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The Structure of 2′-Azido-2′-deoxycytidine

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Abstract. $C_9H_{12}N_6O_4$, $M_r = 268{\cdot}2$, orthorhombic, $P2_12_12_1$, $a = 8{\cdot}659\,(4)$, $b = 8{\cdot}682\,(4)$, $c = 31{\cdot}447\,(16)$ Å, $U = 2364{\cdot}1$ Å^3, $Z = 8$, $D_x = 1{\cdot}507$ Mg m^{-3}, Mo $K\alpha$ radiation, $\lambda = 0{\cdot}71069$ Å, $\mu = 0{\cdot}11$ mm^{-1}, $F(000) = 1120$, $T = 293$ K, $R = 0{\cdot}074$ for 1167 unique observed $[F > 5\sigma(F)]$ reflections. There are two molecules in the asymmetric unit which have similar conformations except for the orientation of the azido group with respect to the C2′—N1′ bond. Both molecules have $^2T_3$ ribose puckers, the glycosidic bonds are *anti* and the conformations about the C4′—C5′ bonds are +*sc*. The C1′—C2′—N1′—N2′ torsion angles are 85 (2) and 156 (2)°. The azido groups are disordered.

Introduction. We have determined the crystal and molecular structure of the title compound as part of our continuing program of investigation of modified nucleosides. 2′-Azido-2′-deoxycytidine inhibits DNA replication in mammalian cells (Skoog, Bjursell, Thelander, Hagerstrom, Hobbs & Eckstein, 1977) and is involved in the inhibition of the enzyme primase (Reichard, Eliasson, Hobbs & Eckstein, 1978). The compound is therefore of great biological interest.

Experimental. Crystals were obtained from aqueous solution. Space group and initial cell dimensions were obtained from Weissenberg photographs. Data were collected on a Nicolet *P*3 (four-circle) diffractometer in Aberdeen by RAH. The crystal had an irregular hemispherical habit 0·4 mm in diameter. Cell parameters were measured on the diffractometer using 14 reflections in the 2θ range 15–18°. Range of indices: $0 \le h \le 10$; $0 \le k \le 9$; $0 \le l \le 33$. Data measured using $\theta/2\theta$ scans in the range $0 < 2\theta < 50°$. Standard reflections, 304 and 2,2,10, were measured every 50 reflections. The intensities of these reflections varied by less than 2σ from their means throughout the data collection. Lorentz and polarization factors were applied. No corrections were made for absorption or secondary extinction. 2035 independent reflections measured, giving 1167 observed $[F > 5\sigma(F)]$ reflections used in the refinement. The structure was solved using the *SHELXS*86 program (Sheldrick, 1986). The *E* map revealed all atomic positions. A difference Fourier calculation subsequent to several cycles of isotropic least squares revealed no peaks which could be interpreted as H atoms. Hence all H atoms were included at calculated positions. The positions of those attached to the O3′ and O5′ atoms were based on their probable involvement in hydrogen bonds. The H atoms were given fixed isotropic temperature factors and allowed to ride on their parent atoms. All other atoms except the hydrogens were refined anisotropically. Blocked full-matrix refinement (on *F*) was carried out using the program *SHELX*76 (Sheldrick, 1976). The refinement converged at $R = 0{\cdot}074$, $wR = 0{\cdot}087$, $w = 2{\cdot}3519[\sigma^2(F) + 0{\cdot}000919F^2]^{-1}$. 343 refined parameters; max. shift/e.s.d. <0·05; max. difference peak, 0·32, min., −0·28 e Å^{-3}. Scattering factors were taken from *International Tables for X-ray Crystallography* (1974).

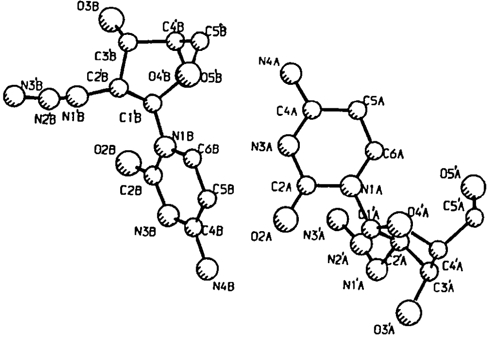

Fig. 1. View of the molecules with atomic numbering.

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Table 1. *Coordinates* (×10⁴) *for non-hydrogen atoms with e.s.d.'s in parentheses*

$$U_{\rm eq} = \tfrac{1}{3}\textstyle\sum_i \sum_j U_{ij} a_i^* a_j^* \mathbf{a}_i.\mathbf{a}_j.$$

	x	*y*	*z*	$U_{\rm eq}$(Å^2 × 10^3)
N1*A*	−3265 (10)	−12222 (10)	−1793 (3)	40 (3)
C2*A*	−3094 (15)	−10636 (12)	−1792 (4)	51 (4)
O2*A*	−2249 (10)	−9966 (9)	−2050 (3)	70 (3)
N3*A*	−3922 (12)	−9855 (10)	−1490 (3)	52 (3)
C4*A*	−4789 (14)	−10611 (14)	−1203 (4)	48 (4)
N4*A*	−5522 (14)	−9774 (12)	−921 (3)	80 (4)
C5*A*	−4965 (14)	−12208 (14)	−1212 (4)	55 (5)
C6*A*	−4182 (14)	12986 (14)	−1526 (4)	51 (4)
C1′*A*	−2543 (13)	−13060 (12)	−2157 (3)	42 (3)
C2′*A*	−1317 (12)	−14221 (12)	−2027 (4)	48 (4)
N1′*A*	307 (20)	−13535 (16)	−2016 (5)	111 (7)
N2′*A*	538 (17)	−12922 (19)	−1667 (5)	112 (7)
N3′*A*	827 (34)	−12113 (28)	−1281 (9)	320 (18)
C3′*A*	−1370 (14)	−15346 (14)	−2391 (4)	54 (4)
O3′*A*	−740 (11)	−14673 (11)	−2780 (3)	82 (3)
C4′*A*	−3070 (14)	−15475 (14)	−2484 (4)	52 (4)
C5′*A*	−3926 (17)	−16730 (15)	−2237 (4)	69 (5)
O5′*A*	−3668 (10)	−16680 (8)	−1797 (3)	64 (3)
O4′*A*	−3715 (9)	−14001 (8)	−2337 (2)	51 (2)
N1*B*	158 (9)	−5721 (10)	−709 (3)	38 (3)
C2*B*	1724 (12)	−5426 (13)	−738 (4)	48 (4)
O2*B*	2343 (9)	−4593 (10)	−468 (3)	65 (3)
N3*B*	2543 (11)	−6082 (13)	−1051 (3)	61 (4)
C4*B*	1839 (14)	−6965 (15)	−1335 (4)	51 (4)
N4*B*	2669 (12)	−7572 (14)	−1662 (3)	78 (4)
C5*B*	231 (13)	−7285 (13)	−1317 (4)	45 (4)
C6*B*	−569 (13)	−6635 (14)	−1002 (4)	46 (4)
C1′*B*	−670 (14)	−5147 (12)	−344 (4)	50 (4)
C2′*B*	−1827 (12)	−3843 (11)	−438 (4)	40 (3)
N1′*B*	−996 (14)	−2383 (13)	−407 (4)	71 (5)
N2′*B*	−1394 (23)	−1362 (23)	−569 (6)	161 (10)
N3′*B*	−1836 (27)	−52 (23)	−648 (6)	194 (11)
C3′*B*	−3000 (14)	−4014 (13)	−89 (3)	50 (4)
O3′*B*	−2424 (10)	−3461 (11)	315 (3)	80 (3)
C4′*B*	−3148 (11)	−5740 (13)	−66 (3)	41 (4)
C5′*B*	−4407 (13)	−6462 (15)	−311 (4)	59 (4)
O5′*B*	−4300 (8)	−6127 (10)	−748 (2)	60 (3)
O4′*B*	−1671 (8)	−6330 (9)	−168 (2)	55 (3)

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

C2*A*—N1*A*	1·385 (13)	C6*A*—N1*A*	1·333 (15)
C1′*A*—N1*A*	1·493 (14)	O2*A*—C2*A*	1·239 (15)
N3*A*—C2*A*	1·369 (16)	C4*A*—N3*A*	1·346 (15)
N4*A*—C4*A*	1·311 (16)	C5*A*—C4*A*	1·395 (17)
C6*A*—C5*A*	1·374 (18)	C2′*A*—C1′*A*	1·519 (16)
O4′*A*—C1′*A*	1·420 (13)	N2′*A*—C2′*A*	1·528 (20)
C3′*A*—C2′*A*	1·506 (17)	N3′*A*—N2′*A*	1·236 (23)
N4′*A*—N3′*A*	1·425 (32)	O3′*A*—C3′*A*	1·460 (15)
C4′*A*—C3′*A*	1·505 (17)	C5′*A*—C4′*A*	1·530 (18)
O4′*A*—C4′*A*	1·472 (14)	O5′*A*—C5′*A*	1·404 (16)
C2*B*—N1*B*	1·383 (13)	C6*B*—N1*B*	1·369 (14)
C1′*B*—N1*B*	1·443 (15)	O2*B*—C2*B*	1·238 (15)
N3*B*—C2*B*	1·339 (16)	C4*B*—N3*B*	1·326 (16)
N4*B*—C4*B*	1·359 (16)	C5*B*—C4*B*	1·422 (17)
C6*B*—C5*B*	1·334 (16)	C2′*B*—C1′*B*	1·541 (15)
O4′*B*—C1′*B*	1·453 (14)	N2′*B*—C2′*B*	1·460 (16)
C3′*B*—C2′*B*	1·504 (16)	N3′*B*—N2′*B*	1·079 (23)
N4′*B*—N3′*B*	1·225 (28)	O3′*B*—C3′*B*	1·447 (14)
C4′*B*—C3′*B*	1·505 (16)	C5′*B*—C4′*B*	1·475 (16)
O4′*B*—C4′*B*	1·415 (13)	O5′*B*—C5′*B*	1·408 (15)

C6*A*—N1*A*—C2*A*	123·8 (10)	C1′*A*—N1*A*—C2*A*	116·2 (9)
C1′*A*—N1*A*—C6*A*	119·4 (9)	O2*A*—C2*A*—N1*A*	121·9 (11)
N3*A*—C2*A*—N1*A*	116·0 (10)	N3*A*—C2*A*—O2*A*	122·1 (10)
C4*A*—N3*A*—C2*A*	121·1 (10)	N4*A*—C4*A*—N3*A*	117·0 (11)
C5*A*—C4*A*—N3*A*	122·1 (11)	C5*A*—C4*A*—N4*A*	120·8 (11)
C6*A*—C5*A*—C4*A*	116·7 (11)	C5*A*—C6*A*—N1*A*	120·1 (11)
C2′*A*—C1′*A*—N1*A*	114·3 (9)	O4′*A*—C1′*A*—N1*A*	106·6 (8)
O4′*A*—C1′*A*—C2′*A*	103·0 (8)	N2′*A*—C2′*A*—C1′*A*	113·0 (10)
C3′*A*—C2′*A*—C1′*A*	101·9 (9)	C3′*A*—C2′*A*—N2′*A*	107·4 (10)
N3′*A*—N2′*A*—C2′*A*	109·7 (14)	N4′*A*—N3′*A*—N2′*A*	175·8 (19)
O3′*A*—C3′*A*—C2′*A*	111·4 (10)	C4′*A*—C3′*A*—C2′*A*	103·0 (10)
C4′*A*—C3′*A*—O3′*A*	103·5 (10)	C5′Å—C4′*A*—C3′*A*	115·4 (10)
O4′*A*—C4′*A*—C3′*A*	104·2 (9)	O4′*A*—C4′*A*—C5′*A*	106·0 (9)
O5′*A*—C5′*A*—C4′*A*	113·7 (11)	C4′*A*—O4′*A*—C1′*A*	110·8 (8)
C6*B*—N1*B*—C2*B*	120·9 (9)	C1′*B*—N1*B*—C2*B*	118·5 (9)
C1′*B*—N1*B*—C6*B*	120·5 (9)	O2*B*—C2*B*—N1*B*	119·1 (11)
N3*B*—C2*B*—N1*B*	119·3 (11)	N3*B*—C2*B*—O2*B*	121·5 (10)
C4*B*—N3*B*—C2*B*	119·8 (10)	N4*B*—C4*B*—N3*B*	119·4 (11)
C5*B*—C4*B*—N3*B*	122·4 (11)	C5*B*—C4*B*—N4*B*	118·3 (11)
C6*B*—C5*B*—C4*B*	117·2 (11)	C5*B*—C6*B*—N1*B*	120·4 (10)
C2′*B*—C1′*B*—N1*B*	115·0 (9)	O4′*B*—C1′*B*—N1*B*	110·8 (8)
O4′*B*—C1′*B*—C2′*B*	101·8 (9)	N2′*B*—C2′*B*—C1′*B*	107·7 (9)
C3′*B*—C2′*B*—C1′*B*	103·0 (9)	C3′*B*—C2′*B*—C2′*B*	111·7 (10)
N3′*B*—N2′*B*—C2′*B*	121·6 (15)	N4′*B*—C3′*B*—N2′*B*	163·3 (22)
O3′*B*—C3′*B*—C2′*B*	112·1 (9)	C4′*B*—C3′*B*—C2′*B*	101·0 (9)
C4′*B*—C3′*B*—O3′*B*	108·5 (9)	C5′*B*—C4′*B*—C3′*B*	117·4 (9)
O4′*B*—C4′*B*—C3′*B*	105·8 (8)	O4′*B*—C4′*B*—C5′*B*	113·3 (9)
O5′*B*—C5′*B*—C4′*B*	111·9 (9)	C4′*B*—O4′*B*—C1′*B*	111·7 (8)

The program packages *XANADU* (Roberts & Sheldrick, 1975) and *PLUTO* (Motherwell & Clegg, 1978) were also used. All calculations were carried out on the Dundee University PRIME computer. No attempt was made to determine the chirality of the molecules.

Discussion. This structure determination is part of our continuing program studying the conformational parameters of modified nucleosides. The atomic numbering is shown in the perspective drawing (Fig. 1), and tables of atomic parameters, bond lengths and angles are given (Tables 1 and 2).* The conformational parameters are in accordance with the IUPAC–IUB Joint Commission on Biochemical Nomenclature (1983) guidelines. The conformational parameters are as follows, molecule *A* values first: $P = 164\,(2)$ and $180\,(2)°$, $\psi = 41\,(2)$ and $40\,(2)°$, $\chi = -127\,(2)$ and $-134\,(2)°$, $\gamma = 51\,(2)$ and $59\,(2)°$. These parameters lie within the expected range for nucleosides. There are several close contacts between the molecules which are almost hydrogen bonds. O5′*A*···N3*A* $(x, y-1, z)$ 2·93 (2); O5′*B*···N3*B* $(x-1, y, z)$, 2·87 (2); O3′*A*···O2*A* $(-x, -\frac{1}{2}+y, -\frac{1}{2}-z)$, 2·66 (2); O3′*B*···O2*B* $(-\frac{1}{2}+x, -\frac{1}{2}-y, -z)$, 2·70 (2); N4*A*···O3′*B* $(-\frac{1}{2}+x, -\frac{3}{2}-y, -z)$, 2·95(2); N4*B*···O3′*A* $(-x, \frac{1}{2}+y, -\frac{1}{2}-z)$, 3·03(2)Å. In all these contacts the first atom is the probable hydrogen donor. The atoms in the azido groups have high thermal parameters, particularly those in molecule *A* in which the N2′—N3′ bond, at 1·425 Å, is very long compared with the equivalent bond in other azido groups reported in the Cambridge Structural Database. This suggests disorder, although examination of a difference synthesis calculated with the azido group atoms removed revealed nothing other than discrete peaks close to expected positions for each atom in the areas associated with each azido group. Throughout the literature examples of azido groups with elevated thermal parameters may be found. The azido group in molecule *B* is similar to that found in 14β-azido-5α-androstane (Chiaroni, Riche & Pascard-Billy, 1974), where N1′—N2′ = 1·14 Å and N2′—N3′ = 1·19 Å. Van Roey, Salerno, Duax, Chu, Ahn &

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* 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 51265 (9 pp.). Copies may be obtained through The Executive Secretary, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England.

Schinazi (1988) report the structures of several 3′-azido-3′-deoxythymidine analogues: in some the azido groups have thermal parameters similar to those of the atoms to which they are attached, in others the azido groups show elevated thermal parameters and, in one case two disordered positions, 26° apart, are found for an azido group. In the present structure molecule *A* does not reach this extreme.

References

Chiaroni, A., Riche, C. & Pascard-Billy, C. (1974). *Cryst. Struct. Commun.* **3**, 111–114.

International Tables for X-ray Crystallography (1974). Vol. IV. Birmingham: Kynoch Press. (Present distributor Kluwer Academic Publishers, Dordrecht.)

IUPAC–IUB Joint Commission on Biochemical Nomenclature (1983). *Pure Appl. Chem.* **55**, 1273–1280.

Motherwell, W. D. S. & Clegg, W. (1978). *PLUTO*. Program for plotting molecular and crystal structures. Univ. of Cambridge, England.

Reichard, R. L., Eliasson, R., Hobbs, J. & Eckstein, F. (1978). *J. Biol. Chem.* **253**, 7011–7016.

Roberts, P. & Sheldrick, G. M. (1975). *XANADU*. Program for torsion angle, mean plane and libration correction calculations. Univ. of Cambridge, England.

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

Sheldrick, G. M. (1986). *SHELXS86*. *Crystallographic Computing* 3, edited by G. M. Sheldrick, C. Kruger & R. Goddard, pp. 175–189. Oxford Univ. Press.

Skoog, L., Bjursell, G., Thelander, L., Hagerstrom, T., Hobbs, J. & Eckstein, F. (1977). *Eur. J. Biochem.* **72**, 371–378.

Van Roey, P., Salerno, J. M., Duax, W. L., Chu, C. K., Ahn, M. K. & Schinazi, R. F. (1988). *J. Am. Chem. Soc.* **110**, 2277–2282.

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Structures of Two Pseudoisomorphic Derivatives of Pseudoneolongifolol*

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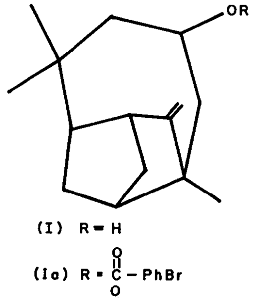
Abstract. $C_{22}H_{27}BrO_2$ (I*a*), pseudoneolongifolyl-*p*-bromobenzoate, $M_r = 403{\cdot}4$, monoclinic, $P2_1$, $a = 7{\cdot}622\,(1)$, $b = 12{\cdot}453\,(1)$, $c = 10{\cdot}433\,(1)$ Å, $\beta = 93{\cdot}81\,(2)°$, $V = 988{\cdot}1\,(2)$ Å^3, $Z = 2$, $D_m = 1{\cdot}37$, $D_x = 1{\cdot}36$ Mg m^{-3}, $\lambda(\text{Mo } K\alpha) = 0{\cdot}7107$ Å, $\mu(\text{Mo } K\alpha) = 2{\cdot}217$ mm^{-1}, $F(000) = 420$, $T = 293$ K, $R = 0{\cdot}055$ for 1009 observed reflections. $C_{22}H_{27}NO_4$ (I*b*), pseudoneolongifolyl-*p*-nitrobenzoate, $M_r = 369{\cdot}5$, triclinic, $P1$, $a = 7{\cdot}569\,(1)$, $b = 10{\cdot}383\,(1)$, $c = 12{\cdot}605\,(1)$ Å, $\alpha = 95{\cdot}52\,(1)$, $\beta = 90{\cdot}19\,(1)$, $\gamma = 94{\cdot}87\,(1)°$, $V = 982{\cdot}3\,(2)$ Å^3, $Z = 2$, $D_m = 1{\cdot}26$, $D_x = 1{\cdot}25$ Mg m^{-3}, $\lambda(\text{Mo } K\alpha) = 0{\cdot}7107$ Å, $\mu = 0{\cdot}042$ mm^{-1}, $F(000) = 396$, $T = 293$ K, $R = 0{\cdot}057$ for 1965 observed reflections. The carbon skeleton (I*a*, I*b*) consists of two eight-membered rings in 'boat-chair' conformation fused to a bicyclo[2.2.1]heptane moiety.

Introduction. Owing to its flexibility, longifolene (decahydro-4,8,8-trimethyl-9-methylene-1,4-methanoazulene) has been used in the preparation of several potential perfumery compounds. In our efforts to analyze conformational flexibility in longifolenes, a study of the silver-ion-assisted solvolysis of 8,11-dibromolongibornane in aqueous acetone resulted in a crystalline compound (I) [m.p. 371 K; 65% yield]. Efforts to obtain crystals suitable for X-ray diffraction studies were futile and hence derivatives (I*a*) and (I*b*) were prepared. Initially crystals of (I*b*) were obtained but attempts to solve the structure failed owing to space-group ambiguity [$P1$ or $P\bar{1}$]. We report here the X-ray structure analyses of (I*a*) and (I*b*).



(I) R = H

(Ia) R = $\overset{\displaystyle O}{\overset{\|}{C}}$ – PhBr

(Ib) R = $\overset{\displaystyle O}{\overset{\|}{C}}$ – PhNO$_2$

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