Stereoselective Alkylation of *N*-Boc-Protected-5-Substituted δ-Lactams: Synthesis of α,δ-Disubstituted δ-Amino Acids

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Supporting Information (17 pages)

Experimental. Amino acid derivatives were purchased from Neosystem or Novabiochem. THF was freshly distilled from Na/benzophenone under Ar before use.. The reactions were carried out under a positive pressure of Ar. HPLC analysis was performed on a Nucleosil C_{18} column (5μm, 3.9 x 150 mm by using a linear gradient of A (0.1% TFA in H_2O) and B (0.08% TFA in MeCN) at a flow rate of 1.2 ml/min with UV detection at 214 nm.

(*R*)-1-[(*tert*-butoxy)carbonyl]-6-benzylpiperidin-2-one (4a). prepared from Boc-β^3-Phe-OH (6.67 g, 23.91 mmol). **4a** (6.49 g, 94 %). White solid; mp 64°C; $[\alpha]^{25}_D$ + 10.0 (*c* 1.3, $CHCl_3$); HPLC t_R 12.10 min (linear gradient, 30-100 % B, 20 min); ^{1}H-NMR (200 MHz, $CDCl_3$): δ 1.53 (s, 9H), 1.63-2.03 (m, 4H), 2.52 (m, 2H), 2.69 (dd, , *J* = 10.5, 13.2 Hz, 1H), 3.10 (dd, , *J* = 4.3, 13.2 Hz, 1H), 4.41 (m, 1H), 7.18-7.34 (m, 5H). ^{13}C-NMR (50 MHz, $CDCl_3$): δ 17.0, 24.6 (CH_2), 28.1 (CH_3), 34.4, 39.9 (CH_2), 57.2 (CH), 83.1 (C), 126.7, 128.7, 129.2 (CH), 138.0, 152.8, 171.7 (C). Anal. Calcd for $C_{17}H_{23}NO_3$: C, 70.56; H, 8.01; N, 4.84. Found: C, 70.49; H, 7.88; N, 4.97.

(*S*)-1-[(*tert*-butoxy)carbonyl]-6-methyl-piperidin-2-one (4b). prepared from Boc-β^3-Ala-OH (7 g, 34.48 mmol). Flash chromatography (ethyle acetate/hexane 1:9) yielded **4c** (4.33 g, 59%). Brown oil; $[\alpha]^{25}_D$ + 5.9 (*c* 1.0, $CHCl_3$); HPLC t_R 7.21 min (linear gradient, 30-100 % B, 20 min); ^{1}H-NMR (200 MHz, $CDCl_3$): δ 1.16 (d, *J* = 6.5 Hz, 3H), 1.41 (s, 9H), 1.51-1.91 (m, 4H), 2.36 (m, 2H), 4.17 (m, 1H. ^{13}C-NMR (50 MHz, $CDCl_3$): δ 14.2 (CH_2), 27.9, 29.3 (CH_3), 34.2 (CH_2), 51.8 (CH), 82.7, 152.9, 171.3 (C).

(*R*)-1-[(*tert*-butoxy)carbonyl]-6-[(*S*)-1-methylpropyl]-piperidin-2-one (4c). prepared from Boc-β^3-HIle-OH (6 g, 24.87 mmol). Flash chromatography (ethyle acetate/hexane 1:7) yielded **4c** (3.84 g, 62%). Colourless oil; $[\alpha]^{25}_D$ + 69.4 (*c* 1.5, $CHCl_3$); HPLC t_R 11.81 min (linear gradient, 30-100 % B, 20 min); ^{1}H-NMR (200 MHz, $CDCl_3$): δ 0.85 (d, *J* = 6.7 Hz, 3H), 0.88 (t, *J* = 7.2 Hz, 3H), 1.05-1.20 (m, 1H), 1.32-1.46 (m, 1H), 1.49 (s, 9H), 1.61-1.89 (m, 5H), 2.34-2.53 (m, 2H), 4.02-4.11 (m, 1H). ^{13}C-NMR (50 MHz, $CDCl_3$): δ 12.0, 14.1 (CH_3), 18.2, 22.9, 25.9 (CH_2), 27.9 (CH_3), 34.1 (CH_2), 37.9, 59.4 (CH), 82.8, 153.3, 172.3

(C). Anal. Calcd for $C_{14}H_{25}NO_3$: C, 65.85; H, 9.87; N, 5.49. Found: C, 65.45; H, 9.88; N, 5.65.

(3*R*,6*R*)-1-[(*tert*-butoxy)carbonyl]-3,6-dibenzylpiperidin-2-one (5). Prepared from **4a** (0.289 g, 1.0 mmol). Flash chromatography (ethyle acetate/hexane 1:10) yielded **5** (0.31 g, 82 %). White solid; mp 69°C; $[\alpha]^{25}_D$ + 66.1 (*c* 1.02, $CHCl_3$); HPLC t_R 16.19 min (linear gradient, 30-100 % B, 20 min); ^{1}H-NMR (200 MHz, $CDCl_3$): δ 1.40-1.54 (m, 2H), 1.56 (s, 9H), 1.68-1.87 (m, 2H), 2.59-2.73 (m, 3H), 3.09 (dd, *J* = 4.2, 13.1 Hz, 1H), 3.34 (m, 1H), 4.35 (m, 1H), 7.15-7.31 (m, 10H). ^{13}C-NMR (50 MHz, $CDCl_3$): δ 22.2, 23.5 (CH_2), 28.1 (CH_3), 37.7, 40.8, 40.8 (CH_2), 45.0, 57.5 (CH), 83.1 (C), 126.4, 126.7, 128.5, 128.6, 129.3 (CH), 137.7, 139.4, 153.4, 174.4 (C). Anal. Calcd for $C_{24}H_{29}NO_3$: C, 75.96; H, 7.70; N, 3.69. Found: C, 75.27; H, 7.86; N, 3.72.

(3*S*,6*R*)-1-[(*tert*-butoxy)carbonyl]-3-methyl-6-benzylpiperidin-2-one (6). Prepared from **4a** (0.56 g, 1.938 mmol). Flash chromatography (ethyle acetate/hexane 1:10) yielded **6** (0.55 g, 94 %). White solid; mp 99°C; $[\alpha]^{25}_D$ + 21.6 (*c* 1.16, $CHCl_3$); HPLC t_R 13.32 min (linear gradient, 30-100 % B, 20 min); ^{1}H-NMR (200 MHz, $CDCl_3$): δ 1.22 (d, *J* = 7.0 Hz, 3H), 1.38-1.63 (m, 2H), 1.52 (s, 9H), 1.86 (m, 1H), 2.07 (m, 1H), 2.54 (m, 1H), 2.68 (dd, *J* = 10.0, 13.1 Hz, 1H), 3.06 (dd, *J* = 4.4, 13.1 Hz, 1H), 4.34 (m, 1H), 7.17-7.33 (m, 5H). ^{13}C-NMR (50 MHz, $CDCl_3$): δ 17.7 (CH_3), 23.7, 26.0 (CH_2), 28.1 (CH_3), 38.0 (CH), 40.7 (CH_2), 57.6 (CH), 83.0 (C), 126.7, 128.6, 129.3 (CH), 137.8, 153.4, 175.3 (C). Anal. Calcd for $C_{18}H_{25}NO_3$: C, 71.26; H, 8.31; N, 4.62. Found: C, 71.15; H, 8.34; N, 4.73.

(3*R*,6*R*)-1-[(*tert*-butoxy)carbonyl]-3-allyl-6-benzylpiperidin-2-one (7). Prepared from **4a** (0.289 g, 1.0 mmol). Flash chromatography (ethyle acetate/hexane 1:10) yielded **7** (0.188 g, 57 %). White paste; $[\alpha]^{25}_D$ + 40.35 (*c* 2.3, $CHCl_3$); HPLC t_R 15.08 min (linear gradient, 30-100 % B, 20 min); ^{1}H-NMR (200 MHz, $CDCl_3$): δ 1.47-1.57 (m, 2H), 1.52 (s, 9H), 1.68-1.86 (m, 2H), 2.01 (m, 1H), 2.22 (m, 1H), 2.40-2.74 (m, 2H), 3.08 (dd, *J* = 4.3, 13.1 Hz, 1H), 4.32 (m, 1H), 5.04 (m, 2H), 5.76 (m, 1H), 7.17-7.33 (m, 5H). ^{13}C-NMR (50 MHz, $CDCl_3$): δ 22.5,

23.5 (CH_2), 28.0 (CH_3), 36.2, 40.6 (CH_2), 42.8, 57.4 (CH), 83.0 (C), 117.2, 126.7, 128.6 (CH), 129.3 (C), 135.8 (CH), 137.8, 153.3, 174.2 (C). HRMS Calcd for $C_{20}H_{27}NO_3$ (MH+) 330.2064, found 330.2068.

(3*R*,6*S*)-1-[(*tert*-butoxy)carbonyl]-3-benzyl-6-methylpiperidin-2-one (8). Prepared from **4b** (1.0 g, 4.695 mmol). Flash chromatography (ethyle acetate/hexane 1:10) yielded **8** (0.93 g, 65 %). Colourless oil; $[\alpha]^{25}_D$ + 88.7 (*c* 1.1, $CHCl_3$); HPLC t_R 13.42 min (linear gradient, 30-100 % B, 20 min); ^{1}H-NMR (200 MHz, $CDCl_3$): δ 1.24 (d, *J* = 6.4 Hz, 3H), 1.37-1.51 (m, 2H), 1.54 (s, 9H), 1.81 (m, 1H), 1.98 (m, 1H), 2.60 (m, 2H), 3.38 (m, 1H), 4.14 (q, *J* = 6.4 Hz, 1H), 7.15-7.32 (m, 5H). ^{13}C-NMR (50 MHz, $CDCl_3$): δ. 21.2 (CH_3), 23.0 (CH_2), 28.0 (CH_3), 28.3, 37.5 (CH_2), 44.8, 52.4 (CH), 82.9, 126.3 (C), 128.5, 129.3 (CH), 139.6, 153.7, 173.8 (C). Anal. Calcd for $C_{18}H_{25}NO_3$: C, 71.26; H, 8.31; N, 4.62. Found: C, 71.52; H, 8.43; N, 4.84.

(3*S*,6*S*)-1-[(*tert*-butoxy)carbonyl]-3,6-dimethylpiperidin-2-one (9). Prepared from **4b** (0.50 g, 2.35 mmol). Flash chromatography (ethyle acetate/hexane 1:5) yielded **9** (0.533 g, 100 %). Yellow oil; $[\alpha]^{25}_D$ + 34.00 (*c* 2.0, $CHCl_3$); HPLC t_R 9.21 min (linear gradient, 30-100 % B, 20 min); ^{1}H-NMR (200 MHz, $CDCl_3$): δ.1.00 (d, *J* = 7.0 Hz, 3H), 1.05 (d, *J* = 6.4 Hz, 3H), 1.22-1.46 (m, 2H), 1.31 (s, 9H), 1.75-1.87 (m, 2H), 2.27 (m, 1H), 3.96 (m, 1H). ^{13}C-NMR (50 MHz, $CDCl_3$): δ 17.2, 20.9 (CH_3), 26.6 (CH_2), 27.8 (CH_3), 28.4 (CH_2), 37.7, 52.3 (CH), 82.6, 153.6, 174.7 (C) Anal. Calcd for $C_{12}H_{21}NO_3$: C, 63.41; H, 9.31; N, 6.16. Found: C, 63.38; H, 9.53; N, 6.06.

(3*R*,6*R*)-1-[(*tert*-butoxy)carbonyl]-3-(2-methylpropene)-6-[(*S*)-1-methylpropyl]-piperidin-2-one (10). Prepared from **4c** (1.17 g, 4.59 mmol). Flash chromatography (ethyle acetate/hexane 1:11) yielded **10** (1.15 g, 81 %). Colourless crystals; mp 43 °C; $[\alpha]^{25}_D$ + 89.0 (*c* 1.2, $CHCl_3$); HPLC t_R 16.09 min (linear gradient, 30-100 % B, 20 min); ^{1}H-NMR (200 MHz, $CDCl_3$): δ 0.85 (d, *J* = 6.8 Hz, 3H), δ 0.90 (t, *J* = 7.3 Hz, 3H), 1.11-1.43 (m, 4H), 1.51 (s, 9H), 1.58-1.66 (m, 4H), 1.69 (s, 3H), 1.73-1.95 (m, 3H), 2.05 (dd, *J* = 10.3, 14.0, 1H), 2.33-2.41 (m, 1H), 2.77 (dd, *J* = 3.7, 14.0, 1H), 4.00-4.10 (m, 1H), 4.69 (br s, 1H), 4.78 (br s,

1H). ^{13}C-NMR (50 MHz, $CDCl_3$): δ 12.0, 13.7 (CH_3), 21.7 (CH_2), 22.0 (CH_3), 24.0, 26.0 (CH_2), 27.9 (CH_3), 37.8 (CH), 39.4 (CH_2), 41.1 (CH), 60.0 (CH), 82.8 (C), 112.6 (CH), 143.0, 154.0, 174.9 (C). Anal. Calcd for $C_{18}H_{31}NO_3$: C, 69.86; H, 10.10; N, 4.53. Found: C, 70.08; H, 10.30; N, 4.68.

(3*S*,6*R*)-1-[(*tert*-butoxy)carbonyl]-3-(2-methylpropene)-6-[(*S*)-1-methylpropyl]-piperidin-2-one (12). Prepared from **10** (260 mg, 0.84 mmol). Flash chromatography (ethyle acetate/hexane 1:11) yielded **12** (234 mg, 90 %). Colourless oil; $[\alpha]^{25}_D$ + 18.8 (*c* 1.2, $CHCl_3$); HPLC t_R 15.82 min (linear gradient, 30-100 % B, 20 min); ^{1}H-NMR (200 MHz, $CDCl_3$): δ 0.86 (d, *J* = 7.0 Hz, 3H), δ 0.88 (t, *J* = 7.8 Hz, 3H), 1.06-1.21 (m, 1H), 1.35-1.45 (m, 1H), 1.50 (s, 9H), 1.54-1.87 (m, 8H), 2.11 (dd, *J* = 10.4, 13.6, 1H), 2.52-2.63 (m, 1H), 2.72 (dd, *J* = 3.9, 13.5, 1H), 3.98-4.10 (m, 1H), 4.71 (br s, 1H), 4.79 (br s, 1H). ^{13}C-NMR (50 MHz, $CDCl_3$): δ 12.0, 14.5 (CH_3), 21.5 (CH_2), 21.7 (CH_3), 23.0, 25.8 (CH_2), 28.0 (CH_3), 38.1 (CH), 39.7 (CH_2), 41.5 (CH), 59.6 (CH), 82.6 (C), 112.9 (CH_2), 142.8, 153.6, 175.2 (C). Anal. Calcd for $C_{18}H_{31}NO_3$: C, 69.86; H, 10.10; N, 4.53. Found: C, 70.43; H, 10.38; N, 4.52.

(2*R*,5*R*,6*S*)-5-{[(*tert*-butoxy)carbonyl]amino)}-6-methyl-2-(2-methylpropene)-octanoic acid (13). Prepared from **10** (1.00 g, 3.22 mmol). **13** (970 mg, 92 %). White solid; mp 66-67 °C; $[\alpha]^{25}_D$ + 10.2 (*c* 1.2, $CHCl_3$); HPLC t_R 12.43 min (linear gradient, 30-100 % B, 20 min); ^{1}H-NMR (200 MHz, $CDCl_3$, signals of rotamers in italics): δ 0.83 (d, *J* = 6.6 Hz, 3H), δ 0.88 (t, *J* = 7.0 Hz, 3H), 0.96-1.06 (m, 1H), 1.21-1.28 (m, 3H), 1.43 (s, 9H), 1.55-1.65 (m, 3H), 1.72 (s, 3H), 2.13 (dd, *J* = 6.5, 14.0 Hz, 1H), 2.38 (dd, *J* = 8.1, 14.0 Hz, 1H), 2.54-2.64 (m, 1H), 3.30-3.55 (m, 1H), 4.32, *5.55* (dd, *J* = 9.8 Hz, 1H), 4.72 (br s, 1H), 4.76 (br s, 1H). ^{13}C-NMR (50 MHz, $CDCl_3$): δ 11.8, 15.0, 22.2 (CH_3), 25.3 (CH_2), 28.4 (CH_3), 29.0 (CH_2), 39.2 (CH), 40.8 (CH_2), 43.5 (CH), 54.3 (CH), 79.0 (C), 112.4 (CH_2), 142.6, 156.0, 181.06 (C). MS (MALDI-TOF) m/z 328.4 $[M + K]^+$, 351.3 $[M + Na]^+$, 328.4 $[M + H]^+$. Anal. Calcd for $C_{18}H_{33}NO_4$: C, 66.02; H, 10.16; N, 4.28. Found: C, 66.15; H, 10.31; N, 4.40.

(2*S*,5*R*,6*S*)-5-{[(*tert*-butoxy)carbonyl]amino)}-6-methyl-2-(2-methylpropene)-octanoic acid (14). Prepared from **12** (200 mg, 0.64 mmol). **14** (192 mg, 91 %). White solid; mp 94-95 °C; $[\alpha]^{25}_{D}$ – 9.5 (*c* 1.5, $CHCl_3$); HPLC t_R 13.37 min (linear gradient, 30-100 % B, 20 min); ^{1}H-NMR (200 MHz, $CDCl_3$, signals of rotamers in italics): δ 0.81 (d, *J* = 6.6 Hz, 3H), δ 0.88 (t, *J* = 6.8 Hz, 3H), 0.93-1.08 (m, 1H), 1.19-1.30 (m, 3H), 1.40 (s, 9H), 1.50-1.63 (m, 3H), 1.79 (s, 3H), 2.11 (dd, *J* = 6.4, 14.0 Hz, 1H), 2.34 (dd, *J* = 8.2, 14.0 Hz, 1H), 2.45-2.56 (m, 1H), 3.30-3.52 (m, 1H), 4.35, *5.58* (dd, *J* = 9.6 Hz, 1H), 4.69 (br s, 1H), 4.73 (br s, 1H). ^{13}C-NMR (50 MHz, $CDCl_3$): δ 11.8, 15.2, 22.3 (CH_3), 24.9 (CH_2), 28.4 (CH_3), 29.2 (CH_2), 38.9 (CH), 40.2 (CH_2), 43.7 (CH), 54.9 (CH), 79.1 (C), 112.4 (CH_2), 142.6, 156.0, 180.8 (C). MS (MALDI-TOF) m/z 328.7 $[M + K]^+$, 351.2 $[M + Na]^+$. Anal. Calcd for $C_{18}H_{33}NO_4$: C, 66.02; H, 10.16; N, 4.28. Found: C, 65.97; H, 10.25; N, 4.43.

Table 1. Crystal data and structure refinement for shelxl.

Identification code	compound **10**	
Empirical formula	C18 H31 N O3	
Formula weight	309.44	
Temperature	293(2) K	
Wavelength	0.71070 Å	
Crystal system	orthorhombic	
Space group	P $2_12_12_1$	
Unit cell dimensions	a = 10.2480(8) Å	α= 90°.
	b = 11.7520(9) Å	β= 90°.
	c = 16.5430(12) Å	γ = 90°.
Volume	1992.3(3) $Å^3$	
Z	4	
Density (calculated)	1.032 Mg/m^3	
Absorption coefficient	0.069 mm^{-1}	
F(000)	680	
Crystal size	.2 x .3 x .35 mm^3	
Theta range for data collection	2.34 to 23.25°.	
Index ranges	0<=h<=11, 0<=k<=13, 0<=l<=18	
Reflections collected	9592	
Independent reflections	1634 [R(int) = 0.0410]	
Completeness to theta = 23.25°	98.7 %	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	1634 / 0 / 200	
Goodness-of-fit on F^2	1.042	
Final R indices [I>2sigma(I)]	R1 = 0.0533, wR2 = 0.1479	
R indices (all data)	R1 = 0.0647, wR2 = 0.1576	
Extinction coefficient	0.019(6)	
Largest diff. peak and hole	0.142 and -0.119 $e.Å^{-3}$	

Table 2. Atomic coordinates (x 10^4) and equivalent isotropic displacement parameters ($Å^2$x 10^3) for shelxl. U(eq) is defined as one third of the trace of the orthogonalized U^{ij} tensor.

	x	y	z	U(eq)
O(1)	10601(3)	3315(2)	1292(2)	74(1)
O(2)	8648(3)	3685(3)	740(2)	87(1)
N(1)	10035(3)	2409(2)	142(2)	58(1)
O(3)	10153(3)	1030(2)	1097(1)	86(1)
C(10)	10221(4)	1291(3)	383(2)	60(1)
C(6)	9724(4)	2786(3)	-697(2)	62(1)
C(5)	9669(4)	3197(3)	757(2)	63(1)
C(1)	10372(5)	3981(4)	2046(2)	85(1)
C(7)	10142(5)	1889(3)	-1304(2)	81(1)
C(8)	9776(5)	715(3)	-1047(2)	85(1)
C(11)	10301(4)	3965(3)	-865(2)	72(1)
C(9)	10493(4)	419(3)	-261(2)	71(1)
C(13)	9934(5)	4430(4)	-1696(3)	92(1)
C(15)	10177(7)	-773(3)	38(3)	112(2)
C(12)	11787(5)	3974(4)	-779(3)	103(2)
C(4)	11612(6)	3730(7)	2517(3)	138(3)
C(14)	8525(6)	4625(7)	-1817(4)	143(3)
C(3)	9230(5)	3523(5)	2473(3)	110(2)
C(2)	10228(9)	5203(4)	1852(3)	151(3)
C(16)	10612(13)	-1699(5)	-517(5)	180(5)
C(18)	12007(16)	-1806(9)	-639(10)	305(9)
C(17)	9700(20)	-2276(9)	-986(9)	325(11)

Table 3. Bond lengths [Å] and angles [°] for shelxl.

O(1)-C(5)	1.309(4)
O(1)-C(1)	1.491(4)
O(2)-C(5)	1.193(4)
N(1)-C(10)	1.387(4)
N(1)-C(5)	1.426(4)
N(1)-C(6)	1.491(4)
O(3)-C(10)	1.222(4)
C(10)-C(9)	1.504(5)
C(6)-C(7)	1.518(5)
C(6)-C(11)	1.531(5)
C(6)-H(6A)	0.9800
C(1)-C(3)	1.470(6)
C(1)-C(2)	1.479(7)
C(1)-C(4)	1.520(7)
C(7)-C(8)	1.491(6)
C(7)-H(7A)	0.9700
C(7)-H(7B)	0.9700
C(8)-C(9)	1.534(6)
C(8)-H(8A)	0.9700
C(8)-H(8B)	0.9700
C(11)-C(13)	1.526(5)
C(11)-C(12)	1.529(6)
C(11)-H(11A)	0.9800
C(9)-C(15)	1.521(5)
C(9)-H(9A)	0.9800
C(13)-C(14)	1.475(8)
C(13)-H(13A)	0.9700
C(13)-H(13B)	0.9700
C(15)-C(16)	1.492(7)
C(15)-H(15A)	0.9700
C(15)-H(15B)	0.9700
C(12)-H(12A)	0.9600
C(12)-H(12B)	0.9600
C(12)-H(12C)	0.9600
C(4)-H(4A)	0.9600
C(4)-H(4B)	0.9600

C(4)-H(4C)	0.9600
C(14)-H(14A)	0.9600
C(14)-H(14B)	0.9600
C(14)-H(14C)	0.9600
C(3)-H(3A)	0.9600
C(3)-H(3B)	0.9600
C(3)-H(3C)	0.9600
C(2)-H(2A)	0.9600
C(2)-H(2B)	0.9600
C(2)-H(2C)	0.9600
C(16)-C(17)	1.390(18)
C(16)-C(18)	1.449(16)
C(18)-H(18A)	0.9600
C(18)-H(18B)	0.9600
C(18)-H(18C)	0.9600
C(17)-H(17A)	0.9300
C(17)-H(17B)	0.9300

C(5)-O(1)-C(1)	120.4(3)
C(10)-N(1)-C(5)	116.5(3)
C(10)-N(1)-C(6)	125.4(3)
C(5)-N(1)-C(6)	114.5(3)
O(3)-C(10)-N(1)	120.5(3)
O(3)-C(10)-C(9)	121.7(3)
N(1)-C(10)-C(9)	117.8(3)
N(1)-C(6)-C(7)	110.4(3)
N(1)-C(6)-C(11)	110.8(3)
C(7)-C(6)-C(11)	113.5(3)
N(1)-C(6)-H(6A)	107.3
C(7)-C(6)-H(6A)	107.3
C(11)-C(6)-H(6A)	107.3
O(2)-C(5)-O(1)	127.2(3)
O(2)-C(5)-N(1)	121.7(3)
O(1)-C(5)-N(1)	111.1(3)
C(3)-C(1)-C(2)	112.4(5)
C(3)-C(1)-O(1)	109.6(4)
C(2)-C(1)-O(1)	110.1(4)
C(3)-C(1)-C(4)	110.4(4)

C(2)-C(1)-C(4)	112.5(5)
O(1)-C(1)-C(4)	101.3(3)
C(8)-C(7)-C(6)	112.6(3)
C(8)-C(7)-H(7A)	109.1
C(6)-C(7)-H(7A)	109.1
C(8)-C(7)-H(7B)	109.1
C(6)-C(7)-H(7B)	109.1
H(7A)-C(7)-H(7B)	107.8
C(7)-C(8)-C(9)	109.3(3)
C(7)-C(8)-H(8A)	109.8
C(9)-C(8)-H(8A)	109.8
C(7)-C(8)-H(8B)	109.8
C(9)-C(8)-H(8B)	109.8
H(8A)-C(8)-H(8B)	108.3
C(13)-C(11)-C(12)	109.1(4)
C(13)-C(11)-C(6)	113.1(4)
C(12)-C(11)-C(6)	112.0(4)
C(13)-C(11)-H(11A)	107.5
C(12)-C(11)-H(11A)	107.5
C(6)-C(11)-H(11A)	107.5
C(10)-C(9)-C(15)	110.9(3)
C(10)-C(9)-C(8)	110.9(3)
C(15)-C(9)-C(8)	112.5(4)
C(10)-C(9)-H(9A)	107.4
C(15)-C(9)-H(9A)	107.4
C(8)-C(9)-H(9A)	107.4
C(14)-C(13)-C(11)	114.8(4)
C(14)-C(13)-H(13A)	108.6
C(11)-C(13)-H(13A)	108.6
C(14)-C(13)-H(13B)	108.6
C(11)-C(13)-H(13B)	108.6
H(13A)-C(13)-H(13B)	107.5
C(16)-C(15)-C(9)	114.0(4)
C(16)-C(15)-H(15A)	108.7
C(9)-C(15)-H(15A)	108.7
C(16)-C(15)-H(15B)	108.7
C(9)-C(15)-H(15B)	108.7
H(15A)-C(15)-H(15B)	107.6

C(11)-C(12)-H(12A)	109.5
C(11)-C(12)-H(12B)	109.5
H(12A)-C(12)-H(12B)	109.5
C(11)-C(12)-H(12C)	109.5
H(12A)-C(12)-H(12C)	109.5
H(12B)-C(12)-H(12C)	109.5
C(1)-C(4)-H(4A)	109.5
C(1)-C(4)-H(4B)	109.5
H(4A)-C(4)-H(4B)	109.5
C(1)-C(4)-H(4C)	109.5
H(4A)-C(4)-H(4C)	109.5
H(4B)-C(4)-H(4C)	109.5
C(13)-C(14)-H(14A)	109.5
C(13)-C(14)-H(14B)	109.5
H(14A)-C(14)-H(14B)	109.5
C(13)-C(14)-H(14C)	109.5
H(14A)-C(14)-H(14C)	109.5
H(14B)-C(14)-H(14C)	109.5
C(1)-C(3)-H(3A)	109.5
C(1)-C(3)-H(3B)	109.5
H(3A)-C(3)-H(3B)	109.5
C(1)-C(3)-H(3C)	109.5
H(3A)-C(3)-H(3C)	109.5
H(3B)-C(3)-H(3C)	109.5
C(1)-C(2)-H(2A)	109.5
C(1)-C(2)-H(2B)	109.5
H(2A)-C(2)-H(2B)	109.5
C(1)-C(2)-H(2C)	109.5
H(2A)-C(2)-H(2C)	109.5
H(2B)-C(2)-H(2C)	109.5
C(17)-C(16)-C(18)	122.9(10)
C(17)-C(16)-C(15)	119.9(11)
C(18)-C(16)-C(15)	116.3(10)
C(16)-C(18)-H(18A)	109.5
C(16)-C(18)-H(18B)	109.5
H(18A)-C(18)-H(18B)	109.5
C(16)-C(18)-H(18C)	109.5
H(18A)-C(18)-H(18C)	109.5

H(18B)-C(18)-H(18C)	109.5
C(16)-C(17)-H(17A)	120.0
C(16)-C(17)-H(17B)	120.0
H(17A)-C(17)-H(17B)	120.0

Symmetry transformations used to generate equivalent atoms:

Table 4. Anisotropic displacement parameters ($Å^2 x\ 10^3$) for shelxl. The anisotropic displacement factor exponent takes the form: $-2\pi^2[\ h^2\ a^{*2}U^{11} + ... + 2\ h\ k\ a^*\ b^*\ U^{12}\ ]$

	U^{11}	U^{22}	U^{33}	U^{23}	U^{13}	U^{12}
O(1)	69(2)	97(2)	56(1)	-26(1)	-5(1)	9(1)
O(2)	83(2)	100(2)	78(2)	-19(2)	-7(2)	30(2)
N(1)	66(2)	67(2)	42(1)	-8(1)	-5(1)	6(1)
O(3)	129(2)	80(2)	51(1)	7(1)	5(2)	9(2)
C(10)	64(2)	66(2)	50(2)	2(2)	2(2)	5(2)
C(6)	62(2)	75(2)	48(2)	0(2)	-3(2)	5(2)
C(5)	67(2)	69(2)	54(2)	-5(2)	1(2)	6(2)
C(1)	97(3)	97(3)	59(2)	-27(2)	-1(2)	7(3)
C(7)	116(3)	82(2)	45(2)	-3(2)	-1(2)	1(3)
C(8)	113(3)	82(3)	60(2)	-21(2)	-3(2)	-14(3)
C(11)	82(3)	66(2)	69(2)	7(2)	-4(2)	3(2)
C(9)	90(3)	65(2)	59(2)	-4(2)	16(2)	2(2)
C(13)	111(4)	86(3)	77(2)	23(2)	-2(3)	10(3)
C(15)	184(6)	64(2)	87(3)	1(2)	50(4)	4(3)
C(12)	91(3)	100(3)	118(4)	25(3)	-9(3)	-23(3)
C(4)	121(4)	215(7)	77(3)	-66(4)	-26(3)	17(5)
C(14)	122(5)	184(6)	122(5)	60(5)	-17(4)	34(5)
C(3)	127(4)	130(4)	73(3)	-25(3)	20(3)	8(3)
C(2)	261(9)	85(3)	107(4)	-30(3)	4(5)	-25(5)
C(16)	326(14)	66(3)	147(6)	-13(4)	96(8)	-3(6)
C(18)	344(18)	219(11)	353(18)	-86(12)	57(16)	168(12)
C(17)	550(30)	149(7)	275(14)	-115(9)	121(18)	-142(13)

Table 5. Hydrogen coordinates (x 10^4) and isotropic displacement parameters ($Å^2$x 10^3) for shelxl.

	x	y	z	U(eq)
H(6A)	8773	2856	-735	80
H(7A)	9740	2052	-1822	105
H(7B)	11081	1927	-1374	105
H(8A)	10011	176	-1467	111
H(8B)	8841	671	-963	111
H(11A)	9947	4488	-460	94
H(9A)	11431	443	-376	92
H(13A)	10390	5143	-1779	119
H(13B)	10237	3900	-2105	119
H(15A)	10588	-884	560	146
H(15B)	9241	-835	114	146
H(12A)	12154	4501	-1160	134
H(12B)	12122	3226	-882	134
H(12C)	12017	4202	-240	134
H(4A)	12350	3769	2161	179
H(4B)	11558	2982	2748	179
H(4C)	11712	4281	2942	179
H(14A)	8378	5410	-1949	186
H(14B)	8063	4437	-1331	186
H(14C)	8218	4153	-2252	186
H(3A)	9514	3011	2889	143
H(3B)	8684	3121	2097	143
H(3C)	8745	4136	2710	143
H(2A)	11074	5552	1827	196
H(2B)	9717	5567	2264	196
H(2C)	9798	5284	1339	196
H(18A)	12435	-1131	-449	397
H(18B)	12185	-1906	-1205	397
H(18C)	12325	-2453	-345	397
H(17A)	9977	-2756	-1398	422
H(17B)	8814	-2181	-886	422

Table 6. Torsion angles [°] for shelxl.

C(5)-N(1)-C(10)-O(3)	-4.6(5)
C(6)-N(1)-C(10)-O(3)	-161.9(4)
C(5)-N(1)-C(10)-C(9)	174.8(3)
C(6)-N(1)-C(10)-C(9)	17.5(5)
C(10)-N(1)-C(6)-C(7)	-21.9(5)
C(5)-N(1)-C(6)-C(7)	-179.7(3)
C(10)-N(1)-C(6)-C(11)	-148.6(4)
C(5)-N(1)-C(6)-C(11)	53.7(4)
C(1)-O(1)-C(5)-O(2)	10.1(6)
C(1)-O(1)-C(5)-N(1)	-172.1(3)
C(10)-N(1)-C(5)-O(2)	-117.2(4)
C(6)-N(1)-C(5)-O(2)	42.6(5)
C(10)-N(1)-C(5)-O(1)	64.9(4)
C(6)-N(1)-C(5)-O(1)	-135.4(3)
C(5)-O(1)-C(1)-C(3)	55.2(5)
C(5)-O(1)-C(1)-C(2)	-69.0(6)
C(5)-O(1)-C(1)-C(4)	171.7(4)
N(1)-C(6)-C(7)-C(8)	44.3(5)
C(11)-C(6)-C(7)-C(8)	169.4(4)
C(6)-C(7)-C(8)-C(9)	-63.1(5)
N(1)-C(6)-C(11)-C(13)	-176.0(3)
C(7)-C(6)-C(11)-C(13)	59.1(5)
N(1)-C(6)-C(11)-C(12)	60.2(5)
C(7)-C(6)-C(11)-C(12)	-64.7(5)
O(3)-C(10)-C(9)-C(15)	20.5(6)
N(1)-C(10)-C(9)-C(15)	-158.9(4)
O(3)-C(10)-C(9)-C(8)	146.3(4)
N(1)-C(10)-C(9)-C(8)	-33.1(5)
C(7)-C(8)-C(9)-C(10)	55.5(5)
C(7)-C(8)-C(9)-C(15)	-179.6(4)
C(12)-C(11)-C(13)-C(14)	-171.5(5)
C(6)-C(11)-C(13)-C(14)	63.1(6)
C(10)-C(9)-C(15)-C(16)	-171.1(7)
C(8)-C(9)-C(15)-C(16)	64.0(8)
C(9)-C(15)-C(16)-C(17)	-105.2(9)
C(9)-C(15)-C(16)-C(18)	64.2(11)

Symmetry transformations used to generate equivalent atoms: