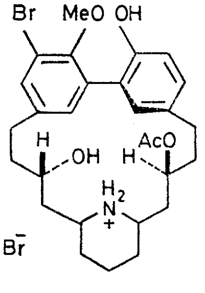
Conformation of the Strained *meta,meta'*-Bridged Biphenyl System in the Lythraceae Alkaloids Lythrancine-II and Lythrancine-IV: *X*-Ray Analyses of Lythrancine-II *O-p*-Bromobenzenesulphonate and Lythrancine-IV †

By **Michael J. Barrow, Peter D. Cradwick,** and **George A. Sim,*** Chemistry Department, The University, Glasgow G12 8QQ

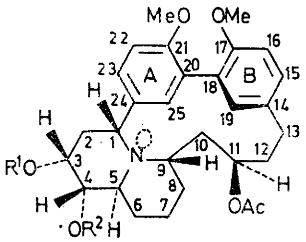
X-Ray structural studies of lythrancine-II *O-p*-bromobenzenesulphonate (2c) and lythrancine-IV (2b) have provided details of the conformation of the macrocycle which is common to a number of lythraceae alkaloids. The biphenyl system has a seven-atom chain bridging the *meta,meta'*-positions and the constraint results in a marked asymmetry in the valency angles around the inter-aryl bond, angles endocyclic with respect to the macrocycle being <120° and exocyclic >120°. The dihedral angle between the benzene planes is 49° in (2b) and 47° in (2c). The C–C–C valency angles at the carbon atoms of the $CH_2{\cdot}CH_2{\cdot}CHR{\cdot}CH_2$ portion of the bridging chain are generally enlarged beyond the tetrahedral value, mean 115 (2b) and 114° (2c). The six-membered rings of the *cis*-quinolizidine system have chair conformations. The *p*-bromobenzenesulphonate group in (2c) adopts a conformation in which the S–OC bond is steeply inclined to the benzene plane and the relative orientation of phenyl and quinolizidine substituents about this bond is gauche.

Crystals of both compounds are orthorhombic, space group $P2_12_12_1$, and $Z = 4$: for (2b) $a = 8{\cdot}769(7)$, $b = 15{\cdot}368(8)$, $c = 22{\cdot}927(11)$ Å; for (2c) $a = 21{\cdot}435(10)$, $b = 13{\cdot}819(14)$, $c = 11{\cdot}537(9)$ Å. The atomic co-ordinates were determined by direct and heavy atom methods and refined by Fourier and least-squares calculations, and the analyses terminated at *R* 4·3% [2745 reflexions, (2b)] and 10·8% [1903 reflexions, (2c)]. The absolute configuration was established for (2c) by the anomalous-dispersion effect.

FUJITA and colleagues isolated and characterized a number of biphenyl alkaloids from *Lythrum anceps* Makino (Lythraceae),[1] and the constitution and absolute stereochemistry of bromolythranine hydrobromide (1) was defined by *X*-ray analysis by McClure and Sim.[2] Recently Fujita established that lythrancine-II and lythrancine-IV have structures (2a) and (2b), respectively,[3] and since these alkaloids have a short seven-atom chain bridging the *meta,meta'*-positions of the biphenyl system we undertook *X*-ray studies of (2b) and the *p*-bromobenzenesulphonate (2c) in order to compare the conformations of the biphenyl systems in (1) and (2). The diffraction data were obtained by means of a computer-controlled four-circle diffractometer, the atomic co-ordinates determined by Fourier and least-squares methods, and the absolute configuration established for (2c) by the anomalous-dispersion effect; the analyses terminated at *R* 4·3% over 2745 reflections for (2b) and *R* 10·8% over 1903 reflections for (2c).



(1)



	R^1	R^2
(2a)	H	H
(2b)	Ac	Ac
(2c)	$O_2S{\cdot}C_6H_4{\cdot}Br$	H

---

† No reprints available.

[1] E. Fujita, K. Bessho, K. Fuji, and A. Sumi, *Chem. and Pharm. Bull* (*Japan*), 1970, **18**, 2215; E. Fujita and K. Fuji, *J. Chem. Soc.* (*C*), 1971, 1651.

[2] R. J. McClure, jun., and G. A. Sim, *J.C.S. Perkin II*, 1972, 2073.

[3] E. Fujita and Y. Saeki, *Chem. Comm.*, 1971, 368; *Chem. and Pharm. Bull.* (*Japan*), 1971, **19**, 1515; *J. Chem. Soc.* (*C*), 1971, 2141; *J.C.S. Perkin I*, 1972, 2141; 1973, 297.

The atomic co-ordinates are listed in Tables 1 and 2, and the various interatomic distances and angles are in Table 3. The arrangements of atoms in the alkaloid molecules are shown in Figures 1 and 2 and these provide independent confirmation of the chemical assignment of structures (2). After the completion of this work a brief report appeared describing the elucidation of the structure of a related alkaloid lythrumine by X-ray analysis of the hydrobromide, but details of the molecular geometry were not provided.[4]

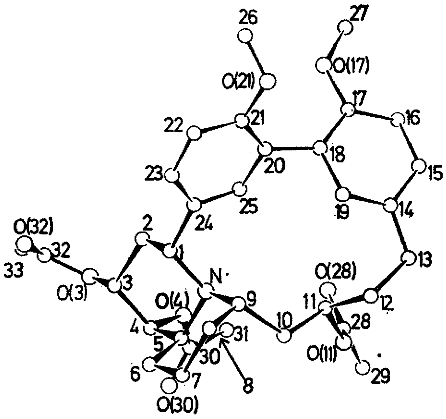


FIGURE 1 Molecular structure of lythrancine-IV projected on the mean plane of the 13-membered ring

TABLE 1

Atomic parameters, with estimated standard deviations in parentheses, for lythrancine-IV (2b)

Atom	x	y	z
N	0·0352(2)	0·2259(1)	0·2579(1)
C(1)	−0·1219(3)	0·2064(2)	0·2779(1)
C(2)	−0·2361(3)	0·2480(2)	0·2360(1)
C(3)	−0·2119(4)	0·2097(2)	0·1752(1)
C(4)	−0·0511(4)	0·2243(2)	0·1550(1)
C(5)	0·0637(3)	0·1901(2)	0·1986(1)
C(6)	0·0754(4)	0·0903(2)	0·1964(1)
C(7)	0·1957(5)	0·0575(2)	0·2393(2)
C(8)	0·1679(4)	0·0966(2)	0·2995(1)
C(9)	0·1581(3)	0·1956(2)	0·2984(1)
C(10)	0·3132(4)	0·2372(2)	0·2851(2)
C(11)	0·3321(3)	0·3330(2)	0·3021(2)
C(12)	0·4250(4)	0·3462(2)	0·3577(2)
C(13)	0·4180(4)	0·4370(3)	0·3862(2)
C(14)	0·2669(4)	0·4586(2)	0·4147(1)
C(15)	0·2363(5)	0·5380(2)	0·4419(1)
C(16)	0·0918(5)	0·5559(2)	0·4631(1)
C(17)	−0·0296(5)	0·4984(2)	0·4567(1)
C(18)	−0·0006(4)	0·4178(2)	0·4306(1)
C(19)	0·1482(4)	0·4009(2)	0·4124(1)
C(20)	−0·1108(3)	0·3496(2)	0·4140(1)
C(21)	−0·2017(4)	0·3020(2)	0·4520(1)
C(22)	−0·2677(4)	0·2245(2)	0·4345(1)
C(23)	−0·2392(4)	0·1920(2)	0·3788(1)
C(24)	−0·1534(3)	0·2395(2)	0·3389(1)
C(25)	−0·0965(3)	0·3190(2)	0·3565(1)
O(21)	−0·2103(4)	0·3292(2)	0·5094(1)
C(26)	−0·3542(6)	0·3385(3)	0·5321(2)
O(17)	−0·1775(4)	0·5162(2)	0·4713(1)
C(27)	−0·2229(8)	0.5936(4)	0·4896(4)
O(11)	0·4175(3)	0·3746(2)	0·2552(1)
C(28)	0·3605(4)	0·4421(3)	0·2274(2)
O(28)	0·2386(4)	0·4722(2)	0·2376(2)
C(29)	0·4633(6)	0·4759(3)	0·1818(3)
O(4)	−0·0288(3)	0·3172(1)	0·1475(1)
C(30)	0·0284(4)	0·3454(2)	0·0975(1)
O(30)	0·0606(4)	0·2993(2)	0·0581(1)
C(31)	0·0481(5)	0·4419(2)	0·0977(2)
O(3)	−0·3135(3)	0·2497(2)	0·1332(1)
C(32)	−0·4552(5)	0·2162(3)	0·1302(2)
O(32)	−0·4981(3)	0·1577(2)	0·1594(1)
C(33)	−0·5480(6)	0·2631(5)	0·0851(2)

TABLE 1 (*Continued*)

Atom	x	y	z
H(1)	−0·133	0·142	0·279
H(2)	−0·220	0·312	0·235
$H(2_1)$	−0·342	0·236	0·249
H(3)	−0·233	0·146	0·178
H(4)	−0·035	0·192	0·118
H(5)	0·167	0·212	0·187
H(6)	0·104	0·072	0·156
$H(6_1)$	−0·026	0·064	0·207
H(7)	0·299	0·075	0·225
$H(7_1)$	0·190	−0·007	0·242
H(8)	0·253	0·079	0·326
$H(8_1)$	0·070	0·073	0·315
H(9)	0·129	0·216	0·338
H(10)	0·331	0·232	0·242
$H(10_1)$	0·393	0·203	0·306
H(11)	0·228	0·358	0·309
H(12)	0·534	0·334	0·348
$H(12_1)$	0·388	0·303	0·387
H(13)	0·439	0·482	0·355
$H(13_1)$	0·500	0·440	0·417
H(15)	0·319	0·582	0·446
H(16)	0·074	0·612	0·484
H(19)	0·170	0·342	0·397
H(22)	−0·336	0·192	0·462
H(23)	−0·281	0·134	0·367
H(25)	−0·043	0·356	0·327
H(26)	−0·357	0·360	0·569
$H(26_1)$	−0·405	0.280	0·532
$H(26_2)$	−0·413	0·379	0·506
H(27)	−0·350	0·583	0·500
$H(27_1)$	−0·209	0·639	0·459
$H(27_2)$	−0·165	0·612	0·525
H(29)	0·518	0·538	0·194
$H(29_1)$	0·403	0·486	0·145
$H(29_2)$	0·544	0·432	0·174
H(31)	0·071	0·469	0·136
$H(31_1)$	−0·048	0·469	0·083
$H(31_2)$	0·133	0·457	0·070
H(33)	−0·500	0·246	0·042
$H(33_1)$	−0·542	0·327	0·091
$H(33_2)$	−0·657	0·245	0·088

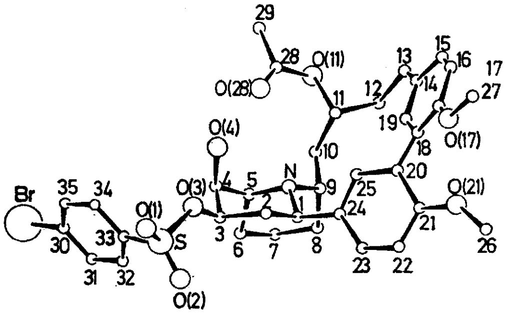


FIGURE 2 Molecular structure of lythrancine-II *O*-*p*-bromobenzenesulphonate

In the alkaloid (1) the biphenyl system is appreciably skewed about the central C(18)–C(20) bond, the dihedral angle between the mean planes of the benzene rings being 75° and the *ortho,ortho'* O · · · O separation 3·39 Å. In (2b) and (2c), on the other hand, the short seven-atom chain bridging the *meta,meta'*-positions constrains the biphenyl system to adopt a less skewed conformation so that the dihedral angle between the benzene planes is

---

[4] H. Wright, J. Clardy, and J. P. Ferris, *J. Amer. Chem. Soc.*, 1973, **95**, 6467.

TABLE 2

Atomic parameters, with estimated standard deviations in parentheses, for lythrancine-II *O*-*p*-bromobenzenesulphonate (2c)

Atom	*x*	*y*	*z*
Br	0·00343(16)	0·0563(3)	0·5263(3)
S	0·2171(2)	−0·0306(3)	0·1546(4)
O(1)	0·1960(5)	−0·0112(9)	0·0409(11)
O(2)	0·2729(6)	0·0080(10)	0·1963(12)
O(3)	0·2233(6)	−0·1453(9)	0·1610(11)
N	0·3002(6)	−0·3681(10)	0·3602(12)
C(1)	0·3454(8)	−0·3051(12)	0·2982(15)
C(2)	0·3090(7)	−0·2482(11)	0·2015(14)
C(3)	0·2567(8)	−0·1879(13)	0·2572(16)
C(4)	0·2138(8)	−0·2520(12)	0·3271(15)
C(5)	0·2503(8)	−0·3061(13)	0·4166(17)
C(6)	0·2753(9)	−0·2418(14)	0·5131(18)
C(7)	0·3073(9)	−0·3050(15)	0·6085(18)
C(8)	0·3575(9)	−0·3696(16)	0·5523(19)
C(9)	0·3306(8)	−0·4304(13)	0·4494(16)
C(10)	0·2838(9)	−0·5088(14)	0·5005(17)
C(11)	0·2761(9)	−0·5932(14)	0·4126(17)
C(12)	0·3172(10)	−0·6835(15)	0·4426(19)
C(13)	0·3220(10)	−0·7638(15)	0·3515(20)
C(14)	0·3587(10)	−0·7403(15)	0·2442(19)
C(15)	0·3718(8)	−0·8008(13)	0·1485(19)
C(16)	0·4035(9)	−0·7755(14)	0·0558(18)
C(17)	0·4260(8)	−0·6787(13)	0·0430(17)
C(18)	0·4152(8)	−0·6153(12)	0·1323(15)
C(19)	0·3846(8)	−0·6445(13)	0·2312(17)
C(20)	0·4304(8)	−0·5088(13)	0·1422(17)
C(21)	0·4929(10)	−0·4726(15)	0·1354(18)
C(22)	0·5027(11)	−0·3744(15)	0·1710(19)
C(23)	0·4566(10)	−0·3241(15)	0·2318(20)
C(24)	0·3971(8)	−0·3620(12)	0·2370(15)
C(25)	0·3846(8)	−0·4528(12)	0·1884(15)
O(21)	0·5398(7)	−0·5275(13)	0·0899(19)
C(26)	0·5946(11)	−0·5303(20)	0·1492(27)
O(17)	0·4568(6)	−0·6454(9)	−0·0526(14)
C(27)	0·4718(12)	−0·7136(16)	−0·1446(25)
O(11)	0·2119(6)	−0·6346(10)	0·4292(11)
C(28)	0·1642(9)	−0·5903(14)	0·3741(17)
O(28)	0·1710(6)	−0·5161(10)	0·3158(12)
C(29)	0·1036(11)	−0·6413(18)	0·3918(20)
O(4)	0·1830(6)	−0·3168(9)	0·2484(11)
C(30)	0·0660(10)	0·0326(17)	0·4108(19)
C(31)	0·1272(9)	0·0396(16)	0·4455(19)
C(32)	0·1730(9)	0·0240(15)	0·3685(17)
C(33)	0·1584(7)	−0·0033(11)	0·2604(13)
C(34)	0·0946(10)	−0·0134(16)	0·2235(19)
C(35)	0·0492(11)	0·0049(18)	0·2994(21)
H(1)	0·366	−0·254	0·359
H(2)	0·290	−0·299	0·140
H(21)	0·341	−0·202	0·156
H(3)	0·276	−0·131	0·312
H(4)	0·179	−0·209	0·369
H(5)	0·219	−0·357	0·457
H(6)	0·236	−0·202	0·550
H(61)	0·308	−0·190	0·478
H(7)	0·272	−0·351	0·650
H(71)	0·328	−0·260	0·673
H(8)	0·375	−0·418	0·617
H(81)	0·394	−0·324	0·521
H(9)	0·369	−0·468	0·409
H(10)	0·240	−0·476	0·516
H(101)	0·303	−0·537	0·580
H(11)	0·283	−0·571	0·323
H(12)	0·296	−0·717	0·519
H(121)	0·363	−0·659	0·462
H(13)	0·276	−0·786	0·324
H(131)	0·344	−0·827	0·391
H(15)	0·354	−0·875	0·152
H(16)	0·412	−0·830	−0·010
H(19)	0·380	−0·593	0·302
H(22)	0·547	−0·340	0·153
H(23)	0·468	−0·257	0·272
H(25)	0·336	−0·478	0·185
H(31)	0·102	0·058	0·524
H(32)	0·217	0·014	0·322
H(34)	0·121	−0·035	0·147
H(35)	0·005	0·017	0·342

TABLE 3

Interatomic distances (Å) and angles (deg.), with estimated standard deviations in parentheses

(*a*) Bond lengths

	(2b)	(2c)
C(1)–C(2)	1·528(4)	1·573(23)
C(1)–C(24)	1·514(3)	1·530(23)
C(2)–C(3)	1·526(4)	1·538(23)
C(3)–C(4)	1·501(5)	1·508(25)
C(4)–C(5)	1·513(4)	1·496(26)
C(5)–C(6)	1·538(4)	1·521(28)
C(6)–C(7)	1·528(5)	1·564(29)
C(7)–C(8)	1·524(5)	1·541(29)
C(8)–C(9)	1·525(4)	1·565(28)
C(9)–C(10)	1·532(4)	1·590(26)
C(10)–C(11)	1·532(5)	1·556(27)
C(11)–C(12)	1·526(5)	1·566(28)
C(12)–C(13)	1·541(5)	1·531(31)
C(13)–C(14)	1·514(5)	1·504(31)
C(14)–C(15)	1·397(5)	1·412(29)
C(14)–C(19)	1·369(5)	1·442(28)
C(15)–C(16)	1·384(6)	1·313(29)
C(16)–C(17)	1·391(6)	1·431(27)
C(17)–C(18)	1·400(4)	1·372(25)
C(18)–C(19)	1·394(5)	1·376(25)
C(18)–C(20)	1·476(4)	1·513(24)
C(20)–C(21)	1·389(4)	1·430(27)
C(20)–C(25)	1·405(4)	1·358(24)
C(21)–C(22)	1·383(5)	1·432(29)
C(22)–C(23)	1·392(4)	1·397(31)
C(23)–C(24)	1·391(4)	1·381(26)
C(24)–C(25)	1·381(4)	1·401(24)
C(28)–C(29)	1·475(7)	1·491(30)
C(30)–C(31)	1·493(5)	1·376(30)
C(30)–C(35)		1·387(33)
C(31)–C(32)		1·342(29)
C(32)–C(33)	1·501(7)	1·340(25)
C(33)–C(34)		1·438(26)
C(34)–C(35)		1·335(32)
C(3)–O(3)	1·449(4)	1·446(22)
C(4)–O(4)	1·451(4)	1·436(21)
C(11)–O(11)	1·459(4)	1·500(23)
C(21)–O(21)	1·383(3)	1·365(26)
C(17)–O(17)	1·367(5)	1·365(24)
C(26)–O(21)	1·372(6)	1·362(28)
C(27)–O(17)	1·323(6)	1·455(30)
C(28)–O(11)	1·316(5)	1·352(24)
C(28)–O(28)	1·188(5)	1·236(24)
C(30)–O(4)	1·324(3)	
C(30)–O(30)	1·182(4)	
C(32)–O(3)	1·346(5)	
C(32)–O(32)	1·182(6)	
C(33)–S		1·793(16)
C(30)–Br		1·920(22)
C(1)–N	1·482(3)	1·486(21)
C(5)–N	1·487(3)	1·517(23)
C(9)–N	1·497(4)	1·492(23)
O(1)–S		1·413(14)
O(2)–S		1·395(14)
O(3)–S		1·591(13)

(*b*) Intramolecular non-bonded distances

	(2b)	(2c)
O(17) · · · O(21)	3·017	2·918
O(3) · · · O(4)	2·723	2·718
O(4) · · · N	2·948	2·911
O(4) · · · O(28)	3·930	2·873
C(9) · · · C(25)	3·218	3·240
C(11) · · · C(19)	3·175	3·208

(*c*) Valency angles

	(2b)	(2c)
C(24)–C(1)–N	112·9(2)	113·2(10)
C(24)–C(1)–C(2)	108·8(2)	106·8(10)
C(2)–C(1)–N	109·3(2)	108·1(10)
C(1)–C(2)–C(3)	108·8(3)	109·7(10)
C(2)–C(3)–C(4)	110·8(3)	110·5(11)
C(2)–C(3)–O(3)	111·0(3)	105·1(10)

TABLE 3 (*Continued*)

(*c*) Valency angles (*contd.*)

	(2b)	(3c)
O(3)–C(3)–C(4)	108·0(2)	110·5(11)
C(3)–C(4)–C(5)	111·7(2)	110·1(12)
C(3)–C(4)–O(4)	108·1(3)	107·9(11)
O(4)–C(4)–C(5)	109·4(2)	111·4(11)
C(4)–C(5)–N	111·3(2)	110·8(12)
C(6)–C(5)–N	114·2(2)	113·3(11)
C(4)–C(5)–C(6)	111·7(2)	113·4(13)
C(5)–C(6)–C(7)	110·7(3)	110·0(13)
C(6)–C(7)–C(8)	110·0(3)	109·5(13)
C(7)–C(8)–C(9)	112·8(3)	111·9(12)
C(8)–C(9)–C(10)	111·6(3)	108·4(12)
C(8)–C(9)–N	111·2(2)	111·9(12)
C(10)–C(9)–N	112·8(2)	111·9(12)
C(9)–C(10)–C(11)	116·5(3)	109·7(12)
C(10)–C(11)–C(12)	113·5(3)	113·2(12)
C(10)–C(11)–O(11)	106·8(3)	107·4(12)
C(12)–C(11)–O(11)	106·4(2)	100·6(13)
C(11)–C(12)–C(13)	117·0(3)	117·7(14)
C(12)–C(13)–C(14)	114·6(3)	116·3(13)
C(13)–C(14)–C(15)	123·6(3)	128·3(13)
C(13)–C(14)–C(19)	120·4(3)	119·0(14)
C(15)–C(14)–C(19)	115·9(3)	112·7(13)
C(14)–C(15)–C(16)	120·4(3)	125·6(13)
C(15)–C(16)–C(17)	122·5(3)	120·4(15)
C(16)–C(17)–C(18)	117·9(3)	117·6(13)
C(16)–C(17)–O(17)	125·0(3)	124·2(13)
C(18)–C(17)–O(17)	117·0(3)	118·2(12)
C(17)–C(18)–C(19)	117·6(3)	121·0(12)
C(17)–C(18)–C(20)	128·3(3)	129·9(12)
C(19)–C(18)–C(20)	113·9(3)	109·0(14)
C(18)–C(19)–C(14)	125·5(3)	122·6(13)
C(18)–C(20)–C(21)	126·0(2)	122·5(12)
C(18)–C(20)–C(25)	114·8(2)	115·3(11)
C(21)–C(20)–C(25)	117·7(3)	119·9(13)
C(20)–C(21)–C(22)	120·7(3)	117·0(14)
C(20)–C(21)–O(21)	118·0(3)	121·1(13)
C(22)–C(21)–O(21)	121·0(3)	121·8(14)
C(21)–C(22)–C(23)	120·0(3)	120·6(15)
C(22)–C(23)–C(24)	120·8(3)	119·2(13)
C(23)–C(24)–C(1)	122·1(2)	119·6(11)
C(23)–C(24)–C(25)	117·9(2)	119·9(13)
C(25)–C(24)–C(1)	120·0(2)	120·4(10)
C(24)–C(25)–C(20)	122·5(2)	121·9(12)
C(29)–C(28)–O(11)	112·9(3)	112·4(12)
C(29)–C(28)–O(28)	123·5(4)	124·8(11)
O(11)–C(28)–O(28)	123·6(4)	122·9(10)
C(31)–C(30)–C(35)		122·5(16)
C(31)–C(30)–Br		116·9(9)
C(35)–C(30)–Br		120·6(10)
C(30)–C(31)–C(32)		119·6(15)
C(31)–C(32)–C(33)		119·4(13)
C(32)–C(33)–C(34)		121·7(15)
C(32)–C(33)–S		121·9(8)
C(34)–C(33)–S		116·5(8)
C(33)–C(34)–C(35)		118·8(14)
C(34)–C(35)–C(30)		118·0(17)
C(31)–C(30)–O(4)	111·5(3)	
C(31)–C(30)–O(30)	124·8(3)	
O(4)–C(30)–O(30)	123·7(3)	
C(33)–C(32)–O(3)	110·6(4)	
C(33)–C(32)–O(32)	125·6(4)	
O(3)–C(32)–O(32)	123·7(4)	
C(3)–O(3)–C(32)	116·1(3)	
C(3)–O(3)–S		118·9(8)
C(4)–O(4)–C(30)	118·5(2)	
C(11)–O(11)–C(28)	120·5(3)	117·5(11)
C(17)–O(17)–C(27)	122·9(4)	118·5(13)
C(21)–O(21)–C(26)	116·3(3)	117·3(16)
C(1)–N–C(5)	111·4(2)	109·6(11)
C(1)–N–C(9)	114·5(2)	112·7(10)
C(5)–N–C(9)	109·3(2)	109·8(12)
C(33)–S–O(3)		103·7(7)
C(33)–S–O(2)		106·7(9)
C(33)–S–O(1)		111·5(8)
O(3)–S–O(2)		107·0(7)
O(3)–S–O(1)		105·0(7)
O(2)–S–O(1)		121·5(8)

TABLE 3 (*Continued*)

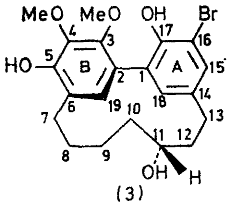
(*d*) Torsion angles. The angle A–B–C–D is defined as positive if, when viewed along the B–C bond, atom A must be rotated clockwise to eclipse atom D. Standard deviations are *ca.* 0·4° for (2b) and 1·6° for (2c)

	(2b)	(2c)
C(24)–C(1)–C(2)–C(3)	−175·9	−179
N–C(1)–C(2)–C(3)	60·5	59
N–C(1)–C(24)–C(23)	−140·9	−145
N–C(1)–C(24)–C(25)	39·1	34
C(2)–C(1)–C(24)–C(23)	97·7	97
C(2)–C(1)–C(24)–C(25)	−82·3	−85
C(1)–C(2)–C(3)–O(3)	−177·6	−176
C(1)–C(2)–C(3)–C(4)	−57·7	−56
O(3)–C(3)–C(4)–O(4)	55·7	51
O(3)–C(3)–C(4)–C(5)	176·0	172
C(2)–C(3)–C(4)–O(4)	−66·0	−65
C(2)–C(3)–C(4)–C(5)	54·3	57
O(4)–C(4)–C(5)–N	66·3	60
O(4)–C(4)–C(5)–C(6)	−164·7	−171
C(3)–C(4)–C(5)–N	−53·2	−59
C(3)–C(4)–C(5)–C(6)	75·8	69
N–C(5)–C(6)–C(7)	−54·5	−58
C(4)–C(5)–C(6)–C(7)	178·1	175
C(5)–C(6)–C(7)–C(8)	50·9	55
C(6)–C(7)–C(8)–C(9)	−53·8	−54
C(7)–C(8)–C(9)–N	57·3	55
C(7)–C(8)–C(9)–C(10)	−69·5	−69
N–C(9)–C(10)–C(11)	73·5	78
C(8)–C(9)–C(10)–C(11)	−160·6	−158
C(9)–C(10)–C(11)–O(11)	−139·9	−151
C(9)–C(10)–C(11)–C(12)	103·1	99
O(11)–C(11)–C(12)–C(13)	77·0	76
C(10)–C(11)–C(12)–C(13)	−165·8	−170
C(11)–C(12)–C(13)–C(14)	70·8	70
C(12)–C(13)–C(14)–C(15)	−178·8	178
C(12)–C(13)–C(14)–C(19)	−1·9	−2
C(13)–C(14)–C(15)–C(16)	175·0	179
C(19)–C(14)–C(15)–C(16)	−2·1	0
C(13)–C(14)–C(19)–C(18)	−171·6	−176
C(15)–C(14)–C(19)–C(18)	5·5	4
C(14)–C(15)–C(16)–C(17)	−2·3	−3
C(15)–C(16)–C(17)–O(17)	−172·9	−177
C(15)–C(16)–C(17)–C(18)	3·5	2
O(17)–C(17)–C(18)–C(19)	176·4	−180
O(17)–C(17)–C(18)–C(20)	2·9	2
C(16)–C(17)–C(18)–C(19)	−0·4	1
C(16)–C(17)–C(18)–C(20)	−173·8	−177
C(17)–C(18)–C(19)–C(14)	−4·3	−4
C(20)–C(18)–C(19)–C(14)	170·0	174
C(17)–C(18)–C(20)–C(25)	129·5	137
C(19)–C(18)–C(20)–C(21)	121·7	122
C(19)–C(18)–C(20)–C(25)	−44·1	−41
C(18)–C(20)–C(21)–O(21)	11·5	17
C(18)–C(20)–C(21)–C(22)	−161·6	−167
C(25)–C(20)–C(21)–O(21)	176·9	180
C(25)–C(20)–C(21)–C(22)	3·8	−4
C(18)–C(20)–C(25)–C(24)	159·2	159
C(21)–C(20)–C(25)–C(24)	−7·9	−4
O(21)–C(21)–C(22)–C(23)	−170·7	−171
C(20)–C(21)–C(22)–C(23)	2·2	13
C(21)–C(22)–C(23)–C(24)	−4·5	−13
C(22)–C(23)–C(24)–C(1)	−179·3	−177
C(22)–C(23)–C(24)–C(25)	0·7	4
C(1)–C(24)–C(25)–C(20)	−174·4	−174
C(23)–C(24)–C(25)–C(20)	5·6	4
Br–C(30)–C(31)–C(32)		−180
C(35)–C(30)–C(31)–C(32)		3
Br–C(30)–C(35)–C(34)		−180
C(31)–C(30)–C(35)–C(34)		−1
C(30)–C(31)–C(32)–C(33)		−4
C(31)–C(32)–C(33)–S		−177
C(31)–C(32)–C(33)–C(34)		2
S–C(33)–C(34)–C(35)		179
C(32)–C(33)–C(34)–C(35)		0
C(33)–C(34)–C(35)–C(30)		0
C(2)–C(3)–O(3)–S		−123
C(2)–C(3)–O(3)–C(32)	−83·7	
C(4)–C(3)–O(3)–C(32)	154·7	
C(3)–C(4)–O(4)–C(30)	−128·9	

TABLE 3 (*Continued*)

	(2b)	(2c)
C(5)–C(4)–O(4)–C(30)	109·4	
C(10)–C(11)–O(11)–C(28)	122·8	84
C(12)–C(11)–O(11)–C(28)	−115·7	−157
C(16)–C(17)–O(17)–C(27)	4·9	−4
C(18)–C(17)–O(17)–C(27)	−171·6	176
C(20)–C(21)–O(21)–C(26)	129·4	−134
C(22)–C(21)–O(21)–C(26)	−57·6	50
C(29)–C(28)–O(11)–C(11)	179·5	177
O(28)–C(28)–O(11)–C(11)	−1·1	−3
C(31)–C(30)–O(4)–C(4)	−178·3	
O(30)–C(30)–O(4)–C(4)	1·2	
C(33)–C(32)–O(3)–C(3)	−179·8	
O(32)–C(32)–O(3)–C(3)	0·0	
C(5)–N–C(1)–C(2)	−60·7	−61
C(5)–N–C(1)–C(24)	178·2	−179
C(9)–N–C(1)–C(2)	174·7	176
C(9)–N–C(1)–C(24)	53·5	58
C(1)–N–C(5)–C(4)	56·7	63
C(1)–N–C(5)–C(6)	−70·9	−66
C(9)–N–C(5)–C(4)	−175·8	−173
C(9)–N–C(5)–C(6)	56·6	58
C(1)–N–C(9)–C(8)	69·1	67
C(1)–N–C(9)–C(10)	−164·7	−171
C(5)–N–C(9)–C(8)	− 56·7	−55
C(5)–N–C(9)–C(10)	69·5	67
C(32)–C(33)–S–O(1)		−151
C(32)–C(33)–S–O(2)		−16
C(32)–C(33)–S–O(3)		96
C(34)–C(33)–S–O(1)		30
C(34)–C(33)–S–O(2)		164
C(34)–C(33)–S–O(3)		−83
C(33)–S–O(3)–C(3)		−76
O(1)–S–O(3)–C(3)		167
O(2)–S–O(3)–C(3)		36

49 in (2b) and 47° in (2c) and the O(17) · · · O(21) distance 3·02 in (2b) and 2·92 Å in (2c). In bromomyricanol (3) a still shorter O · · · O separation of 2·66 Å between *ortho,-ortho'*-substituents is made possible by hydrogen bonding and the dihedral angle between the benzene planes is only 33°.[5] The constraints imposed on (2) and (3) by the short *meta,meta'*-bridge are also reflected in the marked deviations from 120° of the valency angles at the carbon atoms of the central bond of the biphenyl systems; the angles exocyclic to the macrocycle are 126 and 128° in (2b), 123 and 130° in (2c), and 126 and 130° in (3), whereas the endocyclic angles are 115 and 114° in (2b), 115 and 109° in (2c), and 115 and 114° in (3). The greater flexibility of the longer eleven-atom bridge in (1) permits the valency angles at C(18) and C(20) in that molecule to remain close to the ideal value of 120°.



(3)

Another distortion of the biphenyl system in (2) is apparent in the very large displacements (Table 4) of atoms C(18) and C(15) from the plane of ring A [by 0·44 and 1·34 in (2b), and by 0·42 and 1·39 Å in (2c)] in contrast to the much smaller displacements of atoms C(20) and C(23) from the plane of ring B [by −0·17 and −0·21 in (2b), and by −0·10 and 0·10 Å in (2c)]. This unsymmetrical bending is also a characteristic feature of the biphenyl system in bromomyricanol (3) where C(2) and C(5) of that molecule are 0·43 and 1·27 Å above the plane of ring A while C(15) is only 0·25 Å from the plane of ring B.[5]

The strain inherent in the seven-atom *meta,meta'*-chain in (2) is further evident in the enlargement of the bridge C–C(sp^3)–C valency angles beyond the tetrahedral value; *e.g.* the angle at C(12) is 117·0 in (2b) and 117·7° in (2c). Enlargement of valency angles is also apparent in the bromomyricanol bridge.

Corresponding torsion angles for the thirteen-atom macrocycles in (2b), (2c), and (3) are compared in Table 5.

TABLE 4

Equations of least-squares planes in orthogonal (Å) co-ordinates X, Y, Z

Plane (I): C(14)—(19)
(2b): $0{\cdot}2363X - 0{\cdot}3882Y + 0{\cdot}8907Z - 6{\cdot}3085 = 0$
(2c): $0{\cdot}8587X - 0{\cdot}2823Y + 0{\cdot}4277Z - 10{\cdot}7093 = 0$
Plane (II): C(20)—(25)
(2b): $0{\cdot}8218X - 0{\cdot}4798Y + 0{\cdot}3073Z + 0{\cdot}4945 = 0$
(2c): $0{\cdot}2277X - 0{\cdot}3970Y + 0{\cdot}8891Z - 6{\cdot}3386 = 0$

Distances (Å) of atoms from the planes

	Plane (I)		Plane (II)	
	(2b)	(2c)	(2b)	(2c)
C(14)	−0·023	−0·01	1·958	1·98
C(15)	−0·003	−0·01	1·344	1·39
C(16)	0·023	0·02	0·321	0·46
C(17)	−0·017	−0·01	−0·176	−0·10
C(18)	−0·009	−0·01	0·444	0·42
C(19)	0·030	0·02	1·513	1·45
C(20)	−0·169	−0·10	0·035	0·01
C(21)	0·703	0·87	−0·001	0·05
C(22)	0·670	0·85	−0·029	−0·08
C(23)	−0·213	0·10	0·024	0·05
C(24)	−1·134	−0·82	0·011	0·02
C(25)	−1·131	−0·93	−0·041	−0·04
O(17)	−0·132	−0·04	−1·271	−1·11
O(21)	1·694	1·73	0·141	0·11

TABLE 5

Comparison of corresponding endocyclic torsion angles in the thirteen-membered rings in (2b), (2c), and (3)

	(2b)	(2c)		(3) *
ω(10)–(11)	103	99	ω(10)–(11)	−89
ω(11)–(12)	−166	−170	ω(11)–(12)	168
ω(12)–(13)	71	70	ω(12)–(13)	−69
ω(13)–(14)	−2	−2	ω(13)–(14)	−13
ω(14)–(19)	−172	−176	ω(14)–(18)	170
ω(19)–(18)	170	174	ω(18)–(1)	−161
ω(18)–(20)	−44	−41	ω(1)–(2)	32
ω(20)–(25)	159	159	ω(2)–(19)	−174
ω(25)–(24)	−174	−174	ω(19)–(6)	175
ω(24)–(1)	39	34	ω(6)–(7)	2
ω(1)–(N)	54	58	ω(7)–(8)	−74
ω(N)–(9)	−165	−171	ω(8)–(9)	168
ω(9)–(10)	74	78	ω(9)–(10)	−83

* Calculated from the co-ordinates listed in ref. 5.

These angles show that the conformations are closely similar despite the absence of the quinolizidine unit from (3), though the deviations of the rings from C_2 symmetry are somewhat larger in (2b) and (2c) than in (3). A number of the torsion angles differ substantially from their ideal values. The biphenyl units in (2) and (3) have opposite absolute sense of twist, consistent with the

---

[5] M. J. Begley, R. V. M. Campbell, L. Crombie, B. Tuck, and D. A. Whiting, *J. Chem. Soc.* (*C*), 1971, 3634.

correlation between configuration and Cotton effect of chiral biphenyls.[6]

The six-membered rings in the *cis*-quinolizidine have chair conformations with torsion angles in the range 51—61, mean 56°, in (2b) and 54—63, mean 58° in (2c). The C(sp^3)–C(sp^3) bond lengths in the *cis*-quinolizidine in (2b) are 1·501—1·538, mean 1·523 Å; the spread in (2c) is a little larger, though the accuracy is lower, and the mean is 1·538 Å. The mean N–C separation is 1·489 in (2b) and 1·498 Å in (2c). The axial oxygen atom at C(4) in (2c) is 2·72 from the neighbouring oxygen atom O(3), and 2·87 Å from the carbonyl oxygen O(28) of the C(11)-acetate; Figure 2 shows that the latter approach is more likely to represent a hydrogen-bonded interaction and this deduction is supported by the corresponding distances of 2·72 and 3·93 Å in (2b) which lacks this hydrogen bond.

The *p*-bromobenzenesulphonate group at C(3) in (2c) adopts the customary conformation in which the S–O(3) bond is nearly normal to the plane of the benzene ring,[7] the torsion angle C(32)C(33)–SO(3) being 96°. The phenyl and quinolizidine substituents on the S–O(3) bond are gauche, the torsion angle C(33)S–O(3)C(3) being −76°. A recent survey of CS–OC torsion angles of *p*-bromobenzenesulphonates disclosed values as diverse as 52—176°, most of the angles being representative of a gauche conformation;[8] the wide spread of values is consistent with Exner's observation that there is only a small barrier to rotation about the S–OC bond.[9]

There is good agreement among corresponding bond lengths in the three actyl groups in (2b); mean dimensions: C(sp^3)–C(sp^2) 1·490, C=O 1·184, C(sp^2)–O 1·329, and C(sp^3)–O 1·453 Å.

EXPERIMENTAL

Space group information and approximate cell dimensions were obtained from Weissenberg and precession photographs. Intensity data were collected by use of a Hilger and Watts single-crystal four-circle computer-controlled *X*-ray diffractometer. The crystal axes were misaligned with respect to the instrument axes so as to minimize the effects of multiple reflexion. The intensities were measured by use of ω–2θ step scans and were placed on a uniform arbitrary scale through the periodic monitoring of standard reflexions. Intensities were corrected for Lorentz and polarization effects, but not for absorption. Least-squares cell dimensions and orientation matrices were calculated from the positions (as determined by a 'peak-finder' program) of at least 12 reflexions and their Friedel pairs measured at both positive and negative ω–2θ offsets.

(*a*) *Lythrancine*-IV (2b)

Crystal Data.—$C_{33}H_{41}O_8N$, $M = 579·7$. Orthorhombic, $a = 8·769(7)$, $b = 15·368(8)$, $c = 22·927(11)$ Å, $U = 3089·7$ Å^3, $Z = 4$, $D_c = 1·25$ g cm^{-3}, $F(000) = 1240$. Cu-K_α radiation, $\lambda = 1·54178$ Å; μ(Cu-K_α) = 7·4 cm^{-1}. Space group $P2_12_12_1$ (D_2^4, No. 19) by systematic absences.

Crystals of (2b) are rectangular needles elongated along *a*, and the crystal used for intensity measurements had dimensions *ca.* 1·0 × 0·35 × 0·30 mm. The intensities of 3195 independent reflexions having $\theta < 68°$ were measured by use of Ni-filtered Cu-K_α radiation. Several reflexions at low θ were affected by dead-time losses in the counting chain and the 186 reflexions having $\theta < 20°$ were remeasured with a divide-by-thirty attenuator in the diffracted-beam path. The attenuated data were scaled to the full data set by a least-squares process using only the common reflexions of medium intensity; by this means all the most intense reflexions could be assigned intensities free from dead-time losses.

Structure Solution and Refinement.—The scale factor and overall temperature factor ($B \approx 5·5$ Å^2) were estimated from a Wilson plot.[10] $|E|$ values were derived and the 308 reflexions with $|E| \geqslant 1·55$ used as input to the direct-methods program Multan.[11] The 1850 $\Sigma2$ relationships with highest probability were calculated and the following origin- and enantiomorph-defining reflexions were assigned phases: 0,8,1 ($|E| = 3·28$) 0°; 2,1,19 ($|E| = 3·16$) 45°; and 5,0,14 ($|E| = 3·01$) 0°. The reflexion 2,0,20 ($|E| = 2·17$) was determined with the phase of 0° (probability 0·96) from the $\Sigma1$ formula. The reflexions 1,12,10 ($|E| = 3·70$) and 5,11,3 ($|E| = 3·16$) were each assigned in turn the trial phase values of 45, 135, 225, and 315°. The 16 phase sets so generated, after expansion and refinement by the tangent formula, had absolute figures of merit ranging from 0·76 to 1·20 while the Karle R factor R_K varied from 33 to 44%. One of the weighted E maps (absolute figure of merit 1·18, R_K 33·8%) allowed the location of 28 atoms, being those of the quinolizidine ring, the nearest benzene ring, and some atoms of the methoxy- and acetate groups. An F_o Fourier synthesis phased on these atoms revealed the remaining 14 non-hydrogen atom positions.

The atomic co-ordinates were initially refined by one further F_o Fourier synthesis, reducing R to 25%. At this stage the reflexions measured with negative intensity and all those measured with $I < 3\sigma(I)$ were removed from the data set and the subsequent least-squares refinement was based on 2745 reflexions. All refinement calculations used large-block matrices. Two cycles of unit-weight isotropic refinement followed by two cycles of anisotropic refinement reduced R to 8·4%. At this stage a difference-Fourier synthesis located 22 of the 41 hydrogen atoms as peaks of height *ca.* 0·2 e Å^{-3}. The 26 hydrogen atoms which could be positioned by reference to the carbon skeleton of the model were now included at calculated positions with r(C–H) 1·00 Å and B 5·0 Å^2. After one additional cycle of anisotropic refinement, which reduced R to 6·2%, a further difference electron-density synthesis permitted the location of at least one hydrogen on each methyl group and the 15 methyl hydrogen atoms were now included in the model, at calculated positions if necessary. At no stage of the analysis were any of the hydrogen atom parameters refined, although their co-ordinates were periodically recalculated. After two further cycles of unit-weight least-squares calculations, which reduced R to 4·6%, an analytical weighting scheme

---

[6] K. Mislow, in 'Optical Rotatory Dispersion and Circular Dichroism in Organic Chemistry,' ed. G. Snatzke, Heyden, London, 1967, p. 156.

[7] See *e.g.* A. T. McPhail and G. A. Sim, *J. Chem. Soc.* (*B*), 1971, 198; J. R. Hanson, G. M. McLaughlin, and G. A. Sim, *J.C.S. Perkin II*, 1972, 1124.

[8] D. N. J. White, A. T. McPhail, and G. A. Sim, *J.C.S. Perkin II*, 1972, 1280.

[9] O. Exner, Z. Fidlerová, and V. Jehlička, *Coll. Czech. Chem. Comm.*, 1968, **33**, 2019.

[10] A. J. C. Wilson, *Nature*, 1942, **150**, 151.

[11] P. Main, M. M. Woolfson, and G. Germain, 'Multan: A Computer Program for the Automatic Solution of Crystal Structures,' University of York, 1971.

was introduced whereby reflexions were assigned weightssuch that $\Sigma w\Delta^2/N$ was similar for groups of F_o values over the whole range of F_o. The weighting scheme was $w^{-1} = 1 + 0{\cdot}00444(F_o - 3{\cdot}50)^2$. Two cycles of weighted least-squares calculations achieved convergence with a final R 4·25%. A difference electron-density synthesis computed after the completion of refinement showed no peaks or troughs $> \pm 0{\cdot}2$ e Å^{-3}. Atomic scattering factor curves for carbon, nitrogen, and oxygen were taken from ref. 12; scattering factors for hydrogen were taken from ref. 13. No correction was applied during the refinement for either the real or the imaginary part of the anomalous-dispersion effect. Observed and calculated structure factors and atomic thermal parameters for both structures are listed in Supplementary Publication No. SUP 21099 (69 pp., 2 microfiche).*

(*b*) *Lythrancine*-II O-p-*Bromobenzenesulphonate* (2c)

Crystal Data.—$C_{35}H_{40}NO_8BrS$, $M = 714{\cdot}7$. Orthorhombic, $a = 21{\cdot}435(10)$, $b = 13{\cdot}819(14)$, $c = 11{\cdot}537(9)$ Å, $U = 3417{\cdot}4$ Å^3, $D_c = 1{\cdot}39$, $Z = 4$, $D_m = 1{\cdot}36$ g cm^{-3}, $F(000) = 1488$. Mo-K_α radiation, $\lambda = 0{\cdot}71069$ Å; μ(Mo-K_α) = 13·9 cm^{-1}. Space group $P2_12_12_1$ (D_2^4, No. 19) by systematic absences.

The crystals available were small opaque rectangular needles. Intensity data were collected for all unique reflexions having $\theta < 27°$ by use of Zr-filtered Mo-K_α radiation. This analysis is based on the 1903 independent reflexions having $|F| > 4{\cdot}65\ \sigma(F)$.

Structure Solution and Refinement.—Initial co-ordinates for the bromine and sulphur atoms were obtained from a Patterson synthesis. The positions of all the remaining non-hydrogen atoms were determined from three successive F_o Fourier syntheses. Starting with an R value of 33%, several cycles of least-squares adjustment of the atomic co-ordinates and isotropic thermal parameters reduced R to 15·0%. We next allowed for anomalous dispersion with values of $\Delta f'$, and $\Delta f''$ for bromine and sulphur taken from ref. 14*a*. Structure-factor calculations showed that the co-ordinates appropriate to the absolute configuration (2c) gave R 14·90%, whereas the co-ordinates appropriate to the mirror image gave R 15·38%. Hamilton's test [15] indicated that this difference is highly significant. The absolute stereochemistry suggested by these calculations agrees with that deduced by Fujita from c.d. measurements.[3] Subsequent least-squares calculations which included the anomalous dispersion corrections for bromine and sulphur, and during which the bromine atom was assigned an anisotropic temperature factor, reduced R to 12·4%.

A difference electron-density synthesis calculated at this stage had a number of significant peaks in regions appropriate to hydrogen atoms. Accordingly all hydrogen atoms, other than the methyl and the hydroxy-hydrogens, were included in the model at fixed calculated positions with r(C–H) 1·09 Å. When the atoms O(17), O)21), C(26), C(27), and C(29) were also assigned anisotropic thermal parameters the least-squares calculations converged at R 10·83%. Unit weights were retained throughout the refinement procedure since $\Sigma w\Delta^2/N$ did not vary greatly over different ranges of F_o. Atomic scattering factor curves were taken from ref. 14*b*.

We thank the S.R.C. for support and Professor Fujita for supplies of the alkaloids.

[4/600 *Received*, 25th *March*, 1974]

---

* See Notice to Authors No. 7 in *J.C.S. Perkin II*, 1973, Index issue.

[12] D. T. Cromer and J. T. Waber, *Acta Cryst.*, 1965, **18**, 104.

[13] R. F. Stewart, E. R. Davidson, and W. T. Simpson, *J. Chem. Phys.*, 1965, **42**, 3175.

[14] 'International Tables for *X*-Ray Crystallography,' vol. III, Kynoch Press, Birmingham, 1962, (*a*) p. 215; (*b*) p. 202.

[15] W. C. Hamilton, *Acta Cryst.*, 1965, **18**, 502.