ROTAMERIC PROPERTIES OF NOVEL *N*-ACYL AND *N*-ACYLOXY DIMERIC 4-PHENYL-1,4-DIHYDROPRIDINES DERIVED FROM DEVELOPED SOLID-STATE SYNTHESIS

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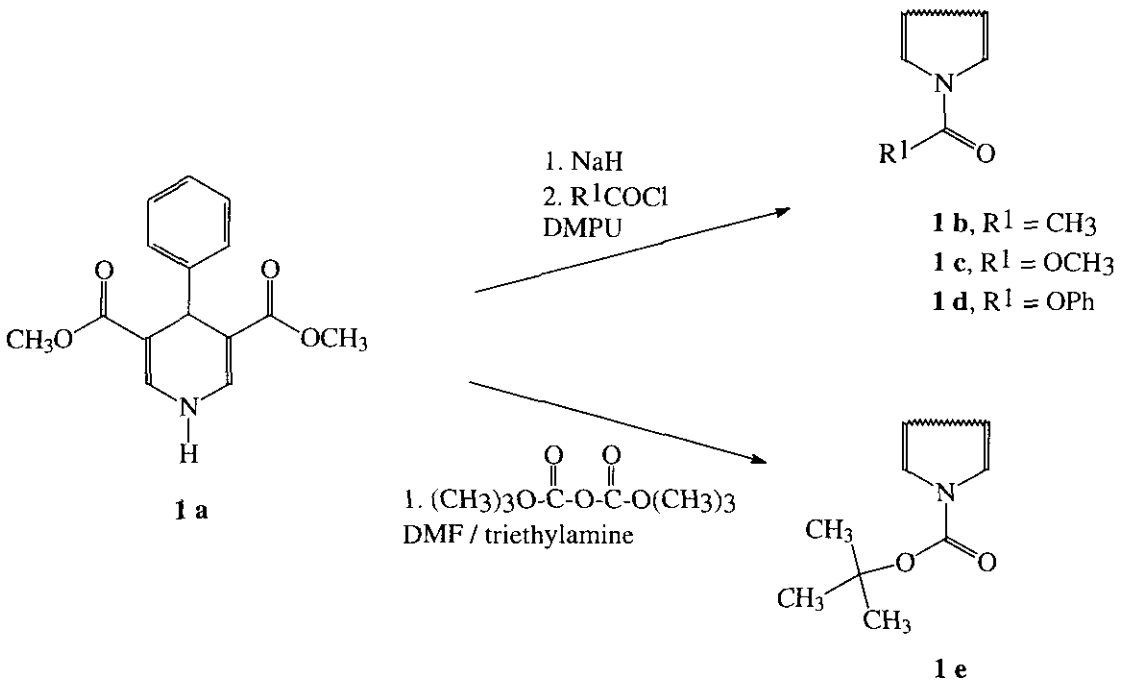
Abstract - Novel *N*-acyl and *N*-acyloxy dimeric 4-phenyl-1,4-dihydropyridines are given by solid-state photodimerization of their monomeric educts in excellent yields. The existence of rotamers was demonstrated by ^{1}H NMR spectroscopical measurement at certain temperatures and additionally supported by X-Ray crystal structure analysis of centrosymmetrical cage-dimeric *N*-acetyl-3,5-dimethoxycarbonyl-4-phenyl-1,4-dihydropyridine (**3b**). Topochemical investigations by X-Ray crystal structure analysis prove the formation of *anti*-dimeric *N*-Boc-3,5-dimethoxycarbonyl-4-phenyl-1,4-dihydropyridine (**4e**) to be controlled by the nearest distance of potentially reacting double bonds with 3.667(3) Å.

3,9-Diazatetraasteranes have been reported as exclusive cycloaddition products of 4-(4-methoxyphenyl)-1,4-dihydropyridines given in a novel solid-state photodimerization reaction.[1,2] Recent investigations in their anti-HIV activity which have made because of the close relationship of diazatetraasteranes to structurally related cubanes with moderate anti-HIV activity[3] suggested them as novel HIV-1 protease inhibitors.[4,5] As their reported solid-state synthesis has been limited so far to *N*-unsubstituted and *N*-alkyl-substituted derivatives[2] we extended our solid-state synthetic activities also on *N*-acyl- and *N*-acyloxy-substituted 1,4-dihydropyridines in order to achieve structurally varied 3,9-diazatetraasteranes. However, in the small series of 4-phenyl-1,4-dihydropyridines (**1**) taken into consideration we yielded either the desired cage-dimeric 3,9-diazatetraasteranes or novel *anti*-dimers. Exhibited multiplicity of signals in the ^{1}H NMR spectra of the dimers is demonstrated to be caused by the existence of certain rotameric structures as will be discussed. The *anti*-dimer formation has been investigated by X-Ray crystal structure analysis.

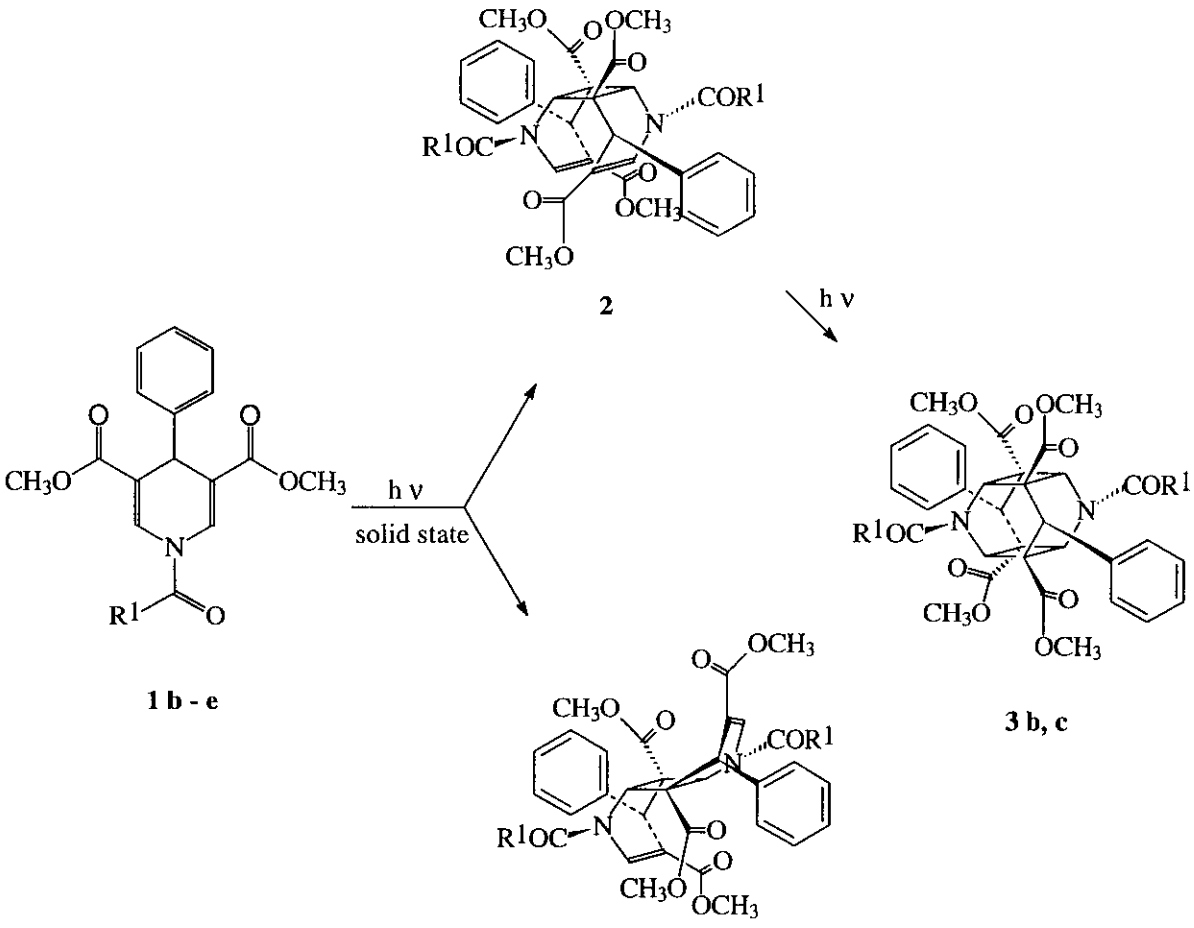
Results and Discussion

Monomeric *N*-acyl- and *N*-acyloxy-3,5-methoxycarbonyl-4-phenyl-1,4-dihydropyridines (**1b-d**) have synthesized by *N*-acylation of the 1,4-dihydropyridine anion of 3,5-methoxycarbonyl-4-phenyl-1,4-dihydropyridine[6] (**1a**) which were produced by proton abstraction with sodium hydride in dimethylpropylenurea (DMPU). The *N*-Boc-substituted derivative (**1e**) was yielded by treatment of **1a** with di-*tert*-butyl dicarbonate in DMF/triethylamine.



Solid-state photodimerization of **1b** and **c** with Ultra-Vitalux lamps® under dihydropyridine chromophore excitation at λmax = 308 (**1b**) and 316 (**1c**) nm, respectively, gives cage dimers (**3b**, **c**) *via syn*-dimers (**2b**, **c**) of which merely **2c** could be isolated and spectroscopically characterized. In the case of **1d** and **1e** photostable *anti*-dimers with λmax = 273 nm (**4d**) and 282 nm (**4e**) were yielded as exclusive products.

Topochemical investigations of the *anti*-dimer formation by X-Ray crystal structure analysis have been made with crystalline *N*-Boc-3,5-dimethoxycarbonyl-4-phenyl-1,4-dihydropyridine (**1e**). Comparing to the *N*-alkyl derivatives[2] the ester carbonyl groups are differently orientated in the molecular structure with one group *anti*-periplanar orientated with respect to the C2-C3 bond (C3-C2-C41-O41 – 172.0(2)°) and the other one in a *syn*-periplanar orientation with respect to the C4-C3 bond (C3-C4-C31-O31 – 10.7(3)°). In the packing scheme neighbouring stacks which consist of translationally generated molecules along [100] show centrosymmetrical arrangement of their molecules. The *anti*-dimer formation between double bonds C1-C2 and C1´-C2´ of neighbouring molecules will be favourable as their distance of 3.667(3) Å



lies far below 4.2 Å which has been postulated as the maximum distance for potentially reacting double bonds.[7-9] Moreover, those double bonds show favorable parallel orientation due to their centrosymmetric relationship.[10] An alternative cage-dimer formation would be possible with a distance of potentially reacting double bonds of 3.961(3) Å (C1···C4′) and 3.930(3) (C2···C5′), respectively. However, no cage dimer formation could be observed. Thus, the dimerization reaction proves to be topochemically controlled by the nearest distance of potentially reacting double bonds.

Contrasting corresponding *N*-alkyl derivatives[2] the ^{1}H NMR spectra of *N*-acetyl cage dimer (**3b**) partly exhibits double (*N*-$COCH_3$ - 2.24, 2.26 ppm) and quadruple sets of signals ($COOCH_3$ - 3.50, 3.54, 3.63, 3.67; 2-H, 4-H, 8-H, 10-H - 5.09, 5.19, 6.08, 6.14 ppm), while the signals of the *N*-methoxycarbonyl derivative (**3c**) are given in just a halved number with a strong broadening (*N*-$COOCH_3$ - 3.84 ppm; $COOCH_3$ - 3.50, 3.59 ppm; 2-H, 4-H, 8-H, 10-H - 5.47, 5.62 ppm). At a temperature of -10 °C **3c** exhibits the same multiplicity of signals that was found for **3b** at room temperature. Coalescence of the broadened signals was achieved at a temperature of 50 °C ($COOCH_3$ - 3.56 ppm; 2-, 4-, 8-, 10-H - 5.57 ppm). Thus it

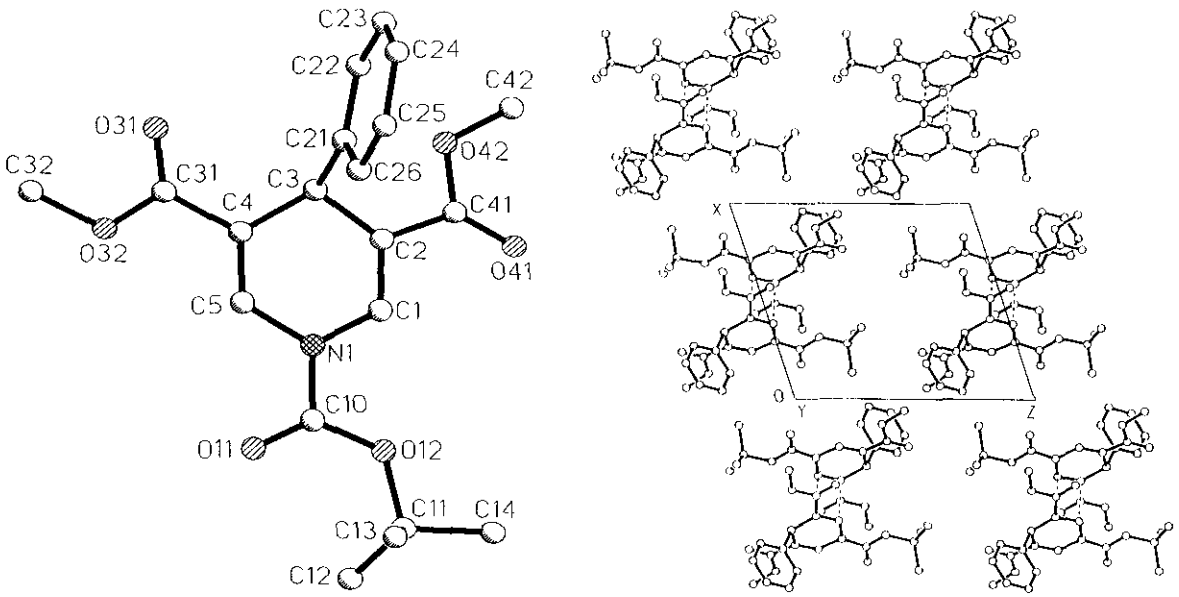


Figure 1. Molecular structure of **1e** (left) and packing scheme of **1e** (projection along [100]) with the shortest distance of neighbouring double bonds (C1···C2′ and C2···C1′; dashed lines).

was concluded that both cage dimers exist as two rotamers (**A**) and (**B**), one as a centrosymmetric rotamer (**A**) and the other one (**B**) possessing C_2-symmetry as is demonstrated below with corresponding chemical shifts attached to each structure. However, rotamers of dialkyl-substituted amide groups are well known in literature.[11]

X-Ray crystal structure analysis of centrosymmetric rotamer of **3b A** proves both phenyl-substituents diaxially orientated with respect to the 1,4-dihydropyridine ring plane in the dimers with cyclobutane bonds C1-C2 and C4-C5 (and their centrosymmetric equivalents) of a significant shorter length with 1.558(5) Å and 1.567(4) Å, respectively, as the other ones (C1-C4′, C2-C5′ and their centrosymmetric equivalents of 1.581(5) Å and 1.588(5) Å, respectively, formed by the dimerization reactions as has been reported for the *N*-alkyl cage dimers.[2]

With 1.328(4) Å the *N*-$COCH_3$ bond (N1-C6 and its centrosymmetric equivalent) proves to have double bond character compared to the CO-bond (C6-O1 and its centrosymmetric equivalent) of 1.225 (4) Å. Thus the pronounced double bond character reflects the existence of rotamers. Corresponding multiple signals due to the existence of four rotamers **A**-**D** with **A** and **B** as centrosymmetric derivatives and **C** and **D** as diastereomers is found in the spectra of the characterized *N*-methoxycarbonyl *syn*-dimer (**2c**) as well as in that of the *N*-phenyloxycarbonyl *anti*-dimer (**4d**) (see **EXPERIMENTAL**).

However, the spectra of *N*-Boc *anti*-dimer (**4e**) shows just one set of signals that may be due to the centrosymmetric structure resulting from the topochemically controlled dimerization reaction discussed above or may suggest unhindered rotability in solution. As is evident from solution dimerization reaction

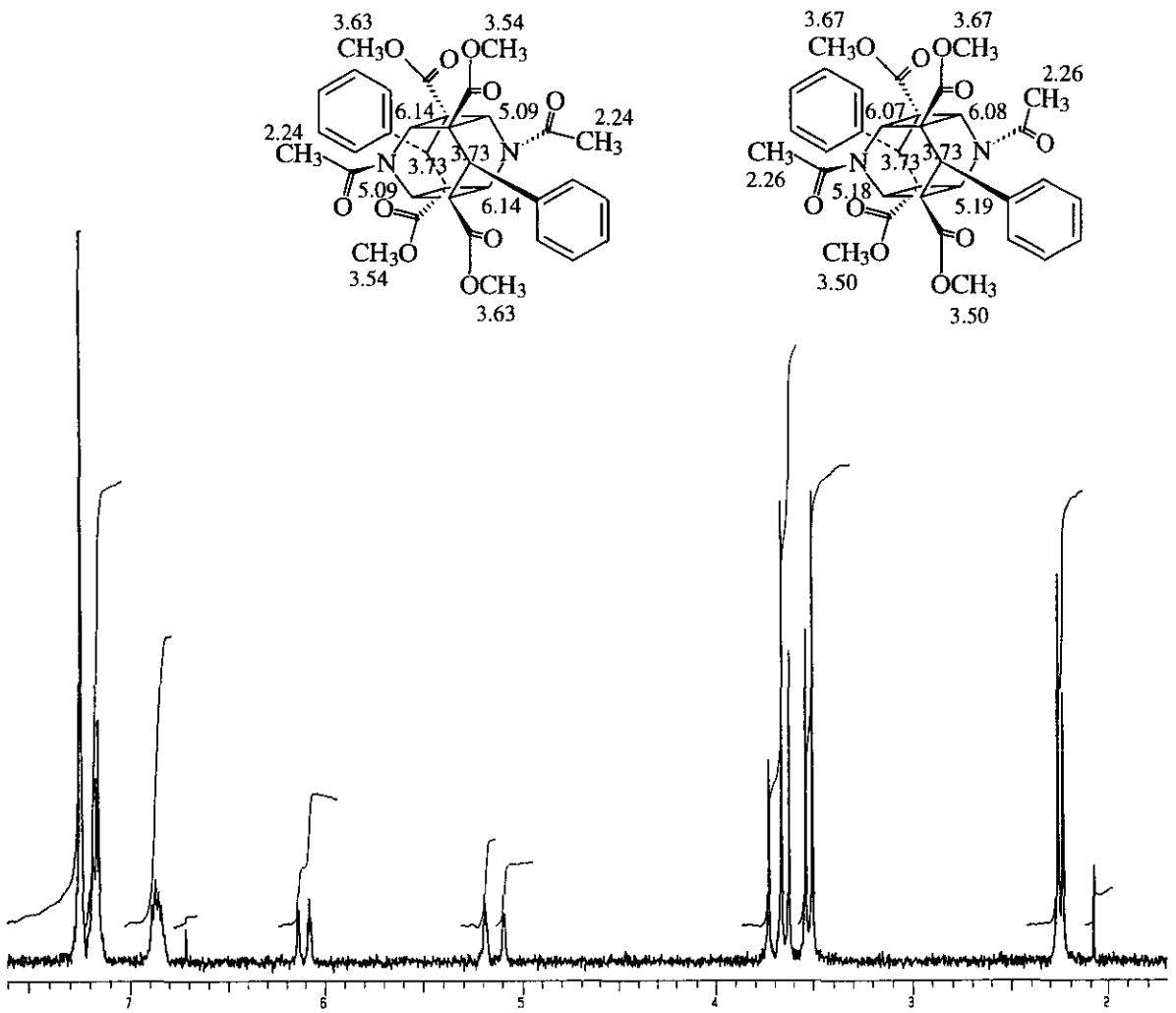


Figure 2. ^{1}H NMR spectrum of **3c** in $CDCl_3$ (200 MHz) with chemical shifts attached to the structures of centrosymmetric rotamer (**A**) and C_2-symmetric rotamer (**B**)

of the monomers (**1b-e**) that are currently investigated the spectra of **4e** are identical to those of the solid-state reaction. With a certain formation of all rotameric structures (**A-D**) of the *anti*-dimer in solution, it has to be concluded that the rotability of the *N*-Boc bond is not hindered in solution.

In summary, solid-state photodimerization of *N*-acyl- and *N*-acyloxy-substituted 3,5-dimethoxycarbonyl-4-phenyl-1,4-dihydropyridines leads to either cage-dimeric 3,9-diazatetraasteranes or novel *anti*-dimers in

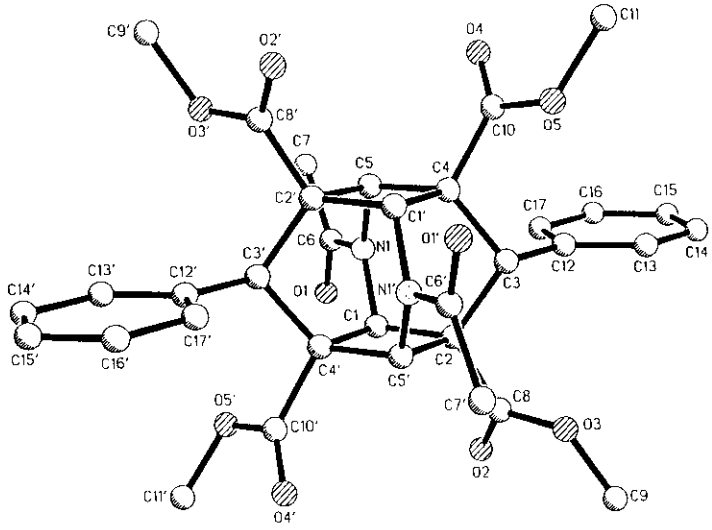


Figure 3. Molecular structure of centrosymmetric rotamer (**3c A**)

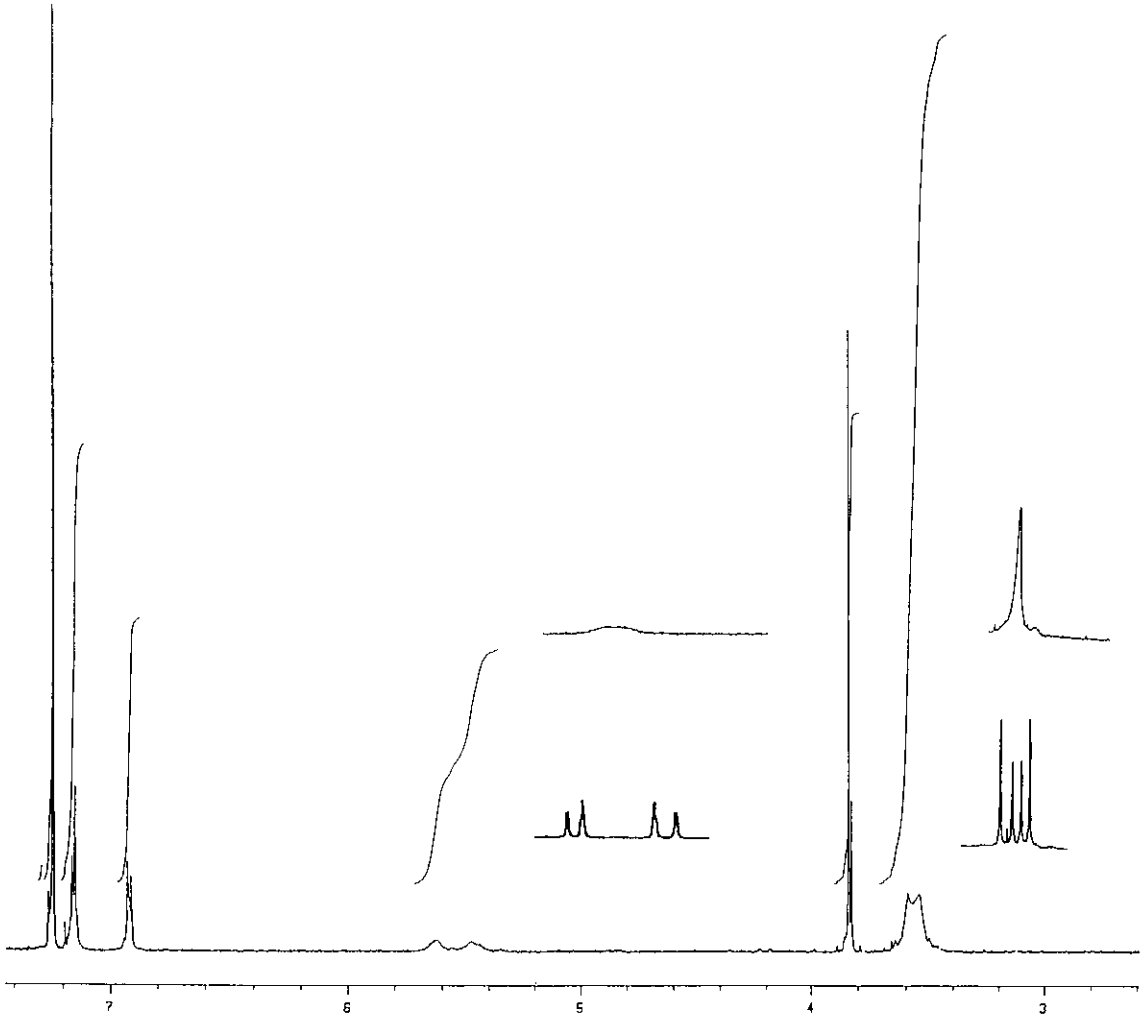


Figure 4. ^{1}H NMR Spectrum of **3d** in $CDCl_3$ (500 MHz) with signals measured at –10 °C (below) and at 50 °C (above).

a topochemically controlled reaction with excellent yields. Their rotameric properties encourage to separation efforts of the rotamers that may lead to centrosymmetric and C_2-symmetric molecules, respectively, with a potential inhibitor activity of the symmetric, dimeric HIV-1 protease.

EXPERIMENTAL

^{1}H NMR spectra were recorded with a Bruker AC-200 F, Varian Gemini-400 and Varian Gemini-500 with tetramethylsilane (TMS) as an internal standard. Chemical shifts are given on the δ scale (ppm). The following abbreviations are used: s = singlet, d = doublet, m = multiplet, sh = shoulder. MS was taken with a AMD 402 spectrometer. IR spectra were recorded on a Bruker IFS-28 spectrophotometer. UV spectra were measured with a Diode Array 8452A spectrophotometer .

N-Acylation of *N*-Unsubstituted 3,5-Dimethoxycarbonyl-4-phenyl-1,4-dihydropyridine (1a)[6]

0.27 g (1.0 mmol) of **1a** were solved in a minimum volume of DMPU. After addition of a 7-fold excess of sodium hydride suspension (80%, 0.17 g, 7 mmol) in oil that has been washed several times before addition with petroleum ether the mixture was stirred for 1 h at 50 °C. The corresponding acyl chloride (10 mmol) was added dropwise to the solution over a period of 30 min. Having stirred for an additional 1 h at 70 °C the mixture was cooled down to 0 °C and hydrolysed with portions of water. The precipitate was filtered off immediately and recrystallized from ethanol or methanol.

Dimethyl 1-Acetyl-1,4-dihydro-4-phenylpyridine-3,5-dicarboxylate (1b)

Yellow powder, mp 178-188 °C (0.281 g, 89%). IR (KBr): 1716 ($COOCH_3$), 1670 ($NCOCH_3$) cm^{-1}. MS *m/z*: 315 (M^+). UV (chloroform) λmax (log ϵ): 242 (3.32), 268 (3.70), 308 (3.10) nm. ^{1}H NMR ($CDCl_3$): 7.28-7.16 (m, 7 H, aromat. H, 2-H, 6-H), 4.90 (s, 1 H, 4-H), 3.68 (s, 6 H, $COOCH_3$) 2.49 (s, 3 H, $NCOCH_3$). *Anal.* Calcd for $C_{17}H_{17}NO_6$: C, 64.76; H, 5.40; N 4.44. Found: C, 64.43; H 5.49; N 4.27.

Dimethyl 1,4-Dihydro-1-methoxycarbonyl-4-phenylpyridine-3,5-dicarboxylate (1c)

Yellow crystals, mp 142-149 °C (0.232 g, 70%). IR (KBr): 1745 ($NCOOCH_3$), 1718 ($COOCH_3$) cm^{-1}. MS *m/z*: 331 (M^+). UV (chloroform) λmax (log ϵ): 254 (3.70), 316 (2.80) nm. ^{1}H NMR ($CDCl_3$): 8.01 (s, 2 H, 2-H, 6-H), 7.31-7.10 (m, 5 H, aromat. H), 4.85 (s, 1 H, 4-H), 3.97 (s, 3 H, $NCOOCH_3$), 3.65 (s, 6 H, $COOCH_3$).). *Anal.* Calcd for $C_{17}H_{17}NO_6$: C, 61.63; H, 5.17; N 4.23. Found: C, 61.23; H, 5.21; N, 4.22.

Dimethyl 1,4-Dihydro-4-phenyl-1-phenyloxycarbonylpyridine-3,5-dicarboxylate (1d)

Yellow powder, mp 126 °C (0.346 g, 88%). IR (KBr): 1765 (NCOOPh), 1716 ($COOCH_3$). MS *m/z*: 393 (M^+). UV (chloroform) λmax (log ϵ): 256 (4.61), 305 (3.87) nm. ^{1}H NMR ($CDCl_3$): 8.14 (s, 2 H, 2-H, 6-H), 7.47-7.15 (m, 10 H, aromat. H), 4.92 (s, 1 H, 4-H), 3.67 (s, 6 H, $COOCH_3$). *Anal.* Calcd for $C_{22}H_{15}NO_6$ x 1.5 CH_3OH: C, 63.93; H, 5.71; N, 3.20. Found: C, 63.70, H, 5.97, N, 3.60.

Dimethyl 1-*tert*-Butyloxycarbonyl-1,4-dihydro-4-phenylpyridine-3,5-dicarboxylate (1e)

0.27 g (1 mmol) of **1a** were solved in a minimum volume of DMF. To the solution 30 mL (29.6 mmol) of triethylamine (10% in DMF) were added. 0.436 g (2 mmol) of di-*tert*-butyl dicarbonate were carried into the solution. After stirring for 1 h at 60 °C the mixture was poured into ice-water, from which **1e**

precipitated as yellow powder, mp 155-160 °C (0.295 g, 79%). IR (KBr): 1738 (NBoc), 1717 ($COOCH_3$). MS *m/z*: 373 (M^+). UV (chloroform) λmax (log ϵ): 262 (4.19), 302 sh nm. ^{1}H NMR ($CDCl_3$): 7.98 (s, 2 H, 2-H, 6-H), 7.34-7.14 (m, 5 H, aromat. H), 4.85 (s, 1 H, 4-H), 3.64 (s, 6 H, $COOCH_3$), 1.51 (s, 9 H, $C(CH_3)_3$). *Anal.* Calcd for $C_{20}H_{23}NO_6$: C, 64.33; H, 6.21; N, 3.75. Found: C, 63.99; H, 6.21; N, 3.75.

X-Ray Diffraction Analysis of **1e**: A colourless crystal $C_{20}H_{23}NO_6$ (from ethanol), crystal size 0.460 x 0.293 x 0.210 mm, was measured at room temperature by using a STADI4 Diffractometer with Mo-K_α radiation (λ = 0.71073 Å) and a graphite monochromator. 11478 Reflexions were collected in ω/2Θ scanning mode in the range 4.08° ≤ 2Θ ≤ 59.94°; *h,k,l* range from –14,-22,-17 to 14, 22, 17. Crystal sytem: Monoclinic, space group $P2_1/c$, $Z = 4$, $a = 10.5362(14)$ Å, $b = 16.286(3)$ Å, $c = 12.1425(11)$ Å, $\beta = 108.592(11)°$; $V = 1974.8(5)$ Å^3; $D_x = 1.256$ g cm^{-3}; $\mu = 0.093$ mm^{-1}. The structure was solved by direct methods (SHELXS-86[12]) using 5739 independent reflections. Structure refinement: Full matrix least-squares methods on F^2 using SHELXL-93[13], all the non-hydrogen atoms with anisotropic displacement parameters. All hydrogen atoms were taken from a difference fourier synthesis and isotropically refined. The refinement converged to a final $wR^2 = 0.1573$ for 5739 unique reflections and $R^1 = 0.0653$ for 2710 observed reflections [$I_0 > 2.0\ \sigma\ (I_0)$] and 337 refined parameters.

Dimerization Reactions

1.0 g (3.17 mmol) of **1b**, 1.0 g (3.02 mmol) of **1c**, 1.0 g (2.54 mmol) of **1d** or 1.0 g (2.68 mmol) of **1e**, respectively, was irradiated with a layer thickness of 1 mm as recently described.[2] After dimerization had occurred as indicated by TLC of the mixed solid substances during a reaction time of 4 weeks, products (**2**, **3** and **4**) were dissolved in boiling tetrahydrofuran, ethanol or acetic anhydride, from which they crystallized. The following yields are based on the weight of **1** corresponding to 100% with those of **3** obtained by direct irradiation of **1**.

Tetramethyl 1,4,4a,4b,5,8,8a,8b-Octahydro-1,5-dimethoxycarbonyl-4,8-diphenylcyclobuta[1,2-*b*:3,4-*b*´]dipyridine-3,4aβ,7,8aβ-tetracarboxylate (2c)

Brownish powder, mp 238-239 °C (ethanol) (0.53 g, 53%). IR (KBr): 1739 ($NCOOCH_3$), 1727 (C4a, C8a-$COOCH_3$), 1706 (C3, C7-$COOCH_3$). ESI-MS *m/z*: 701 ($M+K^+$), 685 ($M+Na^+$). UV (chloroform) λmax (log ϵ): 240 (3.52), 268 (4.42) nm. ^{1}H NMR ($CDCl_3$): 8.07-7.89 (br s, 8 H, 2-H, 6-H of **A-D**), 7.16-6.93 (m, 40 H, aromat. H of **A-D**), 5.78-5.32 (br s, 8 H, 4b-H, 8b-H of **A-D**), 4.23-4.02 (br s, 8 H, 4-H, 8-H of **A-D**), 4.02, 3.99 (br 2 x s, 24 H, *N*-$COOCH_3$ of **A-D**), 3.68 (s, 24 H, C3, C7-$COOCH_3$ of **A-D**), 3.39 (br s, 24 H, C4a, C8a-$COOCH_3$ of **A-D**). *Anal.* Calcd for $C_{34}H_{34}N_2O_{12}$: C, 61.63; H, 5.17; N, 4.23. Found: C, 61.20; H, 5.21; N, 4.22.

Tetramethyl 3,9-Diacetyl-6,12-diphenyl-3,9-diazahexacyclo[6.4.0.0^{2,7}.0^{4,11}.0^{5,10}]dodecane-1,5,7,11-tetracarboxylate (3b)

White powder, mp 365-367 °C (acetic anhydride) (0.90 g, 90%). IR (KBr): 1732 ($COOCH_3$), 1673 ($NCOCH_3$). MS *m/z*: 630 (M^+). ^{1}H NMR ($CDCl_3$): 7.21-6.83 (m, 20 H, aromat. H of **A** and **B**), 6.14 (d,

$J_{2,8/4,10}$ = 1.8 Hz, 2 H, 2-H, 8-H of **A**), 6.08, 6.07 (2 x d, 2 x $J_{2,10/4,8}$ = 1.9 Hz, 2 H, 2-H, 10-H of **B**), 5.19, 5.18 (2 x d, 2 x $J_{4,8/2,10}$ = 1.9 Hz, 4-H, 8-H of **B**), 5.09 (d, $J_{4,10/2,8}$ = 1.8 Hz, 2 H, 4-H, 10-H of **A**), 3.73 (s, 4 H, 6-H, 12-H of **A** and **B**), 3.67 (s, 6 H, $COOCH_3$ of **B**), 3.63 (s, 6 H, $COOCH_3$ of **A**), 3.54 (s, 6 H, $COOCH_3$ of **A**), 3.50 (s, 6 H, $COOCH_3$ of **B**), 2.26 (s, 6 H, *N*$COCH_3$ of **B**), 2.24 (s, 6 H, *N*$COCH_3$ of **A**). *Anal.* Calcd for $C_{34}H_{34}N_2O_{10}$: C, 64.76; H, 5.40; N, 4.44. Found: C, 64.47; H, 5.71; N, 4.47.

X-Ray Diffraction Analysis of **3b**: A colourless crystal $C_{34}H_{34}N_2O_{10}$ (from acetic anhydride), crystal size 0.15 x 0.15 x 0.11 mm, was measured at room temperature by using a Stoe-IPDS Diffractometer with Mo-K_α radiation (λ = 0.71073 Å) and a graphite monochromator. 9078 Reflexions were collected in $\omega/2\Theta$ scanning mode in the range $5.5° \leq 2\Theta \leq 46.0°$; *h,k,l* range from –12,-14,-19 to 12, 14, 19. Crystal sytem: Monoclinic, space group $P2_1/c$, Z = 2, a = 9.313(2) Å, b = 11.245(2) Å, c = 15.070(3) Å, β = 110.62(3)°; V = 1551.2(5) Å^3; D_x = 1.350 g cm^{-3}; μ = 0.100 mm^{-1}. The structure was solved by direct methods (SHELXS-86[12]) using 2157 independent reflections. Structure refinement: Full matrix least-squares methods on F^2 using SHELXL-93[13], all the non-hydrogen atoms with anisotropic displacement parameters. All hydrogen atoms were taken from a difference fourier synthesis and isotropically refined. The refinement converged to a final wR^2 = 0.1440 for 2157 unique reflections and R^1 = 0.0563 for 1436 observed reflections [$I_0 > 2.0\ \sigma\ (I_0)$] and 276 refined parameters.

Tetramethyl 3,9-Dimethoxycarbonyl-6,12-diphenyl-3,9-diazahexacyclo[6.4.0.0^{2,7}.0^{4,11}.0^{5,10}]dodecane-1,5,7,11-tetracarboxylate (3c)

White powder, mp ~ 330 °C (sublimation) (0.89 g, 89%). IR (KBr): 1739 ($NCOOCH_3$), 1706 ($COOCH_3$). ESI-MS *m/z*: 701 ($M+K^+$), 685 ($M+Na^+$). ^{1}H NMR ($CDCl_3$): 7.19-6.91 (m, 20 H, aromat. H of **A** and **B**), 5.62 (br s, 4 H, 2-H, 8-H of **A**, 2-H, 10-H of **B**), 5.47 (br s, 4 H, 4-H, 10-H of **A**, 4-H, 8-H of **B**), 3.84 (s, 12 H, $NCOOCH_3$ of **A** and **B**), 3.83 (s, 4 H, 6-H, 12-H of **A** and **B**), 3.59, 3.50 (br 2 x s, 24 H, $COOCH_3$ of **A** and **B**). *Anal.* Calcd for $C_{34}H_{34}N_2O_{12}$: C, 61.63; H, 5.17; N, 4.23. Found: C, 61.34; H, 4.93; N, 3.98.

Tetramethyl 1,4,4a,4b,5,8,8a,8b-Octahydro-4,8-diphenyl-1,5-diphenyloxycarbonylcyclobuta[1,2-*b*:3,4-*b*´]dipyridine-3,4aα,7,8aβ-tetracarboxylate (4d)

White powder, mp 268-275 °C (ethanol) (0.91 g, 91%). IR (KBr): 1745 (NCOOPh), 1717 (C4a, C8a-$COOCH_3$), 1706 (C3, C7-$COOCH_3$). ESI-MS *m/z*: 825 ($M+K^+$), 809 ($M+Na^+$). UV (chloroform) λmax (log ϵ): 273 (4.55) nm. ^{1}H NMR ($CDCl_3$): 8.12 (s, 1 H, 2-H of **C** or 6-H of **D**), 8.11 (s, 7 H, 2-H, 6-H of **A** and **B**, 6-H of **C** or 2-H of **D**), 7.53-7.06 (m, 80 H, aromat. H of **A**-**D**), 5.62 (s, 5 H, 4b-H, 8b-H of **A** and **B**, 4b-H of **C** or 8b-H of **D**), 5.59, 5.58 (2 x s, 2 H, 4b-H of **C** or 8b-H of **D**, 8b-H of **C** or 4b-H of **D**), 5.57 (s, 1 H, 8b-H of **C** or 4b-H of **D**), 4.57 (s, 1 H, 4-H or 8-H of **C** or **D**), 4.56 (s, 6 H, 4-H, 8-H of **A** and **B**, 4-H or 8-H of **C** and **D**), 4.53 (s, 1 H, 4-H or 8-H of **C** or **D**), 3.62 (s, 3 H, C3- or C7-$COOCH_3$ of **C** or **D**), 3.61, 3.57 (2 x s, 21 H, C3, C7-$COOCH_3$ of **A** and **B**, C3- or C7-$COOCH_3$ of **C** or **D**, C3, C7-$COOCH_3$ of **C** and **D**), 3.26, 3.25, 3.23 (3 x s, 21 H, C4a, C8a-$COOCH_3$ of **A** and **B**, C4a or C8a-$COOCH_3$ of **C** or **D**, C4a, C8a-$COOCH_3$ of **C** and **D**), 3.21 (s, 3 H, C4a or C8a-$COOCH_3$ of **C** or **D**). *Anal.* Calcd for

$C_{44}H_{38}N_2O_{12}$ x CH_3OH: C, 64.93; H, 5.45; N, 3.29. Found: C, 64.92; H, 5.03; N, 3.76.

Tetramethyl 1,5-Di-*tert* butyloxycarbonyl-1,4,4a,4b,5,8,8a,8b-octahydro-4,8-diphenylcyclobuta[1,2-*b*:3,4-*b*´]dipyridine-3,4aα,7,8aβ-tetracarboxylate (4e)

White crystals, mp 254-257 °C (tetrahydrofurane) (0.89, 89%). IR (KBr): 1731 (C4a, C8a-$COOCH_3$, *N*Boc), 1710 (C3, C7-$COOCH_3$). ESI-MS *m/z*: 785 ($M+K^+$), 769 ($M+Na^+$). UV (chloroform) λmax (log ϵ): 242 (3.55), 282 (3.37) nm. ^1H NMR ($CDCl_3$): 8.02 (s, 2 H, 2-H, 6-H), 7.49-7.02 (m, 10 H, aromat. H), 5.34 (s, 2 H, 4b-H, 8b-H), 4.42 (s, 2 H, 4-H, 8-H), 3.60 (s, 6 H, C3, C7-$COOCH_3$), 3.17 (s, 6 H, C4a, C8a-$COOCH_3$), 1.73 (s, 18 H, $C(CH_3)_3$). *Anal.* Calcd for $C_{40}H_{46}N_2O_{12}$: C, 64.33; H, 6.21; N, 3.75. Found: C, 64.03; H, 6.24; N, 3.69.

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