

Pyramidal amide nitrogen in *N*-acyloxy-*N*-alkoxyureas and *N*-acyloxy-*N*-alkoxycarbamates[†]

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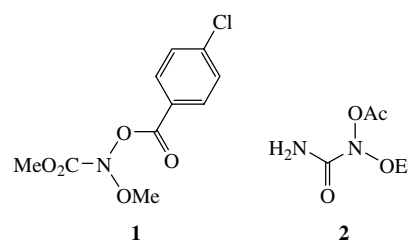
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The XRD studies of *N*-acyloxy-*N*-alkoxyamides **1**, **2** have revealed a highly pyramidal configuration of amide nitrogen in the O–N–O group.

Optically active compounds with asymmetric nitrogen in the open chain were obtained firstly for the series of *N,N*-di-alkoxyamines [RN(OMe)OR', R–H, *tert*-alkyl, $\Delta G_{\text{inv}}^{\ddagger} = 19.0\text{--}24.6$ kcal mol^{−1} at 64–175 °C^{2(a),(b)}]. The high pyramidality of the nitrogen in (MeO)₂NH,^{2(c)} substituted 2-methoxy-1,2-oxazolidines,^{2(d)} (MeO)₂N–N(OMe)₂^{2(e)} and [4–ClC₆H₄C(O)N(OEt)]₂^{3(a)} was established by XRD^{2(c),(e),(3(a))} and GED.^{2(c)} In *N,N*-dialkoxyureas [Me₂NC(O)N(OR)OR'] the pyramidality of *N,N*-dialkoxyamide nitrogen was established using DNMR ($\Delta G_{\text{inv}}^{\ddagger} = 9.8\text{--}10.5$ kcal mol^{−1} at 25 °C).^{2(e)} Recently Glover *et al.*^{3(b)} reported an XRD study of substituted *N*-acyloxy-*N*-alkoxybenzamides with the most pyramidal nitrogen. In discussed geminal systems X–N–Y the theoretical study of the configuration stability of the nitrogen and anomeric effects had been done.^{2(f),(3)}

We synthesised compounds **1**^{4(a)} and **2**^{4(b)} and first studied their crystalline structures.^{‡,§}

The XRD studies of *N*-acyloxy-*N*-alkoxycarbamate **1** and *N*-acyloxy-*N*-alkoxyurea **2** (Figures 1, 2) revealed that amide O–N–O nitrogen has a pyramidal configuration (the sum of bond angles centered at this nitrogen atom is 334.1° for carbamate **1** or 333.6° for urea **2**). Analysis of Winkler–Dunitz parameters⁵



for amides demonstrates that some negligible twist around the C–N bond is observed ($\tau = 2.9$ for **1** and $\tau = -6.8$ for **2**). The nitrogen pyramidality value (in carbamate **1**, $\chi_{\text{N}} = -56.2$; in urea **2**, $\chi_{\text{N}} = -57.1$) is some few as in *N*-acyloxy-*N*-alkoxybenzamides. But this parameter for the amide carbon atom is higher than

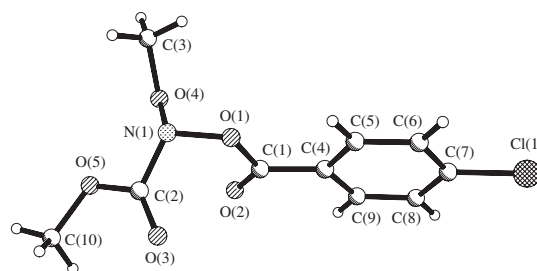


Figure 1 Structure of molecule **1**. Selected bond lengths (Å) and bond angles (°): N(1)–C(2) 1.423(2), N(1)–O(1) 1.424(2), N(1)–O(4) 1.396(2), C(1)–O(1) 1.388(2), C(2)–O(5) 1.322(2), O(1)–N(1)–C(2) 111.4(1), C(2)–N(1)–O(4) 113.4(1), O(1)–N(1)–O(4) 109.3(1).

[†] Asymmetric Nitrogen. Part 97. Geminal Systems. Part 55. Previous communications see ref. 1.

[‡] Methyl *N*-4-chlorobenzoyloxy-*N*-methoxycarbamate **1**. A solution of methyl *N*-chloro-*N*-methoxycarbamate^{4(b)} (0.53 g, 3.80 mmol) in MeCN (30 ml) and 4-ClC₆H₄CO₂Na (1.36 g, 7.61 mmol) was stirred for 77 h at 20 °C, CH₂Cl₂ (10 ml) was added; the solid was filtered off and washed with CH₂Cl₂ (20 ml), the filtrate was concentrated *in vacuo*; the residue was extracted with CH₂Cl₂ (12 ml) at 5 °C. The extract was concentrated *in vacuo*; the residue was extracted with Et₂O–hexane (1:5); the extract was concentrated *in vacuo*; yield, 0.76 g (77%) of **1**, white solid, mp 35–36 °C (*n*-hexane) (lit.^{4(a)} mp 34–35 °C). ¹H NMR (300 MHz, CDCl₃) δ : 3.92 (s, 3H, NOMe), 3.97 (s, 3H, CO₂Me), 7.47 [d, 2H, C(3)H, C(5)H, ³J 8.4 Hz], 8.03 [d, 2H, C(2)H, C(6)H, ³J 8.4 Hz]. ¹³C NMR (75 MHz, CDCl₃) δ : 55.3 (NOMe), 63.4 (CO₂Me), 125.6 [C(4)], 129.2 [C(3), C(5)], 131.5 [C(2), C(6)], 140.8 [C(1)], 158.5 (CO₂Me); 163.7 (C=O). IR (ν/cm^{-1}): 1785 (C=O). MS (FAB) *m/z* (%): 284 (1.6), 282 (6.3) [M + Na]⁺, 141 (64.1), 139 (100), 120 (6.7), 113 (4.1), 111 (17.3), 104 (60.3). Found (%): C, 46.11; H, 3.92; N, 5.20. Calc. for C₁₀H₁₀NO₅Cl (%): C, 46.26; H, 3.88; N, 5.39.

N-Acetoxy-*N*-ethoxyurea **2**. A mixture of a solution of *N*-chloro-*N*-ethoxyurea^{4(b)} (0.76 g, 5.49 mmol) in MeCN (25 ml) and AcONa (0.9 g, 11 mmol) was stirred at 20 °C for 40 h. CH₂Cl₂ (10 ml) was added, the precipitate was filtered off and washed with CH₂Cl₂. The filtrate was concentrated *in vacuo*, the residue was washed with Et₂O (5 ml) and then extracted with CH₂Cl₂ (30 ml). The CH₂Cl₂ extract was concentrated *in vacuo*, the residue was kept at 20 °C and 2 Torr for 0.5 h; yield, 0.54 g (60.8%) of **2**, colourless crystals, mp 104–105 °C [Me₂C(O)–Et₂O at –5 °C] (lit.^{4(b)} mp 93–95 °C). ¹H NMR (300 MHz, CDCl₃) δ : 1.32 (t, 3H, OCH₂Me, ³J 7 Hz), 2.19 [s, 3H, MeC(O)O], 4.14 (q, 2H, OCH₂Me, ³J 7 Hz), 5.68 (br. s, 1H, NH), 6.01 (br. s, 1H, NH). IR (ν/cm^{-1}): 1798 (C=O), 1720 (C=O). Found (%): C, 37.30; H, 6.31; N, 17.15. Calc. for C₅H₁₀N₂O₄ (%): C, 37.04; H, 6.22; N, 17.28.

[§] Crystal data for **1**: C₁₀H₁₀NO₅Cl, monoclinic, space group *P2*₁/*c*, *a* = 13.737(3), *b* = 9.316(2) and *c* = 9.174(2) Å, β = 101.87(2)°, *V* = 1148.9(4) Å³, *F*(000) = 536, *d*_{calc} = 1.501 g cm^{−3}, *Z* = 4, μ = 0.341 mm^{−1}.

Crystal data for **2**: C₅H₁₀N₂O₄, monoclinic, space group *P2*₁/*c*, *a* = 10.760(4), *b* = 7.401(2) and *c* = 10.072(3) Å, β = 102.66(3)°, *V* = 782.6(4) Å³, *F*(000) = 344, *d*_{calc} = 1.376 g cm^{−3}, *Z* = 4, μ = 0.119 mm^{−1}.

Data were measured using a Siemens P3/PC diffractometer (*T* = 165 K, graphite-monochromated MoK α radiation, $2\theta/\theta$ scan, $2\theta_{\text{max}}$ = 50°). The structures were solved by a direct method using the SHELXL PLUS program package. Refinement against *F*² in an anisotropic approximation (the hydrogen atoms isotropic in the riding model) by a full matrix least-squares method for 2006 reflections was carried out to *wR*₂ = 0.085 [156 parameters, *R*₁ = 0.034 for 1492 reflections with *F* > 4 σ (*F*), *S* = 1.00] for **1** and for 1366 reflections was carried out to *wR*₂ = 0.100 [111 parameters, *R*₁ = 0.052 for 824 reflections with *F* > 4 σ (*F*), *S* = 0.91] for **2**.

Atomic coordinates, bond lengths, bond angles and thermal parameters have been deposited at the Cambridge Crystallographic Data Centre (CCDC). These data can be obtained free of charge via www.ccdc.cam.ac.uk/conts/retrieving.html (or from the CCDC, 12 Union Road, Cambridge CB2 1EZ, UK; fax: +44 1223 336 033; or deposit@ccdc.cam.ac.uk). Any request to the CCDC for data should quote the full literature citation and CCDC reference numbers 601354 and 601355 for **1** and **2**, respectively. For details, see 'Notice to Authors', *Mendeleev Commun.*, Issue 1, 2006.

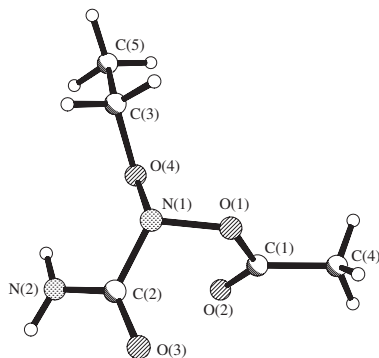


Figure 2 Structure of molecule **2**. Selected bond lengths (Å) and bond angles (°): N(1)–C(2) 1.426(3), N(1)–O(1) 1.426(2), N(1)–O(4) 1.398(2), C(1)–O(1) 1.377(3), O(1)–N(1)–C(2) 111.6(2), C(2)–N(1)–O(4) 113.5(2), O(1)–N(1)–O(4) 108.5(2).

Glover reported^{3(b)} (in carbamate **1**, $\chi_C = 7.9$; in urea **2**, $\chi_C = 7.6$). That reveals at some distortion of the planar configuration of the carbon atom. This also accompanies some deviation of the sum of bond angles, centered on amide carbon atom, from 360° (359.4° in **1** and 359.5° in **2**).

In compounds **1** and **2** bond lengths with amide nitrogen participation are really equivalent. The nitrogen lone pair conjugates with the π system of the carbonyl group. In both molecules, the alkoxy group is in conformation close to anticlynal with respect to the C–N bond [the C–N–O–C torsion angle is 139.6(2)° in carbamate **1** or –131.3(3)° in urea **2**]. The ester substituent has synclinal orientation relatively the same bond [the C–N–O–C torsion angle is 59.0(2)° in carbamate **1** or –56.7(3)° in urea **2**]. At the same time, contrary to compounds studied by Glover, the carbonyl group of the ester substituent is in sc-conformation with respect to the amide nitrogen atom [the N–O–C=O torsion angle is –2.6(2)° in carbamate **1** or 3.3(3)° in urea **2**]. Quantum-chemical calculations⁶ using the MP2/6-311+G(2d,2p)//B3LYP/6-311+G(2d,2p) method demonstrated that such a configuration of the amide nitrogen atom is 3.43 or 4.24 kcal mol^{–1} more stable contrary to inverted configuration for molecules of **1** and **2**, respectively.

The smaller pyramidality of the amide nitrogen atom arouses some shortening of the C–N amide bond as compared to *N*-acyloxy-*N*-alkoxybenzamides.^{3(b)} The considerable differences of the N–O bond lengths attract attention. The N–O_{Acyl} bond is significantly longer as compared to the N–O_{OR} bond. This bond difference results^{2(d),7} in significant degree from the anomeric interaction within the O–N–O fragment, particularly by donation of lone pair of the oxygen atom into the non-bonding orbital of the N–O_{Acyl} bond ($n_O \rightarrow \sigma_{N-OC(O)}^*$).

In addition, it is observed significant nonequality of the O–C(=O) bonds in the molecule of carbamate **1**. The C–O bond elongation in the ester substituent may also be explained by anomeric interactions within the N–O–C fragment. The analysis of intramolecular interactions using the NBO theory^{8,9} for the wavefunction calculated by the B3LYP/6-311+G(2d,2p) method demonstrated that, in the molecule under consideration, the donation of a lone pair of the amide nitrogen atom on non-bonding orbital of the C–O bond is observed ($n_N \rightarrow \sigma_{C-O}^*$).

In conclusion, it should be noted that nitrogen pyramidality observed in crystalline structure, as well as in solution, as in gaseous phase, is mutual property of the compounds with configurationally stable nitrogen, such as aziridines,^{10(a),(b)} diaziridines^{10(c)} and oxaziridines.^{10(d)} The high pyramidality of the P atom was also found in acylphosphines.^{10(e)}

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