Diastereoselective Addition of Allyl Reagents to Variously *N*-Monoprotected and *N*,*N*-Diprotected L-Alaninals

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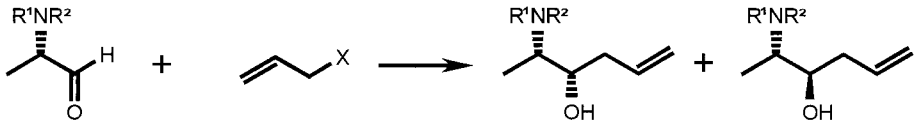
Diastereoselective C_3-elongation processes of *N*-Boc-, *N*-Z-, *N*-Bn-*N*-Boc-, and *N*-Bn-*N*-Z-L-alaninals (Boc = ^{t}BuOCO, Z = $PhCH_2OCO$, Bn = $PhCH_2$) using various allyl reagents, such as allyl bromide in the presence of Zn/aqueous NH_4Cl solution, of $SnCl_2 \cdot 2H_2O$/NaI or of Mg/$CuCl_2 \cdot 2H_2O$, as well as allyltrichlorosilane, are described. A substantially different influence of the *N*-protecting groups replacing either one or two amino protons was observed, allowing the selective synthesis of either the *syn*- or *anti*-diastereoisomer as a major product.

1. Introduction. – Many natural products have been synthesized starting from chiral α-aminocarbaldehydes [1]. The most straightforward and commonly encountered process is the addition of various types of nucleophiles to these important building blocks [1][2]. Among them, allylation of aldehydes to homoallylic alcohols is an important synthetic pathway to aminodeoxysugars, which are components of naturally occurring antibiotics [3]. Furthermore, the homoallylic adducts provide access to hydroxyethylene peptide isosteres which could play a role as potent inhibitors of proteolytic enzymes [4]. Among various types of additions, the *Barbier*-type reaction has recently become very popular [5]. The use of aqueous media for the *Barbier* reaction offers some considerable advantages: the direct use of H_2O-soluble compounds without derivatization and the general avoidance of anhydrous solvents allow for an easier and environmentally friendlier synthesis than experienced with traditional methods. Asymmetric chain elongation of the α-aminocarbaldehyde group can favor *syn*- or *anti*-diastereoselectivity depending on the effects of the protective group at the α-amino functionality, allylation method, solvent, *etc*. So far, *Giannis et al.* [6] showed that the reaction of *N*-monoprotected serinals with allyl halides proceeds smoothly to give the desired homoallylic alcohols in moderate yields as a mixture of *syn*- and *anti*-diastereoisomers. The stereochemical course of the reaction in aqueous medium is similar to that in organic solvents.

Recently, we reported on the diastereoselective C_3-elongation of *N*-tosyl- and *N*-benzyl-*N*-tosyl-L-alaninal by means of various allyl reagents under different reaction conditions [7]. A large difference of the influence of the *N*-protecting groups replacing either one or two amino protons on all C_3- and C_4-elongation processes was observed. In the case of the addition to *N*-tosyl-L-alaninal, we obtained a good *syn*-diastereoselectivity (3:1) but a very poor yield (only 20%). With the diprotected *N*-benzyl-*N*-tosyl-L-alaninal, the direction of asymmetric induction was reversed, which was explained by substantial changes in the nature of the amino group, varying from

chelating to sterically demanding. In many cases, the tosyl protection is difficult to remove when mild conditions are required. The reaction with the *N*,*N*-diprotected L-alaninal afforded both a moderate diastereoselectivity and a moderate chemical yield. Thus, we considered it very important and interesting, especially from the synthetic point of view, to extend our studies to other types of variously *N*-protected α-aminocarbaldehydes with the intention to improve the diastereoselectivity. For this purpose, we decided to study the addition reactions of the two allyl reagents **2a** and **2b** to the *N*,*N*-diprotected and *N*-monoprotected L-alaninals **1a**–**d** (*Scheme 1*).

Scheme 1



1a R^1 = Bn, R^2 = Boc
1b R^1 = Bn, R^2 = Z
1c R^1 = H, R^2 = Boc
1d R^1 = H, R^2 = Z

2a X = Br
2b x = $SiCl_3$

3a R^1 = Bn, R^2 = Boc
3b R^1 = Bn, R^2 = Z
3c R^1 = H, R^2 = Boc
3d R^1 = H, R^2 = Z

4a R^1 = Bn, R^2 = Boc
4b R^1 = Bn, R^2 = Z
4c R^1 = H, R^2 = Boc
4d R^1 = H, R^2 = Z

All L-alaninals **1a**–**d** were obtained from the respective α-amino alcohols using the TEMPO (2,2,6,6-tetramethylpiperidin-1-yloxy radical) oxidation method [8]. In all reactions shown in *Scheme 1*, *syn*/*anti*-mixtures of the diastereoisomeric products **3** and **4**, respectively, were obtained (throughout this paper, we use the *syn*/*anti* notation as proposed by *Masamune* and co-workers [9]).

2. Results and Discussion. – 2.1. *C_3-Elongation of the* N,N-*Diprotected* L-*Alaninals* **1a** *and* **1b**. We chose for these studies *N*-Bn-*N*-Boc and *N*-Bn-*N*-Z protections of the amino group (Bn = $PhCH_2$, Boc = ^{t}BuOCO, Z = $PhCH_2OCO$). On addition of allyl bromide **2a** to the *N*,*N*-diprotected aldehydes **1a** and **1b**, a high (*Table*, *Entries 1*, *2*, *5*, and *7*) or very high (*Entries 3* and *6*) *anti*-diastereoselectivity was observed. Yields were generally also very high, except in the case of the addition of **2a** performed in the presence of magnesium and copper(II) chloride hydrate [10] (*Entries 3* and *7*).

Table. *Addition of Various Allyl Reagents* **2** *to* N-*Mono- and* N,N-*Diprotected* L-*Alaninals* **1a**–**d**

Entry	Aldehyde	Allyl reagent	Modifying additives	Solvent	Temp.	Time [h]	Yield [%]	Ratio *syn*/*anti*
1	**1a**	**2a**	Zn/aq. NH_4Cl soln.	THF	r.t.	3.5	99	**3a**/**4a** 20 : 80
2	**1a**	**2a**	$SnCl_2 \cdot 2H_2O$/NaI	THF	r.t.	2.5	82	**3a**/**4a** 16 : 84
3	**1a**	**2a**	Mg/$CuCl_2 \cdot 2H_2O$	DMF	r.t.	20	11	**3a**/**4a** 5 : 95
4	**1a**	**2b**	–	DMF	0°	2	29	**3a**/**4a** 5 : 95
5	**1b**	**2a**	Zn/aq. NH_4Cl soln.	THF	r.t.	3	99	**3b**/**4b** 10 : 90
6	**1b**	**2a**	$SnCl_2 \cdot 2H_2O$/NaI	DMF	r.t.	1	90	**3b**/**4b** 5 : 95
7	**1b**	**2a**	Mg/$CuCl_2 \cdot 2H_2O$	THF	r.t.	20	30	**3b**/**4b** 10 : 90
8	**1b**	**2b**	–	DMF	0°	5	72	**3b**/**4b** 5 : 95
9	**1c**	**2a**	Mg/$CuCl_2 \cdot 2H_2O$	THF	r.t.	22	65	**3c**/**4c** 37 : 63
10	**1c**	**2b**	–	DMF	0°	2	90	**3c**/**4c** 75 : 25
11	**1d**	**2a**	Mg/$CuCl_2 \cdot 2H_2O$	THF	r.t.	24	53	**3d**/**4d** 40 : 60
12	**1d**	**2b**	–	DMF	0°	2	87	**3d**/**4d** 75 : 25

Addition of allyltrichlorosilane (**2b**) [11] to *N*,*N*-diprotected L-alaninals **1a** and **1b** gave very interesting results, *i.e.*, almost exclusively *anti*-adducts **4a** and **4b** were obtained (*Entries 4* and *8*). With *N*-Bn-*N*-Boc-L-alaninal **1a**, the yield was very low. It seems most likely that this aldehyde is not stable enough under the reaction conditions; we did not isolate any unreacted **1a**. Thus, the use of the Boc or Z instead of the tosyl protection causes the improvement of the *anti*-diastereoselectivity from 77:23 to 95:5 [7]. In summary, we can obtain *anti*-adducts with very high diastereoselection and in very good yield using allyltrichlorosilane (**2b**) or allyl bromide (**2a**) in the presence of tin(II) chloride dihydrate.

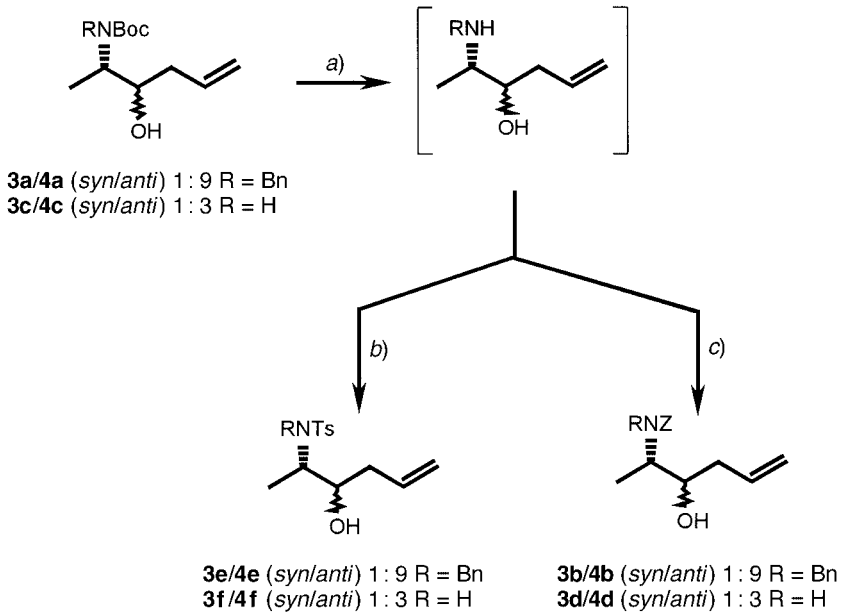
2.2. *C_3-Elongation of* N-*Monoprotected α-Aminocarbaldehydes* **1c** *and* **1d**. Simple addition of allylmagnesium chloride or of allylzinc reagent to *N*-Boc- or *N*-Z-L-alaninals **1c** and **1d**, respectively, resulted in a moderate yield and low *syn*-diastereoselectivity, in agreement with literature data [12]. Thus, we turned our attention to the *Barbier*-type reaction [13]. Addition of allyl bromide (**2a**) in the presence of aqueous ammonium chloride [6][13] or of tin(II) chloride dihydrate and sodium iodide [14] to aldehydes **1c** and **1d** led to better yields than in the case of addition to the *N*-Ts-L-alaninal, but unfortunately, we did not observe any diastereoselectivity. When we used magnesium in the presence of copper(II) chloride hydrate [10] instead of zinc or tin(II) chloride, addition of **2a** to *N*-monoprotected L-alaninals **1c** and **1d** gave mixtures of diastereoisomers with moderate *anti*-diastereoselectivity (*Table*, *Entries 9* and *11*). Aiming at finding a more selective allylation of *N*-monoprotected L-alaninals **1c** and **1d**, we decided to try allyltrichlorosilane (**2b**) as reagent. We observed the same level of diastereoselectivity (3:1) as for the addition to *N*-Ts-L-alaninal, but the yield was much better (*Entries 10* and *12*). In summary, we can selectively obtain either the *syn*- or the *anti*-diastereoisomer as a major product. With allyl bromide (**2a**) in the presence of magnesium and copper(II) chloride hydrate as an allylation reagent, pronounced *anti*-diastereoselectivity was observed, whereas in the case of addition of allyltrichlorosilane (**2b**), *syn*-diastereoselectivity (3:1) was observed.

2.3. *Determination of the Diastereoisomer Ratio* **3**/**4** (*syn*/*anti*). For the *N*,*N*-diprotected products **3a** and **3b** as well as **4a** and **4b**, the determination of the *syn*/*anti* ratio was based on the integration of the separated signals derived from one of the diastereotopic protons at the double bond. The thus-established ratios were confirmed by analytical HPLC (*LiChrospher-100*-NH_2). In the case of the *N*-monoprotected diastereoisomeric adducts **3c** and **3d** as well as **4c** and **4d**, the *syn*/*anti* pairs were unseparable by any chromatographic method. Determination of the *syn*/*anti* ratio was, therefore, based on their ^{1}H-NMR spectra, *i.e.*, on the integration of the Me signals.

2.4. *Chemical Correlations.* Having determined the extent of asymmetric induction, we studied its direction by establishing the configuration of the products. In both cases of *N*,*N*-diprotected and *N*-monoprotected adducts **3** and **4**, we used the method of chemical correlations as shown in *Scheme 2*, because the *anti*-configuration of adduct **4e** and the *syn*-configuration of adduct **3f** are known from X-ray studies [7]. The *syn*/*anti* mixture of adducts **3a** and **4a** (1:9) was transformed into the mixture **3e**/**4e** in which the *anti*-N-Bn-N-Ts-adduct **4e** was the major diastereoisomer, thus establishing that the adduct **4a** possesses *anti*-configuration. The same mixture **3a**/**4a** (1:9) was then transformed into the mixutre **3b**/**4b** with preserved level of diastereoselectivity (1:9);

hence, the adduct **4b** has the *anti*-configuration. Similar correlations were carried out for the *N*-monoprotected products **3c**/**4c** as well as for **3d**/**4d** (*Scheme 2*). Thus, on addition of allyltrichlorosilane (**2b**) to the *N*-monoprotected aldehydes **1c** and **1d**, the *syn*-diastereoisomer was formed as the major one.

Scheme 2



a) CF_3COOH, CH_2Cl_2, r.t. *b*) TsCl, Et_3N, CH_2Cl_2, 0° → r.t. *c*) $PhCH_2OCOCl$ (= ZCl), $NaHCO_3$, AcOEt, 0°.

2.5. *Stereochemical Course of the Additions.* For all additions with *N*-monoprotected L-alaninals, diastereoselectivity is independent of the protecting group used, but it depends on the method applied. Direction of the asymmetric induction can be explained by three transition states **A**, **B**, or **C**, as shown in the *Fig*.

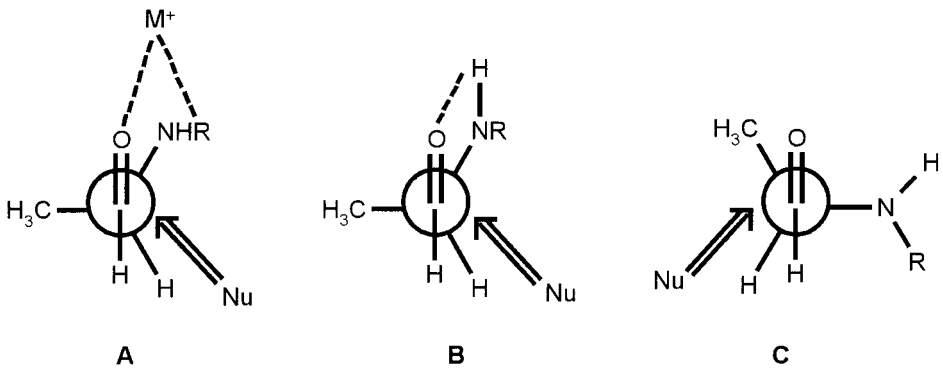


Figure. *Possible transition states for the nucleophilic addition*

Attack by allyl reagents occurs from the less-hindered side of the chelation-controlled cyclic *Cram* [15] model **A** or **B**, formed as a consequence of the H-bonding between NH and the carbonyl group, giving the *syn*-amino alcohols **3c** and **3d**. But in the *Felkin-Anh* [16] model **C**, this attack leads to *anti* amino alcohols **4c** and **4d**. In agreement with this commonly accepted stereochemical model, addition of allylmagnesium chloride to aldehydes **1c** and **1d** led to *syn*-adducts according to the cyclic transition states **A** or **B**. But in the case of addition of allylzinc bromide or allyl bromide in the presence of magnesium and copper(II) chloride hydrate, the *Felkin-Anh* model **C** should operate because we observed *anti*-diastereoselection. In the case of the *N*-monoprotected α-aminocarbaldehydes **1c** and **1d**, addition of the allyl reagents led to *syn*-adducts, according to the cyclic transition state formed as a consequence of the H-bonding between NH and the carbonyl group or to the similar chelation-controlled cyclic *Cram* model **B**. In the case of the addition to *N*,*N*-diprotected L-alaninals **1a** and **1b**, leading preferentially to *anti*-adducts **4a** and **4b**, the *Felkin-Anh* model should operate.

3. Conclusion. – Along with previous results from this laboratory concerning the influence of *N*-mono- and *N*,*N*-diprotection on the stereochemical course of cycloaddition, the present results establish the rationale for planning diastereoselective syntheses that involve C_3-elongation processes. The results obtained appear to yield key information for further studies on asymmetric syntheses involving α-aminocarbaldehydes and for a better knowledge of the rules governing the stereochemical course of organometal addition to chiral α-aminocarbaldehydes.

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Experimental Part

General. Flash column chromatography (FC): silica gel *60* (*Merck*, 200–400 mesh). M.p.: *Kofler* hot-stage apparatus; uncorrected. Optical rotations: *JASCO-DIP-360* polarimeter with a thermally jacketed 10-cm cell. IR Spectra: *Perkin-Elmer-1640-FTIR* spectrophotometer NMR Spectra: *Bruker-AM-500* spectrometer at 500 (^{1}H) or 125 MHz (^{13}C); chemical shifts δ in ppm rel. to $SiMe_4$ (= 0.00 ppm), and coupling constants *J* in Hz. Mass spectra: *AMD-604-Intectra* instrument using the electron-impact (EI) technique; *m*/*z* (rel. %).

Addition of Allyl Reagents **2** *to Protected* α*-Aminocarbaldehydes* **1**. *Method A: Addition of Allyl Bromide* (**2a**) *in the Presence of Zn/NH*$_4$*Cl.* Allyl bromide (**2a**; 2 mmol) was added dropwise at r.t. to the stirred suspension of Zn powder (2 equiv.), the α-aminocarbaldehyde (1 mmol), sat. aq. NH_4Cl soln. (0.5 ml), and THF (10 ml). After stirring at r.t. for several hours (TLC monitoring), the mixture was extracted with Et_2O (2 × 10 ml), the combined extract dried ($MgSO_4$) and evaporated, and the residue worked up as described in [7].

Method B: Addition of *Allyl Bromide* (**2a**) *in the Presence of SnCl*$_2 \cdot 2\,H_2O$*/NaI*. To a stirred soln. of the α-aminocarbaldehyde (1 mmol) and allyl bromide (**2a**; 1.5 mmol) in DMF (10 ml), $SnCl_2 \cdot 2\,H_2O$ (1.5 mmol) was added, followed by NaI (1.5 mmol). After stirring for several hours (TLC monitoring), a sat. aq. NH_4F soln. (10 ml) and Et_2O (10 ml) were added. The aq. layer was separated and re-extracted with Et_2O (2 × 10 ml) and the combined extract worked up as described in *Method A*.

Method C: Addition of Allyl Bromide (**2a**) *in the Presence of Mg/CuCl*$_2 \cdot 2\,H_2O$. Allyl bromide (**2a**; 2.5 mmol) was added dropwise at r.t. under Ar to a stirred suspension of Mg powder (2.5 equiv.), $CuCl_2 \cdot 2\,H_2O$ (2.5 mmol), the α-aminocarbaldehyde (1 mmol), and THF (5 ml). The mixture was stirred for several hours (TLC monitoring). Then it was quenched with 1N HCl and extracted with Et_2O (3 × 10 ml). The combined extracts were worked up as described in *Method A*.

Method D: Addition of Allyltrichlorosilane (**2b**). A soln. of the α-aminocarbaldehyde (1 mmol) and allyltrichlorosilane (**2b**; 1.2 mmol) in DMF (6 ml) was stirred at 0° for several hours (TLC monitoring). Then it

was quenched with sat. aq. NH_4Cl soln. (10 ml) and extracted with Et_2O (3×10 ml). The combined extracts were worked up as described in *Method A*.

*(2S,3S)- and (2S,3R)-2-{Benzyl[(*tert*-butoxy)carbonyl]amino}hex-5-en-3-ol* (**3a** and **4a**, resp.; **3a**/**4a** 1:4). IR (film): 3440, 2977, 2933, 1689, 1667, 1453, 1409, 1366, 1248, 1167, 1015, 913, 701. ^{1}H-NMR ((D$_8$)toluene, 90°): 7.3–7.0 (*m*, 5 arom. H); 5.88 (*ddt*, *J* = 16.9, 10.5, 6.9, 0.2 H, C*H*CH$_2$); 5.69 (*ddt*, *J* = 17.1, 10.3, 6.9, 0.8 H, C*H*CH$_2$); 5.02 (*m*, 0.2 H, CHC*H*$_2$); 5.0–4.9 (*m*, 0.8 H, CHC*H*$_2$); 4.45 (*m*, 0.2 H, C*H*$_2$Ar); 4.4–4.2 (*m*, 1.8 H, C*H*$_2$Ar); 3.80 (*m*, 0.8 H, CHN); 3.70 (*m*, 0.2 H, CHN); 3.59 (*m*, 0.2 H, C*H*OH); 3.52 (*ddt*, *J* = 6.9, 4.2, 6.9, 0.8 H, C*H*OH); 2.20 (*m*, 0.2 H, CH$_2$(All)); 2.1–2.0 (*m*, 1.8 H, CH$_2$(All)); 1.38 (*s*, 7.2 H, ^{t}Bu); 1.37 (*s*, 1.8 H, ^{t}Bu); 1.18 (*d*, *J* = 7.0, 2.4 H, Me); 1.06 (*d*, *J* = 7.0, 0.6 H, Me). ^{13}C-NMR ((D$_8$)toluene, 90°): 156.9; 156.5; 140.5; 140.2; 135.9; 135.8; 128.7; 128.6; 128.0; 127.9; 127.3; 127.2; 117.0; 116.9; 80.1; 80.0; 74.4; 74.0; 65.9; 58.8; 58.5; 51.6; 51.1; 40.2; 39.9; 28.6; 28.5; 15.8; 15.5. EI-MS: 305 (0.3, M^+), 234 (29), 208 (4), 178 (92), 134 (82), 91 (100), 57 (47). HR-EI-MS: 305.21008 ($C_{18}H_{27}NO_3^+$, M^+, calc. 305.1991). Anal. calc. for $C_{18}H_{27}NO_3$ (305.2): C 70.8, H 8.9, N 4.6; found: C 70.6, H 8.9, N 4.6.

(2S,3S)- and (2S,3R)-2-{Benzyl[(benzyloxy)carbonyl]amino}hex-5-en-3-ol (**3b** and **4b**, resp.; **3b**/**4b** 1:4). IR (film): 3443, 2977, 1692, 1678, 1453, 1415, 1330, 1244, 1211, 1027, 915, 733, 698. ^{1}H-NMR ((D$_8$)toluene, 90°): 7.2–7.0 (*m*, 10 arom. H.); 5.9–5.8 (*m*, 0.2 H, C*H*CH$_2$); 5.7–5.6 (*m*, 0.8 H, C*H*CH$_2$); 5.09, 5.06 (*AB*, *J* = 12.4, 1 H each, OC*H*$_2$Ar); 4.99 (*m*, 0.4 H, CHC*H*$_2$); 5.0–4.9 (*m*, 1.6 H, CHC*H*$_2$); 4.50 (*m*, 0.2 H, C*H*$_2$Ar); 4.4–4.3 (*m*, 1.8 H, C*H*$_2$Ar); 3.81 (br. *s*, 1 H, CHN); 3.62 (br. *s*, 1 H, C*H*OH); 2.2–2.1 (*m*, 0.2 H, CH$_2$(All)); 2.1–2.0 (*m*, 1.8 H, CH$_2$(All)); 1.18 (*d*, *J* = 7.0, 2.4 H, Me); 1.05 (*d*, *J* = 7.0, 0.6 H, Me). ^{13}C-NMR ((D$_8$)toluene, 90°): 157.5; 157.1; 139.9; 139.6; 137.7; 137.6; 135.8; 135.7; 135.6; 128.7; 128.6; 128.5; 128.4; 128.4; 128.3; 127.5; 127.4; 117.1; 74.2; 73.8; 67.7; 65.9; 58.8; 51.2; 51.0; 40.1; 39.7; 15.9; 15.5. LSI-MS: 362 ([M + Na$^+$]), 340 ([M + H$^+$]). HR-LSI-MS: 340.1915. ($C_{21}H_{26}NO_3^+$, [M + H$^+$]; calc. 340.1913). Anal. calc. for $C_{21}H_{25}NO_3$ (339.2): C 74.3, H 7.4, N 4.2; found: C 74.3, H 7.6, N 4.2.

*(2S,3S)- and (2S,3R)-2-{[(*tert*-Butoxy)carbonyl]amino}hex-5-en-3-ol* (**3c** and **4c**, resp.; **3c**/**4c** 1:1). ^{1}H-NMR ((D$_8$)toluene, 90°): 5.8–5.7 (*m*, 1 H, C*H*CH$_2$); 4.96 (*m*, 2 H, CHC*H*$_2$); 4.77 (br. *s*, 1 H, NH); 3.7–3.6 (*m*, 1 H, CHN); 3.50 (*ddd*, *J* = 6.5, 6.5, 3.7, 0.5 H, CHOH); 3.31 (*ddd*, *J* = 7.7, 5.1, 3.4, 0.5 H, C*H*OH); 2.44 (br. *s*, 1 H, OH); 2.2–2.1 (*m*; 1 H, CH$_2$(All)); 2.1–2.0 (*m*, 1 H, CH$_2$(All)); 1.39 (*s*, 4.5 H, ^{t}Bu); 1.38 (*s*, 4.5 H, ^{t}Bu); 1.03 (*d*, *J* = 6.8, 1.5 H, Me); 0.96 (*d*, *J* = 6.8, 1.5, Me). ^{13}C-NMR ((D$_8$)toluene, 90°): 156.3; 156.0; 135.6; 135.5; 117.3; 117.2; 79.1; 79.0; 74.3; 74.0; 51.0; 50.5; 39.5; 39.0; 28.7; 28.6; 18.5; 14.6. EI-MS: 215 (0.7, M^+), 144 (34), 142 (18), 118 (100), 100 (4), 88 (66), 81 (8), 74 (12). HR-EI-MS: 215.1524 ($C_{11}H_{21}NO_3^+$, M^+; calc. 215.1521). Anal. calc. for $C_{11}H_{21}NO_3$ (215.15): C 61.7, H 9.9, N 6.5; found: C 61.6, H 10.0, N 6.5.

(2S,3S)- and (2S,3R)-2-{[(Benzyloxy)carbonyl]amino}hex-5-en-3-ol (**3d** and **4d**, resp.; **3d**/**4d** 3:1). IR (KBr): 3315, 1686, 1542, 1323, 1289, 1267, 1038, 919, 731, 697. ^{1}H-NMR ((D$_8$)toluene, 90°): 7.3–7.0 (*m*, 5 arom. H); 5.7–5.6 (*m*, 1 H, C*H*CH$_2$); 5.04 (*s*, 2 H, OC*H*$_2$Ar); 4.97 (*m*, 1 H, CHC*H*$_2$); 4.93 (*m*, 1 H, CHC*H*$_2$); 4.68 (br. *s*, 1 H, NH); 3.65 (*m*, 1 H, CHN); 3.42 (*m*, 1 H, C*H*OH); 2.0–1.9 (*m*, 2 H, CH$_2$(All)); 1.67 (br. *s*, 1 H, OH); 0.99 (*d*, *J* = 6.7, 0.1 H, Me); 0.92 (*d*, *J* = 6.7, 2.9 H, Me). ^{13}C-NMR ((D$_8$)toluene, 90°): 156.2; 137.8; 135.3; 129.3; 128.7; 128.5; 128.2; 117.4; 73.6; 66.8; 51.3; 38.9; 14.5. EI-MS: 249 (0.2, M^+), 208 (1.8), 178 (10), 134 (16), 91 (100), 88 (27). HR-EI-MS: 249.1363 ($C_{14}H_{19}NO_3^+$, M^+; calc. 249.1365). Anal. calc. for $C_{14}H_{19}NO_3$ (249.15): C 67.4, H 7.7, N 5.6; found: C 67.4, H 7.5, N 5.7.

General Procedures for Chemical Correlations. Removal of the Boc protecting group: To a stirred soln. of the *N*-Boc-protected or *N*-Bn-*N*-Boc-diprotected adduct (1 mmol) in CH_2Cl_2 (5 ml), CF_3COOH (5 mmol) was added dropwise at r.t. Stirring was continued at r.t. until the disappearance of the substrate was noted (TLC). Then the mixture was diluted with sat. $NaHCO_3$ soln. (10 ml) and extracted with CH_2Cl_2 (3×5 ml). The combined extracts were washed with brine (10 ml), dried ($MgSO_4$), and evaporated. The crude product was used for further treatment.

Introduction of the tosyl [17] or (benzyloxy)carbonyl [18] protecting group was carried out according to the known literature procedures.

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