Mendeleev Commun., 2000, 10(3), 106–107

Chirality-directed self-assembling of long-chain dialkyl 3,7-diazabicyclo[3.3.1]nonane-2,6-dione-1,5-dicarboxylates

Remir G. Kostyanovsky,*[a] Konstantin A. Lyssenko,[b] Irina A. Bronzova,[a] Oleg N. Krutius,[a] Yurii A. Strelenko[c] and Alexander A. Korlyukov[b]

[a] *N. N. Semenov Institute of Chemical Physics, Russian Academy of Sciences, 117977 Moscow, Russian Federation. Fax: +7 095 938 2156; e-mail: kost@center.chph.ras.ru*

[b] *A. N. Nesmeyanov Institute of Organoelement Compounds, Russian Academy of Sciences, 117813 Moscow, Russian Federation. Fax: +7 095 135 5085; e-mail: kostya@xray.ac.ru*

[c] *N. D. Zelinsky Institute of Organic Chemistry, Russian Academy of Sciences, 117913 Moscow, Russian Federation. Fax: +7 095 135 5328; e-mail: strel@nmr.ioc.ac.ru*

10.1070/MC2000v010n03ABEH001294

Dihexyl and didodecyl 3,7-diazabicyclo[3.3.1]nonane-2,6-dione-1,5-dicarboxylates **4a**,**b** were synthesised, and the self-assembling of the molecules of strictly alternating configurations was observed in a crystal of bis-lactam **4b**, which resulted in formation of H-bonded heterochiral polymer tapes of a diagonal zigzag type combined into monomolecular layers separated by hydrophobic groups.

Bicyclic bis-lactams of C_2 symmetry hold much promise for building supramolecular structures.[1–8] It was shown recently[6] that bis-lactam **A** in crystal is self-assembled into heterochiral H-bonded tapes of a diagonal zigzag type. The first similar motive of structure was reported for cyclo-di-β-alanine[3,9] and then for bis-lactams of the [2.2.2],[1,2,4,8] [3.3.0][5] and [3.3.1][6] series. Are the long-chained dialkyl dicarboxylates of bis-lactams capable of similar self-assembling in a crystal? This is an intriguing question because the interlayered suprastructures containing hydrophobic long alkyl chains are of interest in relation to the possibilities for creating monomolecular coats, surfactants, liquid crystals and other useful materials.

In this work, an affirmative answer to the above question is given. Dihexyl and didodecyl 3,7-diazabicyclo[3.3.1]nonane-2,6-dione-1,5-dicarboxylates **4a**,**b** were synthesised on the basis of bis-lactam **1**[6] (Scheme 1).† The structures of **4a**,**b** were confirmed by ^{1}H and ^{13}C NMR spectra, which are in good agreement with published data for similar compounds.[6,7]

The molecular and crystal structures of bis-lactam **4b** were studied by X-ray diffraction.‡ In the basic geometric parameters of the skeleton, compound **4b** is almost identical to its diethyl analogue **A** studied previously.[6] Moreover, a comparison of the crystal structures of **4b** and **A** indicates that the main packing motive remained unchanged upon the introduction of long-chain substituents. Likewise in a crystal of **A**, the molecules of **4b** are linked in a crystal by N–H···O bonds into heterochiral infinite tapes of a diagonal zigzag type directed along the crystallographic axis *b* (Figure 1). In turn, the diagonal zigzags are combined by C–H···O contacts into layers parallel to the crystallographic plane *ab* (Figure 2). The distance between parallel zigzags is 7.04 Å, they are inclined to the plane *ab* at an angle of 54°. The C_{12}-substituents are emerged from both sides of the plane and drawn out along the crystallographic directions [011] [O(11)–C(23)] and [011] [O(25)–C(37)]. Thus, the crystal structure of **4b** is constructed from parallel layers with hydrophobic coatings formed by C_{12}-substituents (Figure 3), the thickness is about 31 Å. The conformations of $C_{12}O$-substituents are somewhat different. Thus, a deviation from the all-*trans* conformation in the chain O(11)–C(23) is observed for the terminal atoms C(22) and C(23) disordered at two positions, whereas in the chain O(25)–C(37) a deviation from the *trans* configuration is observed for the fragment O(26)–C(29). This can be caused by the participation of the O(4) atom in the formation of the above strong C–H···O contact that results in a distortion of the torsion

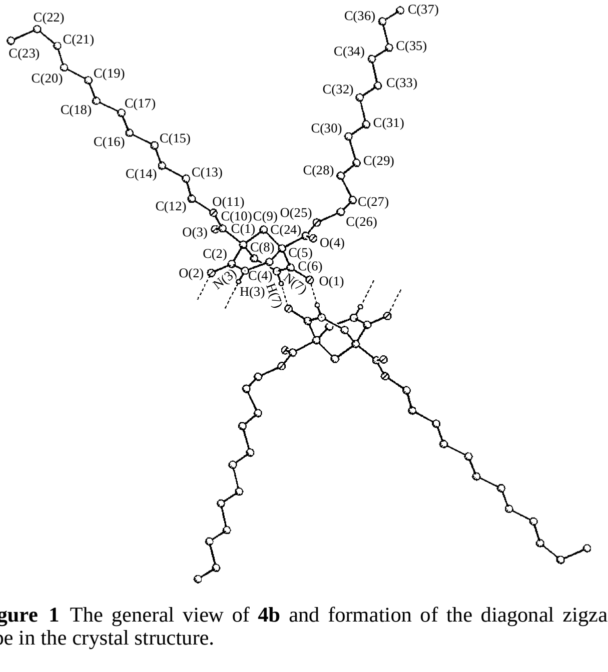


Figure 1 The general view of **4b** and formation of the diagonal zigzag tape in the crystal structure.

---

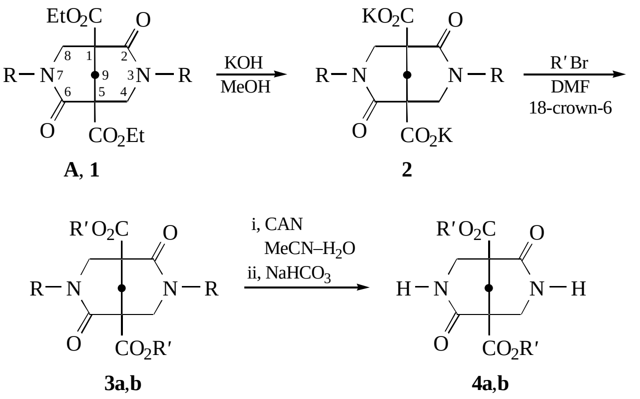
† NMR spectra were recorded on Bruker WM 400, AM 300 and WM 250 spectrometers. All new compounds gave satisfactory elemental analysis data.

1: was obtained by known method,[5] 52.3% yield, mp 198–200 °C.

2: a mixture of 0.98 g (3.3 mmol) of diester **1** and 0.48 g (8.5 mmol) of KOH in 15 ml of a mixture of EtOH and H_2O (2:1) was kept for 2 days at 20 °C and then for 1.5 h at 4 °C. The salt precipitate was separated, washed with EtOH and dried in air. Yield 0.82 g (78.4%). ^{1}H NMR (CD_3OD) δ: 2.64 (s, 2H, 9-CH_2), 3.60 (m, 4H, 4,8-CH_2, AB, $\Delta\nu$ 16.0, ^2J –8.0 Hz), 4.48 (m, 4H, 3,7-NCH_2, AB, $\Delta\nu$ 172.0, ^2J –14.6 Hz), 6.82 and 7.13 (m, 8H, 2C_6H_4).

3a: a mixture of 0.41 g (1.29 mmol) of **2**, 15 mg of 18-crown-6 and 0.55 g (1.35 mmol) of hexyl bromide in 10 ml of dry DMF was boiled (9 h), cooled, diluted with a 10-fold excess of H_2O, and extracted with diethyl ether (2×150 ml). The extract was dried over $MgSO_4$ and evaporated. The ester was isolated as a light yellow oil and purified by gradient chromatography on silica [L40/100, eluent: hexane–ethyl acetate (5–15%)] in a yield of 0.19 g (36.6%). ^{1}H NMR ($CDCl_3$) δ: 0.88 (t, 6H, 2*Me*CH_2, ^2J 6.7 Hz), 1.28 [m, 12H, 2(C*H*$_2$)$_3$Me], 1.63 (m, 4H, 2C*H*$_2$$CH_2O$), 2.60 (s, 2H, 9-$CH_2$), 3.71 (m, 4H, 4,8-$CH_2$, AB, $\Delta\nu$ 16.0, ^2J –12.8 Hz), 3.80 (s, 6H, 2MeO), 4.17 (m, 4H, 2CH_2O), 4.51 (m, 4H, 3,7-NCH_2, AB, $\Delta\nu$ 264.0, ^2J –14.5 Hz), 6.83 and 7.13 (m, 8H, 2C_6H_4). ^{13}C NMR ($CDCl_3$) δ: 14.0 (2*Me*C), 22.47, 25.40, 28.31, 31.35 [2(CH_2)$_4$], 33.64, (9-CH_2), 50.01 (3,7-NCH_2), 50.10 (1,5-C), 52.91 (4,8-CH_2), 55.19 (2MeO), 66.14 (2CH_2O), 114.10, 127.84, 129.31, 159.18 (C_6H_4), 166.36, 168.92 (2,6-CO, 2CO_2).

3b: was obtained similarly to **3a** and isolated as a light yellow oil in 85.2% yield. ^{1}H MNR ($CDCl_3$) δ: 0.85 (t, 6H, 2*Me*CH_2, ^3J 6.9 Hz), 1.25 [m, 36H, 2(C*H*$_2$)$_9$Me], 1.60 (m, 4H, 2C*H*$_2$$CH_2O$), 2.58 (s, 2H, 9-$CH_2$), 3.68 (m, 4H, 4,8-$CH_2$, AB, $\Delta\nu$ 28.0, ^2J –12.6 Hz), 3.77 (s, 6H, 2MeO), 4.15 (m, 4H, 2CH_2O), 4.51 (m, 4H, 3,7-NCH_2, AB, $\Delta\nu$ 254.0, ^2J –14.4 Hz), 6.81 and 7.11 (m, 8H, 2C_6H_4). ^{13}C NMR ($CDCl_3$) δ: 14.13 (2*Me*C), 22.70, 25.77, 28.39, 29.36, 29.45, 29.51, 29.65, 31.92 [2(CH_2)$_{10}$], 33.65, (9-CH_2), 50.04 (3,7-NCH_2), 50.13 (1,5-C), 52.93 (4,8-CH_2), 55.20 (2MeO), 66.18 (2CH_2O), 114.15, 127.88, 129.34, 159.24 (C_6H_4), 166.44, 168.97 (2,6-CO, 2CO_2).



A R = H
1–3 R = 4-MeOC$_6$H$_4$CH$_2$

a R′ = *n*-C$_6$H$_{13}$
b R′ = *n*-C$_{12}$H$_{25}$

Scheme 1

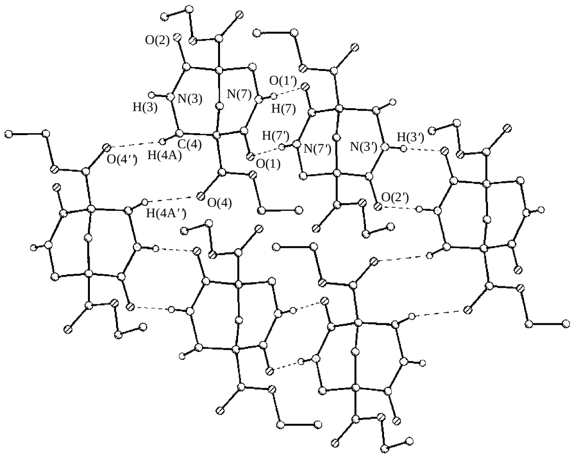


Figure 2 The formation of layers parallel to the crystallographic plane *ab* in the crystal structure of **4b**; C$_{10}$H$_{22}$ groups are omitted for clarity.

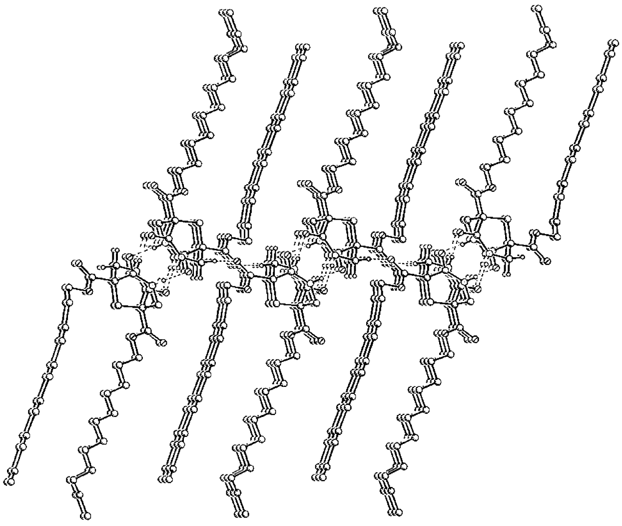


Figure 3 The formation of the hydrophobic coated (C$_{12}$-substituents) layers in the crystal of **4b**.

angle O(25)–C(26)–C(27)–C(28) to 73.2° against 173.9° for O(11)–C(12)–C(13)–C(14). Apparently, this contact also affects the geometry of N–H···O bonds making the N(4)···O(2) distance longer than N(7)···O(1); this elongation was not observed in the case of **A**.[6]

This work was supported by INTAS (grant no. 157) and the Russian Foundation for Basic Research (grant nos. 00-03-32738 and 00-03-32807a).

References

1 J.-M. Lehn, *Supramolecular Chemistry*, VCH, Weinheim, 1995.
2 M.-J. Brienne, J. Gabard, M. Leclercq, J.-M. Lehn, M. Cesario, C. Pascard, M. Cheve and G. Dutruc-Rosset, *Tetrahedron Lett.*, 1994, **35**, 8157.
3 J. C. MacDonald and G. M. Whitesides, *Chem. Rev.*, 1994, **94**, 2383.
4 R. G. Kostyanovsky, Yu. I. El'natanov, O. N. Krutius, I. I. Chervin and K. A. Lyssenko, *Mendeleev Commun.*, 1998, 228.
5 R. G. Kostyanovsky, Yu. I. El'natanov, O. N. Krutius, K. A. Lyssenko, and Yu. A. Strelenko, *Mendeleev Commun.*, 1999, 70.
6 R. G. Kostyanovsky, K. A. Lyssenko, Yu. I. El'natanov, O. N. Krutius, I. A. Bronzova, Yu. A. Strelenko and V. R. Kostyanovsky, *Mendeleev Commun.*, 1999, 106.
7 R. G. Kostyanovsky, K. A. Lyssenko, D. A. Lenev, Yu. I. El'natanov, O. N. Krutius and I. A. Bronzova, *Mendeleev Commun.*, 1999, 151.
8 R. G. Kostyanovsky, K. A. Lyssenko and D. A. Lenev, *Mendeleev Commun.*, 1999, 154.
9 D. N. J. White and J. D. Dunitz, *Israel J. Chem.*, 1972, **10**, 249.

Received: 2nd March 2000; Com. 00/1620

4a: H$_2$O (32 ml) and CAN (32.4 g, 59 mmol) were added to a solution of 4.03 g (7.5 mmol) of **3a** in 100 ml of MeCN, and the mixture was stirred for 10 min; the orange solution grew muddy and separated into layers. The mixture was kept for 2 days at 20 °C; next, 60 g of NaHCO$_3$ was added in small portions. After the completion of gas evolution, 160 ml of MeCN was added, and the resulting precipitate was rubed with a spatula. The solution was poured off and evaporated, the residue was extracted with diethyl ether (2×160 ml) to separate anisaldehyde and then with ethyl acetate (2×200 ml). The evaporation of the last extract gave an orange oil, which was purified by gradient chromatography on silica [L40/100, eluent: hexane–ethyl acetate (5–30%)] and crystallised from light petroleum in a yield of 24.7%, mp 132–134 °C. ^{1}H NMR (CDCl$_3$) δ: 0.88 (t, 6H, 2*Me*CH$_2$, ^3J 7.0 Hz), 1.30 [m, 12H, 2(C*H*$_2$)$_3$Me], 1.65 (m, 4H, 2C*H*$_2$CH$_2$O), 2.64 (s, 2H, 9-CH$_2$), 3.73 (m, 4H, 4,8-CH$_2$, ABX, $\Delta\nu$ 32.0, ^2J −12.7 Hz, $^3J_{\mathrm{HCNH}}$ 4.0 Hz), 4.18 (t, 4H, 2CH$_2$O, ^3J 6.8 Hz), 7.38 (d, 2H, 3,7-NH, $^3J_{\mathrm{HNCH}}$ 4.0 Hz). ^{13}C NMR (CDCl$_3$) δ: 14.03 (2*Me*C), 22.51, 25.41, 28.31, 31.34 [2(CH$_2$)$_4$], 33.15 (9-CH$_2$), 48.38 (3,7-NCH$_2$), 49.36 (1,5-C), 66.42 (2CH$_2$O), 168.62 (1,5-C*C*O), 169.20 (2,6-CO).

4b: was obtained similarly to **4a**, 36.5% yield, mp 89–90 °C (from MeOH). ^{1}H NMR (CDCl$_3$) δ: 0.88 (t, 6H, 2*Me*CH$_2$, ^3J 7.0 Hz), 1.27 [m, 36H, 2(C*H*$_2$)$_9$Me], 1.65 (m, 4H, 2C*H*$_2$CH$_2$O), 2.65 (s, 2H, 9-CH$_2$), 3.77 (m, 4H, 4,8-CH$_2$, AB, $\Delta\nu$ 38.0, ^2J −12.6 Hz, $^3J_{\mathrm{HNCH}}$ 4.0 Hz), 4.17 (m, 4H, 2CH$_2$O), 6.74 (d, 2H, 3,7-NH, $^3J_{\mathrm{HNCH}}$ 4.0 Hz). ^{13}C NMR (CDCl$_3$) δ: 14.16 (2*Me*C), 22.73, 25.76, 28.39, 29.23, 29.40, 29.52, 29.67, 31.95 [2(CH$_2$)$_{10}$], 33.20, (9-CH$_2$), 48.49 (3,7-NCH$_2$), 49.43 (1,5-C), 66.46 (2CH$_2$O), 168.58 (1,5-C*C*O), 169.14 (2,6-CO). The product is highly soluble in CHCl$_3$, C$_6$H$_6$, toluene and glyme; less soluble in MeCN, MeOH, EtOH and acetone; poorly soluble in hexane, heptane and undecane (1.28 g in 100 ml), but insoluble in D$_2$O (by ^{1}H NMR data). When crystallising from undecane, no inclusion of the solvent into crystals was observed.

‡ *Crystallographic data for* **4b**: at 110 K, crystals of C$_{33}$H$_{58}$N$_2$O$_6$ are triclinic, space group $P\bar{1}$, a = 9.7081(5), b = 11.0367(6), c = 17.1644(8) Å, α = 78.115(1), β = 74.050(1), γ = 71.604(1)°, V = 1663.5(2) Å^3, Z = 2, M = 578.81, d_{calc} = 1.156 g cm^{-3}, μ(MoKα) = 0.078 mm^{-1}, F(000) = 636. Intensities of 15442 reflections were measured with a Smart 1000 CCD diffractometer at 110 K [λ(MoKα) = 0.71072 Å, ω-scans with a 0.3° step in ω and 10 s per frame exposure, $2\theta < 60°$], and 7620 independent reflections (R_{int} = 0.0272) were used in further refinement. The structure was solved by a direct method and refined by the full-matrix least-squares technique against F^2 in the anisotropic–isotropic approximation. The analysis of electron density synthesis have revealed additional maxima in the terminal part of the O(11)–C(20) moiety, which was interpreted as a disorder. The refinement of the occupancies for C(22), C(23) and C(22′), C(23′) leads to 0.40 and 0.60, respectively. Hydrogen atoms were located from the Fourier synthesis and refined in the isotropic approximation. The refinement converged to wR_2 = 0.1312 and GOF = = 0.863 for all independent reflections [R_1 = 0.0483 was calculated against F for 4693 observed reflections with $I > 2\sigma(I)$]. All calculations were performed using the SHELXTL PLUS 5.0 program on IBM PC AT. Atomic coordinates, bond lengths, bond angles and thermal parameters have been deposited at the Cambridge Crystallographic Data Centre (CCDC). For details, see 'Notice to Authors', *Mendeleev Commun.*, Issue 1, 2000. Any request to the CCDC for data should quote the full literature citation and the reference number 1135/65.