Diastereoselective Synthesis of Diamino 1,2-Diols from Homochiral \( \alpha \)-Aminoacylsilanes

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Abstract: We have developed a new synthetic access to stereodefined diamino 1,2-diols starting from homochiral \( \alpha \)-aminoacylsilanes. A \([3+2]\) cycloaddition with benzo nitrile oxide of the vinylated adducts and a reductive ring opening constitute key steps of the reaction sequence.

Key words: \( \alpha \)-aminoacylsilanes, vinylation, dipolar cycloaddition, aminopolysilanes

Stereodefined hydroxy amino alcohols are well recognised as key components for a variety of protease inhibitors and other new generation pharmaceutics and as ligands for asymmetric catalysis.\(^1\) We recently reported\(^2\) the stereoselective synthesis of functionalized amino alcohol units and of statine analogs via three- and two-carbon elongations respectively, from \( \alpha \)-aminoacylsilanes. The use of these synthetic equivalents of aldehydes, allows to overcome\(^2\) the serious problems due to the easy racemization and avoids the special precautions necessary for the synthesis, handling and storing frequently encountered with \( \alpha \)-amino aldehydes.\(^3\) In this paper we present a new approach to the two-carbon homologation of acylsilanes based on the delivery of a vinyl unit to a carbonyl group. The reaction under study is aimed at the synthesis of stereodefined aminopolysilanes possessing the core-unit present in dihydroxypropylamine derivatives capable of highly efficient renin\(^4\) and HIV-1 protease\(^5\) inhibitions (Fig.1).

![Figure 1](image)

Our approach started with the homochiral aminoacylsilanes \( 1 \) and \( 2 \) derived from phenylalanine and isoleucine.\(^2\) Since the addition of vinylmagnesium and lithium organometallics to acylsilanes studied by Kuwajima\(^6\) gives rise to extensive amounts of silyl enol ethers along with the expected allylic alcohols, in a previous paper\(^7\) we devised a convenient new entry to silylated allylic alcohols from acylsilanes by using the magnesium to cerium transmetallation technique.

Treatment of \( 1 \) and \( 2 \) with the vinylmagnesium bromide/\( \text{CeCl}_3 \) complex, led (Scheme 1) to the formation of adducts \( 3 \) and \( 4 \) in good isolated yields and high diastereaselectivities (99% d.e.).

![Scheme 1](image)

For introducing new hydroxy and amino functionalities in the vinyl moiety we envisioned the \([3+2]\) cycloaddition with nitriloxides. Cycloadditions of this type are usually regarded as mildly electrophilic in character. Therefore (\( \alpha \)-hydroxyallyl)silanes in which the preferred location of allylic substituents maximizes\(^9\) electron donation should, as shown by Curran,\(^10\) as efficient dipolarophiles. When \( 3 \) and \( 4 \) were reacted with the in situ prepared benzo nitrile oxide, isoxazolines \( 5 \) and \( 6 \) were obtained in 70% and 55% yields. In contrast with the modest diastereomeric excess (20%) observed in the case of \( 5 \), only one diastereoisomer (99% d.e.) could be detected and isolated in the case of \( 6 \). The diastereomeric couple \( 5a,b \) could be...
separated by column chromatography on silica gel and characterized.\textsuperscript{11}

The subsequent desilylation of the \( \alpha \)-hydroxyethyl cyanoacetate carried out on a model compound, was disappointing. Under the action of bases the \( \beta \)-elimination of silanol led to ring opening with generation of an enolic form which upon rearrangement resulted in the formation of the desilylated hydroxylamino derivative 7 (Scheme 3).

Scheme 3

To prevent the occurrence of the above mentioned Peterson elimination reaction from the \( \beta \)-hydroxyethylcyanoacetate moiety\textsuperscript{12} in the presence of strong base reagents, isoazolines 5a, the major diastereoisomer, and 6 were subjected to an oxidative desilylation. This reaction, although already reported in the literature,\textsuperscript{13} has been however scarcely investigated. Since the oxidation with pyridinium dichromate (PDC) has found an useful and high yielding technique\textsuperscript{13b} we applied this procedure to the desilylation of 5a and 6. Upon treatment with PDC at room temperature, these compounds underwent (Scheme 4) smooth desilylative oxidation to give 8 and 9 in high yields and virtually diastereomerically pure.\textsuperscript{14}

Scheme 4

The reductive ring opening of the oxazolidine ring aimed at the formation of the new hydroxy and amino functionalities was then performed. To avoid reaction conditions able to promote an acidic proton abstraction, we exploited the use of NaBH\textsubscript{4} in methanol in the presence of NiCl\textsubscript{2}\cdot6H\textsubscript{2}O. Exposure of 8 and 9 to this reagent at \(-30^\circ\text{C}\) according to the literature\textsuperscript{15} led to heterocyclic ring opening and reduction of the carbonyl function and afforded after 65 h, the expected aminopolys. These were directly converted to the corresponding bis-Boc derivatives: in both cases one diastereoisomer was found to largely prevail which was isolated by column chromatography and characterized.\textsuperscript{16} By this procedure N-Boc protected aminopolys 10 and 11 are produced in 35% and 30% overall yields in three steps from oxazolines 5a and 6 respectively. Connectivity of diamin 1,2-diol 10 and 11 was achieved by homonuclear and heteronuclear correlation. The stereochemical assignment of the three unknown stereogenic centers of 11 was attempted on the basis of 2D-

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References and Notes

(8) 3: Yellowish oil: [\( \alpha \)]\textsubscript{D}\textsuperscript{20} = 49.3 (c = 2.0, CHCl\textsubscript{3}); \( ^{1}H\) NMR (200 MHz, CDCl\textsubscript{3}) \( \delta \) 0.38 (s, 3H, Si-CH\textsubscript{3}); (3H, Si-CH\textsubscript{3}); 1.24 (s, 3H, C(CH\textsubscript{3})\textsubscript{3}); 1.46 (s, 1H, OH), 2.54 (dd, 1H, \( J = 13.6, 10.4\) Hz, CH\textsubscript{2}-Ph), 2.90 (dd, 1H, \( J = 13.6, 3.6\) Hz, CH\textsubscript{2}-Ph).
Let us consider the following discussion:

For discussions of such electronic effects of allylic substituents, see: (a) Eyer, M.; Seebach, D. Tetrahedron 1988, 44, 3945.

(11) **Representative procedure**: preparation of (5a-b):

Triethylamine (0.27 mL, 1.90 mmol) and 3 (600 mg, 1.52 mmol) were dissolved in Et₂O (15 mL). To this solution benzhydroxysomyl chloride (300 mg, 1.90 mmol) in Et₂O (10 mL) was slowly added (3.5 h) through a funnel. After the addition was completed the reaction was stirred for 48 h. The solvent was evaporated and the crude was purified by column chromatography on silica gel (petroleum ether : Et₂O : 3:1).

affording a 560 mg (70%) of two diastereoisomers in the ratio 60:40. **Major diastereoisomer** (5a): R₁ = 0.042 cm (petroleum ether : Et₂O : 3:1). \([\alpha]_D^{20} = +23.65 \text{ (c = 4.0, CHCl₃)}\); **Minor diastereoisomer** (5b): R₂ = 0.011 cm (petroleum ether : Et₂O : 3:1). \([\alpha]_D^{20} = -107.63 \text{ (c = 4.0, CHCl₃)}\); **1H NMR** (300 MHz, CDCl₃) δ: -4.97, -4.34, 11.40, 17.94, 23.50, 28.34, 36.93, 59.68. 76.39, 78.78, 110.60, 127.67, 129.28, 134.60, 141.25, 156.05.

**Figure 2**: The two alternative structures of 11 obtained on the basis of 2D-NOESY constraints. (oxygens are represented as black, nitrogens as grid)
Representative procedure: Preparation of 8: To a solution of 5a (503 mg, 0.77 mmol) in DMF (20 mL) pyridinium dichromate (PDC) (1.74 g, 4.36 mmol) was added under Ar and the mixture was stirred for 18 h. The reaction was quenched with water, the aqueous phase extracted twice with ethyl acetate, and the organic phases were combined, washed twice with water and dried over MgSO4, evaporated and to the residue 25 mL of conc. NH4OH were filtered and the solvent evaporated giving 1H NMR (200 MHz, CDCl3) δ: 0.15-0.20 (m, 2H, CH2OH), 0.6-0.80 (2S, 6H, CH2CH2CH2CH), 1.00-1.10 (m, 1H, CH2), 1.30-1.55 (m, 19H, 2Me2C, CH2CHPh), 1.85-1.95 (m, 1H, CH2CH), 1.95-2.00 (m, 1H, 2CH2CH2), 3.35-3.45 (m, 1H, CH2CH2CH2), 3.76 (dd, 1H, J = 11.2, 6.0 Hz, CH-O), 4.51 (dd, 1H, J = 8.7 Hz, NH), 5.10 (d, 1H, J = 8.7 Hz, NH), 5.15-5.30 (m, 1H, Ar-H); 13C NMR (200 MHz, CDCl3) δ: 28.18, 36.28, 38.84, 58.04, 80.22, 83.15, 126.93, 136.35, 155.35, 156.90, 203.69. (HRMS (EI): m/z found: 496.2749 C28H40N2O4Si requires 496.2757.

Preparation of 11: Crystal Data of 11: C52H36N6O4 (466.61), Orthorhombic, Space group P212121. 2D NOEY spectra were recorded using mixing times of 1.5 s and 2.0 s. Conformational search was performed with PC-Spartan Pro v1.0.5, using the MMFF force field, and then the conformational minima were refined using PC-Model V7.5 and the MMX force field.

Representative procedure: Preparation of 10: To a solution of 8 (297 mg, 0.75 mmol) in methanol (19.3 mL) stirred under Ar, NiCl2·6H2O (750 mg, 3.1 mmol) was added. The temperature was lowered to 30 °C and NaBH4 (290 mg, 7.7 mmol) was added in three portions. The reaction mixture was stirred at 30 °C for 65 h in a cryostat, the solvent was evaporated and to the residue 25 mL of conc. NH4OH was added. The aqueous phase was extracted twice with CH2Cl2 and the combined organic phases were dried over MgSO4, filtered and the solvent evaporated under vacuum. The crude, without any further purification, di-tert-butyl dicarbonate (188 mg, 0.86 mmol) and triethylamine (0.13 mL, 0.99 mmol) were sequentially dissolved in methanol (16 mL). The reaction mixture was stirred under Ar 4 days at room temperature. The solvent was evaporated and the crude purified by column chromatography over silica gel (petroleum ether: Et3O/1:1) giving 1.34 mg of the largely prevailing diastereoisomer 10 as a white solid (overall yield for three steps 35%). 10: mp 200-203 °C; [α]D20 = -13.3 (c = 1.5, CHCl3); 1H NMR (200 MHz, CDCl3) δ: 1.20 (s, 9H, CH3(CH3)), 1.35 (s, 9H, C(CH3)3), 1.70 (bs, 1H, OH), 2.10 (bs, 1H, OH), 1.40-1.50 (m, 2H, CH2PhCH2), 2.40-2.50 (m, 2H, PhCH2), 3.10 (d, 1H, J = 9.9 Hz, CHPhCHOH), 3.60-3.65 (m, 1H, PhCH2CH2), 3.70-3.75 (m, 1H, PhCH2CH2), 4.55-4.60 (m, 1H, PhCH2CH2CHOH), 4.90-5.00 (m, 1H, PhCH2NH), 5.10 (d, 1H, J = 10.1 Hz, PhCHNH), 7.00-7.40 (m, ArH, 10H); 13C NMR (50.3 MHz, CDCl3) δ: 28.33, 28.46, 36.68, 39.08, 52.14, 53.04, 67.11, 75.26, 77.79, 79.64, 127.73-129.53, 137.68, 142.06, 156.05, 156.76. (HRMS (EI): m/z found: 500.2894 C28H30N2O5 requires 500.2886.

11: White solid; 30% overall yield for three reaction steps. M.p. 184-186 °C; [α]D20 = -11.46 (c = 3.0, CHCl3); 1H NMR (200 MHz, CDCl3) δ: 0.15-0.20 (m, 1H, CH2OH), 0.60-0.80 (2S, 6H, CH2CH2CH2CH), 1.00-1.10 (m, 1H, CH2), 1.30-1.55 (m, 19H, 2Me2C, CH2CHPh), 1.85-1.95 (m, 1H, CH2CH), 1.95-2.00 (m, 1H), 2CH2CH2), 3.35-3.45 (m, 1H, CH2CH2CH2), 3.76 (dd, 1H, J = 11.2, 6.0 Hz, CH-O), 4.51 (dd, 1H, J = 8.7 Hz, NH), 5.10 (d, 1H, J = 8.7 Hz, NH), 5.15-5.30 (m, 1H, Ar-H); 13C NMR (200 MHz, CDCl3) δ: 28.25, 36.65, 38.84, 58.04, 80.22, 83.15, 126.93, 136.35, 155.35, 156.90, 203.69. (HRMS (EI): m/z found: 466.3052 C23H22N2O4 requires 466.3043.

NMR spectra were recorded at 400 MHz in CD3OD. Homonuclear correlations were obtained by the gCOSY sequence. Heteronuclear correlations were obtained by edited-gHSQC sequence. 2D NOESY spectra were recorded using mixing times of 1.5 s and 2.0 s. Conformational search was performed with PC-Spartan Pro v1.0.5, using the MMFF force field, and then the conformational minima were refined using PC-Model V7.5 and the MMX force field.

Crystal Data of 11: C52H36N6O4 (466.61), Orthorhombic, Space group P212121. Z = 4, a = 10.8904(6), b = 11.2626(6), c = 22.5995(12) Å, V = 2771.9(3) Å3, Dc = 1.118 g cm−3 F(000) = 1016. µcalcd = 0.079 cm−1, T = 298 K. Data were collected using a graphite monochromated Mo-Kα X-radiation (λ = 0.71073 Å) in the range 3.25° < ϡ < 30.00°. Of 31346 reflections measured, 8104 were found to be independent (Rint = 0.0847), 3670 of which were considered as observed [Fobs > 4σ(Fobs)]. The structure was solved by direct method and refined by full-matrix least squares on F2, using SHELXTL 97 program packages. In refinements were used weights according to the scheme w = [σ2(Fo)+0.0085P(Fo)+0.00000P2]1/2 where P = (Fo)2+2(Fo)2/3. The hydrogen atoms were located by geometrical calculations and refined using a "riding" method; wR2 was equal to 0.1447. The other atoms were anisotropically refined except the two t-butyl groups that were disordered and so split into two position and isotropically refined. The goodness of fit parameters S was 0.846. The largest difference between peak and hole was 0.572 and 0.272 e Å−3. Crystallographic data (excluding structure factors and including selected torsion angles) have been deposited with the Cambridge Crystallographic Data Center. CCDC-160358.