ellipsoids for non-hydrogen atoms are drawn for 50% probability. Thermal parameters for H atoms have not been drawn to scale. Also shown are the crystallographic numbering scheme and the nomenclature for the various types of C atoms (shown in square brackets) and the intramolecular hydrogen-bonded distances (Å).

* Tables of H-atom parameters, thermal parameters, least-squares planes and structure factors have been deposited with the British Library Lending Division as Supplementary Publication No. SUP 38634 (13 pp.). Copies may be obtained through The Executive Secretary, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England.

Table 2. *Interatomic distances (Å) and angles (°)*

Bond angles involving the intramolecular hydrogen bond are also given. The N—H and average C—H values are 1·09 (3) and 0·98 Å, respectively.

|			
O(1)—C(1)	1·342 (3)	N(1)—C(1)	1·300 (3)
O(1)—C(16)	1·417 (4)	N(1)—C(4)	1·416 (3)
O(2)—C(14)	1·335 (4)	N(2)—C(6)	1·387 (3)
O(2)—C(15)	1·410 (4)	N(2)—C(9)	1·339 (3)
O(3)—C(14)	1·195 (3)		
C(1)—C(2)	1·440 (4)	C(7)—C(8)	1·409 (4)
C(2)—C(3)	1·359 (4)	C(7)—C(11)	1·498 (4)
C(2)—C(17)	1·494 (4)	C(8)—C(9)	1·389 (4)
C(3)—C(4)	1·466 (4)	C(8)—C(12)	1·496 (4)
C(3)—C(18)	1·483 (4)	C(9)—C(10)	1·504 (4)
C(4)—C(5)	1·357 (4)	C(12)—C(13)	1·527 (4)
C(5)—C(6)	1·426 (4)	C(13)—C(14)	1·482 (4)
C(6)—C(7)	1·384 (4)	C(18)—C(19)	1·495 (5)
C(1)—O(1)—C(16)	117·3 (2)	C(5)—C(6)—C(7)	132·4 (3)
C(14)—O(2)—C(15)	117·0 (2)	C(6)—C(7)—C(8)	107·5 (2)
C(1)—N(1)—C(4)	104·0 (2)	C(6)—C(7)—C(11)	126·8 (3)
C(6)—N(2)—C(9)	109·6 (2)	C(8)—C(7)—C(11)	125·7 (3)
O(1)—C(1)—N(1)	124·4 (3)	C(7)—C(8)—C(9)	106·8 (2)
O(1)—C(1)—C(2)	120·3 (3)	C(7)—C(8)—C(12)	127·5 (2)
N(1)—C(1)—C(2)	115·3 (3)	C(9)—C(8)—C(12)	125·6 (3)
C(1)—C(2)—C(3)	105·1 (2)	N(2)—C(9)—C(8)	108·8 (3)
C(1)—C(2)—C(17)	124·6 (3)	N(2)—C(9)—C(10)	120·4 (3)
C(3)—C(2)—C(17)	130·3 (3)	C(8)- C(9)—C(10)	130·8 (3)
C(2)—C(3)—C(4)	106·2 (3)	C(8)—C(12)—C(13)	112·6 (2)
C(2)—C(3)—C(18)	128·0 (3)	C(12)—C(13)—C(14)	113·6 (3)
C(4)—C(3)—C(18)	125·8 (3)	O(2)—C(14)—O(3)	123·0 (3)
N(1)—C(4)—C(3)	109·4 (3)	O(2)—C(14)—C(13)	111·6 (3)
N(1)—C(4)—C(5)	122·0 (3)	O(3)—C(14)—C(13)	125·4 (3)
C(3)—C(4)—C(5)	128·6 (3)	C(3)—C(18)—C(19)	114·2 (3)
C(4)—C(5)—C(6)	127·0 (3)	C(6)—N(2)—H(N2)	112 (1)
N(2)—C(6)—C(5)	120·3 (2)	C(9)—N(2)—H(N2)	138 (2)
N(2)—C(6)—C(7)	107·2 (2)	N(2)—H(N2)—N(1)	138 (2)
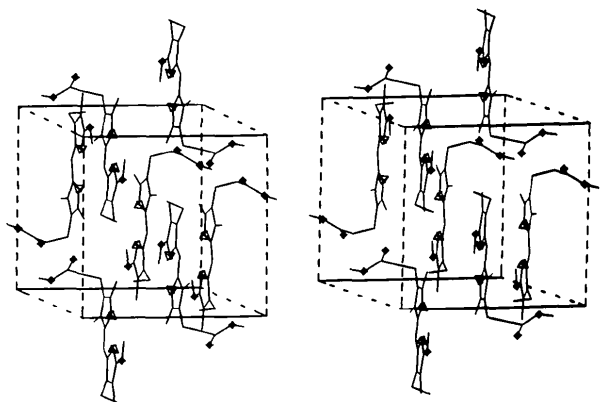
Fig. 2. Stereoview of the packing in the unit cell, viewed approximately down the c axis. Unit-cell edges are indicated by a solid line for a, long-dashed lines for b, and short-dashed lines for c. N atoms are designated by tetrahedral marks, O atoms by octahedral marks. (This diagram drawn with the aid of computer program *PACK*; Swanson, Rosenfield & Meyer, 1982.)

The degree of delocalization is greater in ring B, but even in this ring the N(2)—C(6) bond length is longer than the N(2)—C(9) distance. These distances correspond to approximate bond orders of 1·5 and 1 respectively. This would be expected given the localization found in ring A.

Because only one N atom bears an H atom, steric effects should be less than in the lactam form of Z-oxodipyrromethenes, where both N atoms bear H atoms. This is especially evident in the C_a—C_m—C_a angle of 127·0 (3)° which is significantly smaller than the value found (133°) in the Z-synperiplanar oxodipyrromethenes. The trends in bond parameters discussed here are similar to those found in diethoxybilirubin diethyl ester (Sheldrick & Becker, 1979).

There is an intramolecular $N(1)\cdots H(N2)$—N(2) hydrogen bond, the existence of which may in part account for the planarity of the molecule. Bond parameters for this hydrogen bond are given in Fig. 1 and Table 2. The other reported lactam oxodipyrromethenes all have intermolecular hydrogen bonding, but none is possible in this case, given the observed planarity of the molecule.

The title compound may also be considered as an unsymmetrically substituted pyrromethene, which might exist as either of the following tautomeric forms.
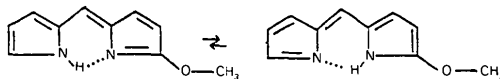
Pyrromethenes are known to exist in a canonically structured form from ESCA measurements (Falk, Hofer & Lehner, 1974). As there is a very rapid tautomerization process available in the pyrromethene series (*e.g.* Falk, Gergely & Hofer, 1974*a*) the equilibrium position is not given *a priori*. This position might be on either extremum or it might correspond to a 50/50 mixture. Such a tautomerism has been observed in another O-methylated pyrromethene, which may be compared to the title compound (Falk, Grubmayr, Thirring & Gurker, 1978). Earlier X-ray structural results on a symmetric neutral pyrromethene were inconclusive on the question of the imino H atom, since its position was disordered (Sheldrick, Borkenstein, Struckmeyer & Engel, 1978). Therefore, this study presents the first case of a structure of an unsymmetrically substituted pyrromethene where the tautomeric situation is clearly defined. The only other work which indicated a single tautomer was a LIS–NMR study of unsymmetrically substituted pyrromethenes (Falk, Gergely & Hofer, 1974*b*).

In contrast to pyrromethenones, the O-methyl derivatives do not isomerize photochemically (Falk, Grubmayr & Neufingerl, 1979) and have very little fluorescence (Falk & Neufingerl, 1979*a*). The intramolecular hydrogen bond in the O-methyl derivatives gives rise to an extremely efficient radiationless deexcitation process and is responsible for these differences (Falk & Neufingerl, 1979*b*).

A packing diagram of the contents of the unit cell is given in Fig. 2. As is observed for many of the planar

dipyrromethenes, the molecules pack in parallel sheets, approximately 3·5–3·7 Å apart. It is believed that this arrangement stabilizes the planarity of the pyrrolic skeleton because of dispersion forces between the sheets (Sheldrick, Borkenstein, Blacha-Puller & Gossauer, 1977). There are no intermolecular contacts less than 3·5 Å between non-hydrogen atoms.

References

BONNETT, R., DAVIES, J. E., HURSTHOUSE, M. B. & SHELDRICK, G. M. (1978). *Proc. R. Soc. London Ser. B*, **202**, 249–268.

CROMER, D. T. (1974). *International Tables for X-ray Crystallography*, Vol. IV, pp. 149–150. Birmingham: Kynoch Press.

CROMER, D. T. & WABER, J. T. (1974). *International Tables for X-ray Crystallography*, Vol. IV, pp. 99–101. Birmingham: Kynoch Press.

CULLEN, D. L., BLACK, P. S., MEYER, E. F., LIGHTNER, D. A., QUISTAD, G. B. & PAK, C. S. (1977). *Tetrahedron*, **33**, 477–483.

CULLEN, D. L., PÈPE, G., MEYER, E. F. JR, FALK, H. & GRUBMAYR, K. (1979). *J. Chem. Soc. Perkin Trans.* 2, pp. 999–1003.

FALK, H., GERGELY, S., GRUBMAYR, K. & HOFER, O. (1977). *Justus Liebigs Ann. Chem.* pp. 565–581.

FALK, H., GERGELY, S. & HOFER, O. (1974a). *Monatsh. Chem.* **105**, 853–862.

FALK, H., GERGELY, S. & HOFER, O. (1974b). *Monatsh. Chem.* **105**, 1004–1018.

FALK, H., GRUBMAYR, K. & NEUFINGERL, F. (1979). *Monatsh. Chem.* **110**, 1127–1146.

FALK, H., GRUBMAYR, K., THIRRING, K. & GURKER, N. (1978). *Monatsh. Chem.* **109**, 1183–1189.

FALK, H., HOFER, O. & LEHNER, H. (1974). *Monatsh. Chem.* **105**, 366–378.

FALK, H. & NEUFINGERL, F. (1979a). *Monatsh. Chem.* **110**, 987–1001.

FALK, H. & NEUFINGERL, F. (1979b). *Monatsh. Chem.* **110**, 1243–1255.

FISCHER, H. & ADLER, E. (1931). *Hoppe Seyler's Z. Physiol. Chem.* **197**, 237–280.

FRENZ, B. A. (1978). *Computing in Crystallography*, edited by H. SCHENK, R. OLTHOF-HAZEKAMP, H. VAN KONINGSVELD & G. C. BASSI, pp. 64–71. Delft Univ. Press.

HOARD, J. L. (1975). *Porphyrins and Metalloporphyrins*, edited by K. M. SMITH, pp. 317–380, see especially p. 337. Amsterdam: Elsevier.

HORI, A., MANGANI, S., PÈPE, G., MEYER, E. F. JR, CULLEN, D. L., FALK, H. & GRUBMAYR, K. (1981). *J. Chem. Soc. Perkin Trans.* 2, pp. 1525–1528.

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

MAIN, P., HULL, S. E., LESSINGER, L., GERMAIN, G., DECLERCQ, J.-P. & WOOLFSON, M. M. (1978). *MULTAN78. A System of Computer Programs for the Automatic Solution of Crystal Structures from X-ray diffraction Data*. Univs. of York, England, and Louvain, Belgium.

MORIMOTO, C. N. & MEYER, E. F. JR (1976). *Crystallographic Computing Techniques*, edited by F. R. AHMED, pp. 488–496. Copenhagen: Munksgaard.

SHELDRICK, W. S. (1976). *J. Chem. Soc. Perkin Trans.* 2, pp. 1457–1462.

SHELDRICK, W. S. & BECKER, W. (1979). *Z. Naturforsch. Teil B*, **34**, 1542–1546.

SHELDRICK, W. S., BORKENSTEIN, A., BLACHA-PULLER, M. & GOSSAUER, A. (1977). *Acta Cryst.* B**33**, 3625–3635.

SHELDRICK, W. S., BORKENSTEIN, A., STRUCKMEYER, G. & ENGEL, J. (1978). *Acta Cryst.* B**34**, 329–332.

SWANSON, S. M., ROSENFIELD, R. E. JR & MEYER, E. F. JR (1982). *J. Appl. Cryst.* **15**, 439–442.

Structure of Dibenzoyldisulphane, C14H10O2S2

BY G. C. ROUT AND M. SESHASAYEE

Department of Physics, Indian Institute of Technology, Madras 600 036, India

AND T. SUBRAHMANYAN AND G. ARAVAMUDAN

Department of Chemistry, Indian Institute of Technology, Madras 600 036, India

Abstract. $M_r = 274·35$, monoclinic, $P2_1/a$, $a = 9·079$ (2), $b = 12·073$ (2), $c = 12·370$ (3) Å, $\beta = 107·21$ (2)°, $V = 1295·32$ Å^3, $Z = 4$, $D_x = 1·407$ Mg m^{-3}, $\lambda(Cu\, K\alpha) = 1·54184$ Å, $\mu(Cu\, K\alpha) = 3·49$ mm^{-1}, $F(000) = 568$, $T = 298$ K, $R = 0·063$, $R_w = 0·064$ for 1259 reflections. S—S is 2·021 (2) Å and the C—S—S—C dihedral angle is 80·8 (3)°. The compound is monomeric and has a *gauche* conformation with respect to the S—S bond. Short contacts (~ 3·0 Å) are present between the S and O of the two halves of the disulphane.

Introduction. The symmetric disulphone compounds of type *RSSR* contain the disulphide bridge which plays an important role in stabilizing macromolecular (protein) structures in three dimensions. The title compound