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Diastereoselectivity of the reactions of organolithium reagents with protected erythrulose oximes

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Abstract

The addition of organolithium reagents to the C=N bond of several erythrulose-derived chiral (*E*)- and (*Z*)-ketoxime ethers has been shown to be highly diastereoselective in the case of the (*E*)-isomers. Chelated and nonchelated transition states have been proposed to rationalize these results, with additional support of computational methods.

1. Introduction

The addition of carbon nucleophiles to C=N bonds[1] is a synthetically important method of preparing many types of nitrogen-containing compounds of biological importance. Among these, the non-proteinaceous amino acids are particularly worth mentioning. This class of amino acids, which are used, for example, for the synthesis of modified peptides,[2] comprises a variety of structural types, one of them being the α,α-disubstituted α-amino carboxylic acids.[3] The latter are characterized by a quaternary carbon atom, to which the carboxyl function, the amino group and two alkyl/aryl residues are bonded. There are few methods for preparing such compounds in enantiopure form. Most of them rely on the alkylation of amino acid enolate anion equivalents.[3] This fact places some limits on their applicability, as certain α-amino acids such as those with α-*tert*-alkyl or α-aryl substituents cannot be easily, if at all, prepared in this way. In contrast, there are fewer alternative synthetic methods based on *nucleophilic* alkylation of amino acid enolate cation equivalents. Indeed, reports on diastereoselective nucleophilic additions to the C=N bond of chiral *ketone* imino derivatives are not frequent in the literature and usually involve reduction processes.[4] Diastereoselective additions of carbon nucleophiles have been investigated in a limited number of cases.[5–7]

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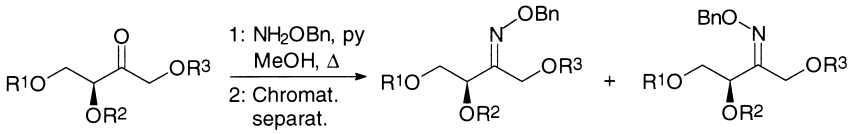
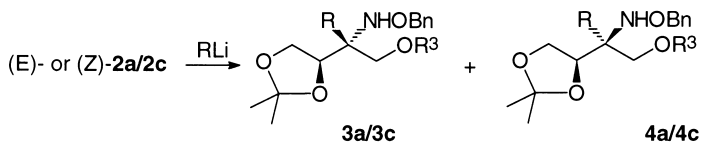


(1)

1a R^1, $R^2 = CMe_2$; R^3 = TPS
1b R^1, R^2 = Bn; R^3 = TPS
1c R^1, $R^2 = CMe_2$; R^3 = Tr
1d R^1, R^2 = Bn; R^3 = Tr

We have previously reported on the diastereoselective addition of organometallic reagents to the C=O bond of O-protected L-erythrulose derivatives **1a**–**d**.[8] Through reaction with O-benzyl hydroxylamine, these four ketones have now been converted into *E*/*Z* mixtures of the corresponding ketoxime ethers **2a**–**d** (Eq. 1), which were then separated into pure geometric isomers by column chromatography. These oximes were at least 98% enantiomerically pure, as confirmed by NMR analysis of their Mosher derivatives.[9] The configurational assignments of the C=N bond were based on ^{1}H and ^{13}C NMR data,[10] and supported by NOE measurements.

We now report that additions of organolithium reagents to the C=N bond of chiral ketoxime ethers (*E*)- and (*Z*)-**2a**–**d** often take place with high stereocontrol to yield the differentially protected, stereoisomeric amino polyols **3**/**4** (Eqs 2 and 3).[11a] The results are presented in Tables 1 and 2. As shown in the following article,[11b] these amino alcohols can be subsequently converted into enantiopure α,α-disubstituted α-amino acids, including those not easily available by previous methodologies.



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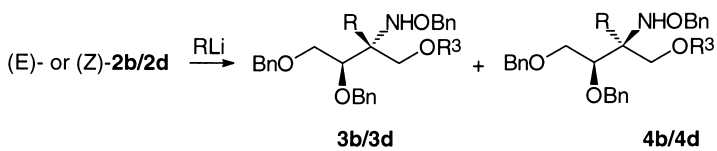


(3)

2. Results and discussion

In our initial report,[11a] we used oximes **2a**/**2b**, which bear a *t*-butyldiphenylsilyl (TPS) group bonded to the hydroxyl at C-1. In search of an alternative and less expensive protecting group, we have also tested the reactivity of the structurally analogous oximes **2c**/**2d**, in which a trityl moiety replaces the TPS group. As shown by Tables 1 and 2, the trityl group provides essentially the same results as the similarly bulky TPS group, with the added advantage of its introduction requiring a cheaper reagent.[12] We have also investigated oximes with a 1-O-*t*-butyldimethylsilyl (TBS) group but its results were inferior to those of the other protecting groups (lower stereoselectivity) and are thus not reported here.

Nucleophilic additions to C=N bonds face some difficulties when compared with additions to the related C=O bond. The less polar imino group has a comparatively low reactivity and it often happens that side reactions, such as deprotonation or reduction, take precedence over the desired nucleophilic addition.[1,5] In fact, ketoximes **2a**–**d** were not very reactive, a circumstance most likely due to steric hindrance to the approach of nucleophiles to the imino carbon atom. Many types of organometallic reagents were essayed on the compounds under study and found to be unreactive. Only organolithium

Table 1
Stereoisomer distribution in additions of organolithium reagents to oximes **2a**/**2b**[a]

Entry	Oxime	RLi	T[b]	Yield[c]	3 / 4[d]
1	(E)-**2a**	MeLi	0	91	93 : 7
2	(E)-**2b**	MeLi	0	71	>95 : 5
3	(Z)-**2a**	MeLi	0	62	25 : 75
4	(Z)-**2b**	MeLi	0	41	23 : 77
5	(E)-**2a**	*n*BuLi	—78	73	>95 : 5
6	(E)-**2b**	*n*BuLi	—78	95	>95 : 5
7	(Z)-**2a**	*n*BuLi	0	42	30 : 70
8	(Z)-**2b**	*n*BuLi	0	Dec.[e]	
9	(E)-**2a**	*t*BuLi	—78	60	>95 : 5
10	(E)-**2b**	*t*BuLi	—78	Dec.	
11	(Z)-**2a**	*t*BuLi	0	Dec.[e]	
12	(Z)-**2b**	*t*BuLi	0	Dec.[e]	
13	(E)-**2a**	PhLi	—78	70	>95 : 5
14	(E)-**2b**	PhLi	—78	85	>95 : 5
15	(Z)-**2a**	PhLi	0	68	75 : 25
16	(Z)-**2b**	PhLi	0	70	68 : 32
17	(E)-**2a**	allylLi	—78	73	80 : 20
18	(E)-**2b**	allylLi	—78	50	>95 : 5
19	(Z)-**2a**	allylLi	—78	61	33 : 67
20	(Z)-**2b**	allylLi	—78	50	13 : 87

[a]All reactions were performed in Et_2O. Reaction time was 1 hour in all cases, although some of the reactions, mostly those of the (E) isomers, were complete in a much shorter time (see text). [b]In degrees (°C). [c]Overall yield (%) of both stereoisomers. [d]Determined by $^1H/^{13}C$ NMR. [e]At lower temperatures, a partial recovery of the starting material was the sole result.

derivatives eventually met with success. In almost all cases where these reagents were used, an addition took place with subsequent formation of N-*tert*-alkyl O-benzyl hydroxyl amines **3**/**4**. The main exceptions were reactions involving *t*-butyllithium (entries 9–12 in both tables), which usually led to decomposition. It is not known whether this lack of success is due to steric hindrance to the approach of the reagent to the C=N bond, to competitive deprotonation of the oxime by the highly basic reagent or to some type of retroaldol-like process. Only oximes (*E*)-**2a** and (*E*)-**2c** (entry 9 in both Tables) reacted with the aforementioned reagent with a fair yield and an excellent diastereoisomeric ratio (d.r.). In any case, this represents an interesting result, as these reactions give rise to the appendage of a bulky *tert*-alkyl group to a crowded tertiary position. The reactions involving phenyllithium (entries 13–16) are also interesting as they open the possibility of synthesizing enantiopure α-aryl-α-alkyl-α-amino acids.

Table 2
Stereoisomer distribution in additions of organolithium reagents to oximes **2c**/**2d**[a]

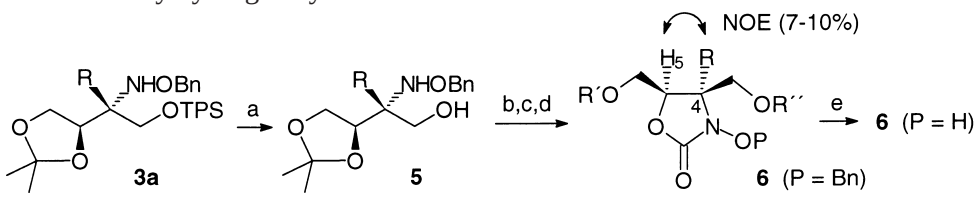
Entry	Oxime	RLi	T[b]	Yield[c]	3 / 4[d]
1	(E)-**2c**	MeLi	0	80	90 : 10
2	(E)-**2d**	MeLi	0	70	>95 : 5
3	(Z)-**2c**	MeLi	0	61	31 : 69
4	(Z)-**2d**	MeLi	0	60	30 : 70
5	(E)-**2c**	*n*BuLi	—78	81	>95 : 5
6	(E)-**2d**	*n*BuLi	—78	85	>95 : 5
7	(Z)-**2c**	*n*BuLi	0	75	20 : 80
8	(Z)-**2d**	*n*BuLi	0	Dec.[e]	
9	(E)-**2c**	*t*BuLi	—78	75	>95 : 5
10	(E)-**2d**	*t*BuLi	—78	Dec.	
11	(Z)-**2c**	*t*BuLi	0	Dec.[e]	
12	(Z)-**2d**	*t*BuLi	0	Dec.[e]	
13	(E)-**2c**	PhLi	—78	67	>95 : 5
14	(E)-**2d**	PhLi	—78	82	>95 : 5
15	(Z)-**2c**	PhLi	0	72	84 : 16
16	(Z)-**2d**	PhLi	0	68	66 : 34
17	(E)-**2c**	allylLi	—78	73	75 : 25
18	(E)-**2d**	allylLi	—78	62	91 : 9
19	(Z)-**2c**	allylLi	—78	70	50 : 50
20	(Z)-**2d**	allylLi	—78	62	13 : 87

[a]All reactions were performed in Et_2O. Reaction time was 1 hour in all cases, although some of the reactions, mostly those of the (E) isomers, were complete in a much shorter time (see text). [b]In degrees (°C). [c]Overall yield (%) of both stereoisomers. [d]Determined by $^1H/^{13}C$ NMR. [e]At lower temperatures, a partial recovery of the starting material was the sole result.

In addition to these positive results, we have observed some negative findings which are also worth mentioning. For instance, aside from the aforementioned organolithium reagents we have essayed chloromethyllithium, generated from chloroiodomethane and *n*-butyllithium.[13] No reaction was observed with this reagent, even at 0°C. The same result was observed after treating the oximes in toluene at −20°C with methyl- or *n*-butyllithium in the presence of BF_3. This and other Lewis acids such as $ZnCl_2$ or $TiCl_4$ were not able to promote the addition of Grignard reagents, even at room temperature. Either methyllithium in the presence of $TiCl_4$ or preformed[14] $MeTiCl_3$ caused only decomposition at 0°C, with no reaction being observed at lower temperatures. These facts show the relatively low reactivity of the C=N bond in the compounds under study.

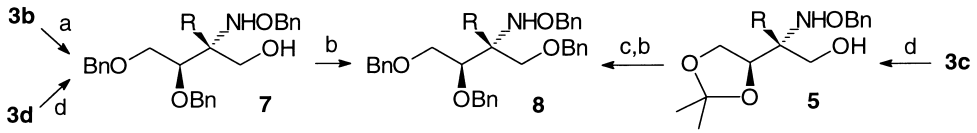
The configuration of the new stereogenic centre in stereoisomers **3a**–**d** was established with the series

of reactions illustrated below. Compounds **3a** were desilylated to amino alcohols **5**, which were then converted as indicated into oxazolidinones of general formula **6** (R′ and R′′=Tr, TPS or TBS, according to ease of preparation). In each of these oxazolidinones, a characteristic NOE (7–10%) was observed between H-5 (heterocycle numbering) and the proximal protons of the R group at C-4 (CH_2 protons for R=*n*Bu and allyl, CH_3 protons for R=Me and *t*Bu, *ortho* protons of the aromatic ring for R=Ph). The observation of this NOE unequivocally settled the configuration at C-4 as depicted. In the case of **3a** (R=Ph), the aromatic hydrogen signals of the protecting groups TPS and OBn interfered with the measurement of the NOE. For this reason, TBS was selected as the protecting group and the benzyl group was eliminated by hydrogenolysis.



Reaction conditions. a) TBAF, THF, RT. b) pyridinium *p*-toluenesulphonate (PPTS), aq MeOH, Δ . c) Tritylation or silylation. d) triphosgene, Et_3N, CH_2Cl_2, RT. e) H_2, Pd/C, MeOH (only for R = Ph).

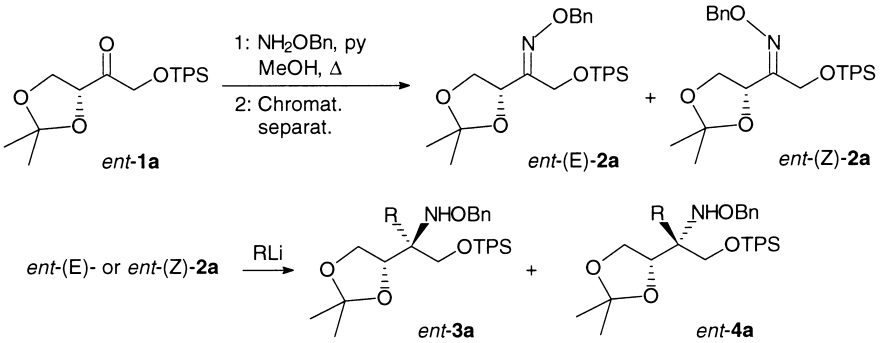
Configurational assignments for compounds **3b** were made by desilylation to **7** and subsequent conversion into the perbenzylated derivatives **8**, also obtained from **5** as indicated below. Configurational assignments in **3c** and **3d** were established by detritylation to yield **5** and **7**, respectively.



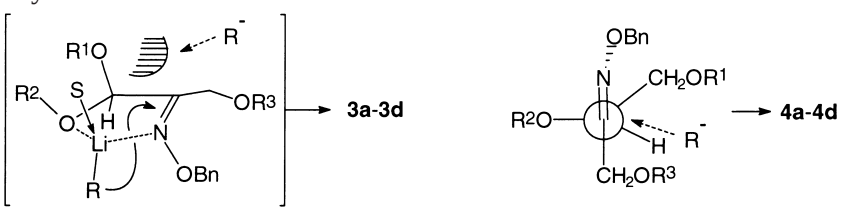
Reaction conditions. a) TBAF, THF, RT. b) NaH, THF, BnBr. c) PPTS, aq MeOH, Δ. d) TFAA, TFA, Et_3N, CH_2Cl_2.

As shown by the data in Tables 1 and 2, the reactions of the (*E*)-isomers were markedly faster than those of their (*Z*)-counterparts. As a matter of fact, most additions to the C=N bond of (*E*)-oximes take place at −78°C, whereas those involving the (*Z*)-oximes had to be conducted at 0°C (except for allyllithium, entries 19 and 20). For the sake of comparison of the relative reactivity of both isomeric oximes, the reaction of (*E*)-**2a** with 1.1 equiv. of MeLi is complete in less than 5 min at 0°C. The obtained addition product displays the same diastereoisomeric composition as that obtained after 1 h at the same temperature. In contrast, the reaction of (*Z*)-**2a** with the same reagent is still incomplete after 15 min. The difference was still more evident in the case of the reaction of (*E*)-**2a** with *n*BuLi (1.1 equiv.), which was complete in less than 5 min at −78°C, while (*Z*)-**2a** required almost 1 h at 0°C. A further interesting feature is that the highest diastereoselectivities are observed in the reactions of the (*E*)-oximes, whereby stereoisomer **3** is always predominantly or exclusively formed (exclusive formation means that the minor diastereoisomer was not detectable by high-field NMR spectroscopy; this has been indicated in the last column of Tables 1 and 2 with d.r. >95:5).

The aforementioned compounds can also be prepared with the enantiomeric configuration by using D-erythrulose precursors as the starting materials.[8e] As a matter of fact, reaction of *ent*-**1a**[8e] with O-benzyl hydroxylamine afforded a mixture of the stereoisomeric oximes *ent*-(*E*)-**2a** and *ent*-(*Z*)-**2a**. As expected, these oximes reacted with organolithium reagents with the same yield and diastereoselectivity as their enantiomers.



Diastereoselective additions of carbon nucleophiles to chiral aldoximes have been often investigated.[15] In contrast, related studies on ketoximes are scarce.[16] In some cases, the stereochemical outcome of nucleophilic additions has been shown to be dependent on the configuration of the C=N bond. When oxygen atoms are present in the vicinity of the C=N bond, a differential chelation ability of either isomer has been claimed to be at the origin of the diverging stereochemical behaviour.[15b] In the present case, we believe that the higher reactivity *and* stereoselectivity of the (*E*)-oximes are due to the formation of a five-membered α-chelate involving the lithium, nitrogen and oxygen atoms of the α-OR group (see the following scheme).[1d,5,17] This allows the prediction of a preferred approach from the less hindered *Si* face of the C=N bond and the predominant formation of amino polyols **3a**–**d**, in good agreement with observations. Moreover, the participation of the nitrogen atom in a chelate is expected to increase the electrophilicity of the imino carbon atom of the oxime, with a concomitant increase in the reactivity of the C=N bond.[18] In the previous paragraph, we have commented on the fact that the reactions of the (*E*)-oximes are complete in a very short time, even if only 1.1 equiv. of the organolithium reagent is added. This suggests that a chelate between the (*E*)-oxime and the organolithium reagent is rapidly formed, followed by an internal magnesium-to-carbon 1,3-transfer within the chelate.[18,19] Most likely, the (*Z*)-isomers react through a non-chelated transition state of the Felkin–Anh type,[1d,5,20] which should lead predominantly to stereoisomers **4a**–**d**.

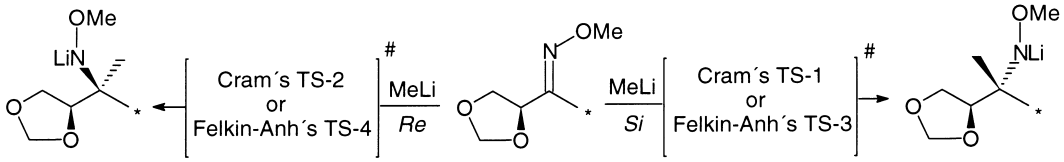


Cram´s cyclic (chelation) mechanism in (E)-**2a-2d**

Felkin-Anh mechanism in (Z)-**2a-2d**

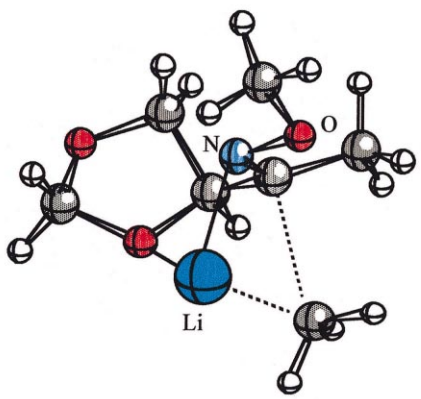
Although many quantum-mechanical calculations on nucleophilic additions to carbonyl groups have been published, there are few theoretical investigations on additions to C=N bonds.[21] We have thus performed computational studies with the aim of providing the aforementioned mechanistic models with a more firm basis. We will show here only preliminary results centred on a reaction with the synthetically more useful (*E*)-isomer. In order to reduce the calculation time, we have studied the simplified model **9**, in which the O-benzyl group has been replaced by an O-methyl group and the two acetonide methyl groups have been replaced by hydrogen atoms. Furthermore, a methyl group substitutes for the bulky CH_2OTPS group, a simplification justified on the basis that the CH_2OTPS fragment may be assumed to play the role of an inert spectator which does not participate in the chelation process.[18] Methyllithium was the model reagent (no new stereogenic centre is created in the addition of MeLi to **9** but this does not affect

the calculation of transition state energies). With the assumption of the alternative Cram's chelation and Felkin–Anh models, four different transition states (**TS-1** to **TS-4**, represented below) may be proposed according to whether the organolithium reagent approaches the imino carbon atom from the *Re* or from the *Si* face. Attack from the *Re* face leads to stereoisomer **11**, which corresponds to stereoisomers **4a**/**4d** in the actual reaction. These may be formed through either Cram's **TS-2** or Felkin–Anh's **TS-4**. Correspondingly, attack from the *Si* face leads to stereoisomer **10**, which is the model equivalent of stereoisomers **3a**/**3d**. The latter may arise through either Cram's **TS-1** or Felkin–Anh's **TS-3**:

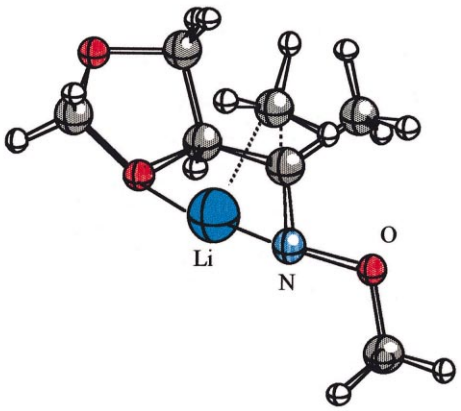


11 (=**4a**/**4d**) **9** **10** (=**3a**/**3d**)

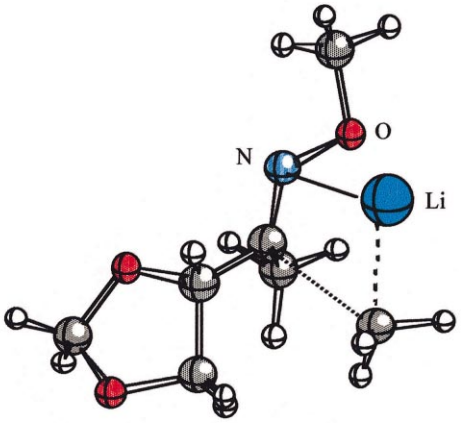
With the aid of *ab initio* methods,[22] it has been shown that Cram's **TS-1**, which explains the formation of the major stereoisomer (**3a**/**3d**) in the reactions of the (*E*)-oximes, is in fact the most favourable transition state, its energy contents being well below that of the alternative ones.



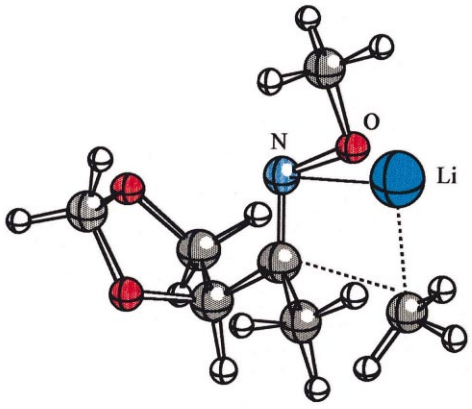
TS-1



TS-2



TS-3

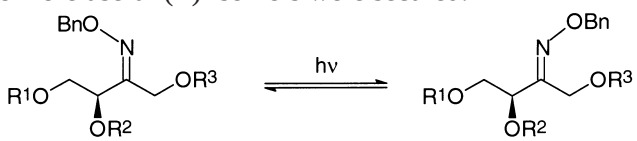


TS-4

As a matter of fact, Cram's transition state **TS-2**, which leads to the minor stereoisomer (**4a**/**4d**) in the reaction of the (*E*)-oximes, is around 3.33 kcal/mol higher than **TS1**. In accordance with this energy difference, a very high d.r. (**10**:**11** >99:1) is expected.[23]

Felkin–Anh transition states **TS-3** and **TS-4** lie 9.54 and 6.74 kcal/mol, respectively, above **TS-1**. This shows once again that chelation is able to decrease to an important extent the energy contents of transition states.[8d,17,18] Moreover, **TS-4** has a markedly lower energy content (2.8 kcal/mol) than **TS-3**, which means that the predicted d.r. **10**/**11** (i.e. **3**/**4**) would be about 1:99,[23] in clear disagreement with experimental data. Therefore, we are able to conclude that the proposed preference for Cram's chelation mechanism is also well founded from the theoretical point of view.

Inspection of the data contained in Tables 1 and 2 clearly reveals that only the (*E*)-oximes display a good synthetic utility. For this reason, we have investigated ways of converting the less desirable (*Z*)-oximes into their (*E*)-isomers. One practical procedure for achieving this purpose has turned out to be a photochemical method.[24] By UV irradiation of the (*Z*)-oximes, a photostationary equilibrium was reached in which a ca. 1:1 mixture of both isomers was present. Through chromatographic separation, additional amounts of the more useful (*E*)-isomers were secured.



(Z)-**2** (E)-**2**

The methodology we have described in this communication may be very useful for the preparation of chiral, nitrogen-containing compounds in general, and α,α-disubstituted α-amino acids in particular. Examples of the practical application of this methodology are presented in the following article.[11b]

3. Experimental

NMR spectra were measured in $CDCl_3$ solution at 22°C with a Varian Unity 400 NMR spectrometer (400 and 100 MHz resonance frequencies for ^1H and ^{13}C, respectively). Mass spectra were run either by the electron impact mode (EIMS, 70 eV), by the chemical ionization mode (CIMS, CH_4) or by the fast atom bombardment mode (FABMS) on a VG AutoSpec mass spectrometer. IR spectra were recorded as films on NaCl plates (oils) or as KBr pellets (solids). Optical rotations were measured at 22°C. Reactions which required an inert atmosphere were performed under argon with flame-dried glassware. Commercial reagents (Aldrich or Fluka) were used as received. Et_2O was freshly distilled under argon from sodium–benzophenone ketyl. Dichloromethane was distilled from P_2O_5 and stored over 4 Å molecular sieves (4 Å MS). Triethylamine was distilled from CaH_2. Trityl chloride (TrCl) was crystallized from isooctane prior to use. Unless detailed otherwise, 'work-up' means pouring the reaction mixture into brine, extraction with the indicated solvent, additional washing with 5% aq $NaHCO_3$ (if acids had been utilized in the reaction) or with 5% aq HCl (if bases had been utilized), then again with brine, drying over anhydrous Na_2SO_4 or $MgSO_4$ and elimination of the solvent *in vacuo*. The obtained material was then chromatographed on a silica gel column (Süd-Chemie AG, 60–200 μ) with the indicated eluent.

*3.1. (*E*)- and (*Z*)-O-Benzyloximes of 1-O-*t*-butyldiphenylsilyl-3,4-O-isopropylidene-L-erythrulose, (*E*)- and (*Z*)-(**2a**)*

Erythrulose derivative **1a**[8e] (4.783 g, 12 mmol) was dissolved in MeOH (40 ml) and treated with pyridine (1 ml) and O-benzyl hydroxylamine hydrochloride (1.95 g, 12.2 mmol). The reaction mixture

was heated at reflux under Ar for 30 min. Work-up (CH_2Cl_2) and column chromatography (hexane:EtOAc=19:1) afforded (*Z*)-**2a** (1.94 g, 32%) and (*E*)-**2a** (2.57 g, 42%). The respective enantiomeric oximes *ent*-(*Z*)-**2a** and *ent*-(*E*)-**2a** were prepared in the same way from *ent*-**1a**[8e] as the starting material.

(*Z*)-**2a**: oil, $[\alpha]_D$ −45.4 ($CHCl_3$, *c* 3.1); IR ν_{max} cm^{-1}: 3071, 3031, 1589 (C=N); CIMS, *m/z* 504.2561 ($M+H^+$). Calcd for $C_{30}H_{38}NO_4Si$, M=504.2570; ^{1}H NMR: δ 7.70–7.65 (4H, *m*, arom.), 7.40–7.30 (11H, *m*, arom.), 5.11 (1H, *dd*, J=8, 7.5 Hz, H-3), 5.07 (2H, *s*, NOCH_2Ph), 4.44 (1H, *d*, J=13 Hz, H-1), 4.34 (1H, *d*, J=13 Hz, H-1′), 4.32 (1H, *dd*, J=8, 7.5 Hz, H-4), 3.64 (1H, *t*, J=8 Hz, H-4′), 1.32, 1.31 (2×3H, 2×*s*, acetonide Me), 1.03 (9H, *s*, Si*t*Bu); ^{13}C NMR: δ 158.1 (C-2), 137.7, 133.5, 133.2 (arom. C), 135.7, 135.6, 129.6, 128.4, 128.1, 127.9, 127.6 (arom. CH), 109.3 (acetonide C), 76.4 (NO*C*H_2Ph), 71.7 (C-3), 67.9 (C-4), 61.6 (C-1), 26.7 (SiC*Me*$_3$), 25.8, 25.3 (2×acetonide Me), 19.2 (Si*C*Me_3). Anal. calcd for $C_{30}H_{37}NO_4Si$: C, 71.53; H, 7.40; N, 2.78. Found: C, 71.60; H, 7.49; N, 2.67.

(*E*)-**2a**: oil, $[\alpha]_D$ −6.7 ($CHCl_3$, *c* 6.3); IR ν_{max} cm^{-1}: 3071, 3031, 1589 (C=N); CIMS, *m/z* 504.2563 ($M+H^+$). Calcd for $C_{30}H_{38}NO_4Si$, M=504.2570; ^{1}H NMR: δ 7.70–7.65 (4H, *m*, arom.), 7.40–7.20 (11H, *m*, arom.), 5.03 (2H, *s*, NOCH_2Ph), 5.00 (1H, *dd*, J=7, 6.5 Hz, H-3), 4.53 (2H, *s*, H-1, H-1′), 4.21 (1H, *dd*, J=8.5, 7 Hz, H-4), 4.19 (1H, *dd*, J=8.5, 6.5 Hz, H-4′), 1.41, 1.39 (2×3H, 2×*s*, acetonide Me), 1.03 (9H, *s*, Si*t*Bu); ^{13}C NMR: δ 156.9 (C-2), 137.5, 132.8, 132.5 (arom. C), 135.6, 135.5, 129.9, 129.8, 128.2, 128.1, 127.8, 127.7 (arom. CH), 109.8 (acetonide C), 76.3 (NO*C*H_2Ph), 74.0 (C-3), 67.1 (C-4), 57.6 (C-1), 26.7 (SiC*Me*$_3$), 26.2, 25.7 (2×acetonide Me), 19.1 (Si*C*Me_3). Anal. calcd for $C_{30}H_{37}NO_4Si$: C, 71.53; H, 7.40; N, 2.78. Found: C, 71.31; H, 7.61; N, 2.87.

*3.2. (*E*)- and (*Z*)-O-Benzyloximes of 1-O-*t*-butyldiphenylsilyl-3,4-O-isopropylidene-D-erythrulose,* ent-*(*E*)- and* ent-*(Z)-(**2a**)*

Prepared as above from *ent*-**1a**[8e]: *ent*-(*Z*)-**2a**: $[\alpha]_D$ +45.5 ($CHCl_3$, *c* 2.7); *ent*-(*E*)-**2a**: $[\alpha]_D$ +6.4 ($CHCl_3$, *c* 5.9). Other physical properties identical to those of (*Z*)- and (*E*)-**2a**.

*3.3. (*E*)- and (*Z*)-O-Benzyloximes of 1-O-*t*-butyldiphenylsilyl-3,4-di-O-benzyl-L-erythrulose, (*E*)- and (*Z*)-(**2b**)*

Obtained as described above from **1b**[8e] using similar molar amounts. Work-up (CH_2Cl_2) and column chromatography (hexane:EtOAc=19:1) provided (*Z*)-**2b** (39%) and (*E*)-**2b** (46%).

(*Z*)-**2b**: oil, $[\alpha]_D$ −20.1 ($CHCl_3$, *c* 8.2); IR ν_{max} cm^{-1}: 3087, 3067, 3031, 1589 (C=N); FABMS, *m/z* 644.3228 ($M+H^+$). Calcd for $C_{41}H_{46}NO_4Si$, M=644.3196; ^{1}H NMR: δ 7.70–7.60 (4H, *m*, arom.), 7.40–7.20 (21H, *m*, arom.), 5.13 (1H, *dd*, J=8, 2.5 Hz, H-3), 5.08, 5.05 (2H, AB system, J=12 Hz, NOCH_2Ph), 4.53, 4.50 (2H, AB system, J=12 Hz, OCH_2Ph), 4.46, 4.43 (2H, AB system, J=12 Hz, OCH_2Ph), 4.43 (1H, *d*, J=12 Hz, H-1), 4.14 (1H, *d*, J=12 Hz, H-1′), 3.85 (1H, *dd*, J=11, 8 Hz, H-4), 3.62 (1H, *dd*, J=11, 2.5 Hz, H-4′), 1.00 (9H, *s*, Si*t*Bu); ^{13}C NMR: δ 157.7 (C-2), 138.4, 138.0, 137.8, 133.1 (arom. C), 135.7, 129.7, 129.6, 128.3, 128.2, 128.1, 127.8, 127.7, 127.6, 127.5, 127.4 (arom. CH), 76.2 (NO*C*H_2Ph), 74.2 (C-3), 73.1, 72.5 (2×OCH_2Ph), 71.5 (C-4), 62.0 (C-1), 26.7 (SiC*Me*$_3$), 19.2 (Si*C*Me_3). Anal. calcd for $C_{41}H_{45}NO_4Si$: C, 76.48; H, 7.04; N, 2.18. Found: C, 76.28; H, 7.30; N, 2.17.

(*E*)-**2b**: oil, $[\alpha]_D$ −23.7 ($CHCl_3$, *c* 3.7); IR ν_{max} cm^{-1}: 3088, 3062, 1589 (C=N); FABMS, *m/z* 644.3182 ($M+H^+$). Calcd for $C_{41}H_{46}NO_4Si$, M=644.3196; ^{1}H NMR: δ 7.65–7.60 (4H, *m*, arom.), 7.40–7.20 (21H, *m*, arom.), 5.04 (2H, *s*, NOCH_2Ph), 4.62 (1H, *dd*, J=7.5, 4 Hz, H-3), 4.60–4.50 (4H, *m*, 2×OCH_2Ph), 4.54 (1H, *d*, J=14.3 Hz, H-1), 4.40 (1H, *d*, J=14.3 Hz, H-1′), 3.89 (1H, *dd*, J=10.5, 7.5 Hz, H-4), 3.82 (1H, *dd*, J=10.5, 4 Hz, H-4′), 0.99 (9H, *s*, Si*t*Bu); ^{13}C NMR: δ 157.1 (C-2), 138.4, 138.3, 137.7, 132.8, 132.7 (arom. C), 135.6, 129.7, 128.3, 128.2, 128.1, 128.0, 127.8, 127.7, 127.6, 127.4 (arom.

CH), 77.2 (C-3), 76.2 (NO*C*H$_2$Ph), 73.3, 71.5 (2×O*C*H$_2$Ph), 71.9 (C-4), 57.3 (C-1), 26.7 (SiC*Me*$_3$), 19.1 (Si*C*Me$_3$). Anal. calcd for $C_{41}H_{45}NO_4Si$: C, 76.48; H, 7.04; N, 2.18. Found: C, 76.34; H, 7.25; N, 2.10.

*3.4. (*E*)- and (*Z*)-O-Benzyloximes of 1-O-trityl-3,4-O-isopropylidene-L-erythrulose, (*E*)- and (*Z*)-(**2c**)*

Obtained as described above from **1c**[8d] using similar molar amounts. Work-up (CH_2Cl_2) and column chromatography (hexane:EtOAc=19:1) provided (*Z*)-**2c** (44%) and (*E*)-**2c** (40%).

(*Z*)-**2c**: oil, $[\alpha]_D$ −45.3 ($CHCl_3$, *c* 3.1); IR ν_{max} cm^{-1}: 3086, 3060, 3032, 1598 (C=N); CIMS, *m/z* 508.2479 (M+H$^+$). Calcd for $C_{33}H_{34}NO_4$, M=508.2488; ^{1}H NMR: δ 7.70–7.60 (6H, *m*, arom.), 7.55–7.20 (14H, *m*, arom.), 5.35 (1H, *t*, J=7.5 Hz, H-3), 5.30 (2H, *s*, NOC*H*$_2$Ph), 4.52 (1H, *dd*, J=8, 7.5 Hz, H-4), 4.05 (1H, *d*, J=11.7 Hz, H-1), 3.99 (1H, *d*, J=11.7 Hz, H-1′), 3.96 (1H, *t*, J=8, 7.5 Hz, H-4′), 1.44, 1.35 (2×3H, 2×*s*, acetonide Me); ^{13}C NMR: δ 157.9 (C-2), 144.0, 137.8 (arom. C), 128.9, 128.6, 128.5, 128.2, 128.1, 128.0, 127.8, 127.2 (arom. CH), 109.6 (acetonide C), 87.7 (*C*Ph$_3$), 76.7 (NO*C*H$_2$Ph), 71.7 (C-3), 68.3 (C-4), 62.0 (C-1), 26.0, 25.4 (2×acetonide Me). Anal. calcd for $C_{33}H_{33}NO_4$: C, 78.08; H, 6.55; N, 2.76. Found: C, 78.31; H, 6.27; N, 2.52.

(*E*)-**2c**: oil, $[\alpha]_D$ −18.5 ($CHCl_3$, *c* 6.8); IR ν_{max} cm^{-1}: 3086, 3060, 3031, 1598 (C=N); FABMS, *m/z* 508.2492 (M+H$^+$). Calcd for $C_{33}H_{34}NO_4$, M=508.2488; ^{1}H NMR: δ 7.50–7.40 (6H, *m*, arom.), 7.40–7.20 (14H, *m*, arom.), 5.11, 5.08 (2H, AB system, J=12 Hz, NOC*H*$_2$Ph), 4.90 (1H, *dd*, J=7, 6.5 Hz, H-3), 4.20 (1H, *d*, J=12.5 Hz, H-1), 4.16 (1H, *dd*, J=8.5, 6.5 Hz, H-4), 4.05 (1H, *dd*, J=8.5, 7 Hz, H-4′), 3.86 (1H, *d*, J=12.5 Hz, H-1′), 1.40, 1.25 (2×3H, 2×*s*, acetonide Me); ^{13}C NMR: δ 155.2 (C-2), 143.4, 137.4 (arom. C), 128.97, 128.3, 128.2, 127.9, 127.8, 127.2 (arom. CH), 109.8 (acetonide C), 87.5 (*C*Ph$_3$), 76.4 (NO*C*H$_2$Ph), 74.8 (C-3), 66.8 (C-4), 56.6 (C-1), 26.1, 25.7 (2×acetonide Me). Anal. calcd for $C_{33}H_{33}NO_4$: C, 78.08; H, 6.55; N, 2.76. Found: C, 78.22; H, 6.38; N, 2.62.

*3.5. (*E*)- and (*Z*)-O-Benzyloximes of 1-O-trityl-3,4-di-O-benzyl-L-erythrulose, (*E*)- and (*Z*)-(**2d**)*

Obtained as described above from **1d**[8d] using similar molar amounts. Work-up (CH_2Cl_2) and column chromatography (hexane:EtOAc=19:1) provided (*Z*)-**2d** (30%) and (*E*)-**2d** (42%).

(*Z*)-**2d**: oil, $[\alpha]_D$ −33.4 ($CHCl_3$, *c* 1.8); IR ν_{max} cm^{-1}: 3062, 3030, 1597 (C=N); FABMS, *m/z* 648.3093 (M+H$^+$). Calcd for $C_{44}H_{42}NO_4$, M=648.3114; ^{1}H NMR: δ 7.45–7.40 (6H, *m*, arom.), 7.40–7.20 (24H, *m*, arom.), 5.15 (1H, *dd*, J=8, 2.5 Hz, H-3), 5.15, 5.13 (2H, AB system, J=12.4 Hz, NOC*H*$_2$Ph), 4.54, 4.50 (2H, AB system, J=12 Hz, OC*H*$_2$Ph), 4.41 (2H, *s*, OC*H*$_2$Ph), 3.91 (1H, *dd*, J=11, 8 Hz, H-4), 3.85 (1H, *d*, J=11 Hz, H-1), 3.70 (1H, *dd*, J=11, 2.5 Hz, H-4′), 3.69 (1H, *d*, J=11 Hz, H-1′); ^{13}C NMR: δ 157.0 (C-2), 143.7, 138.3, 137.9, 137.7 (arom. C), 128.8, 128.7, 128.3, 128.2, 128.0, 127.9, 127.8, 127.7, 127.6, 127.5, 127.4, 127.3, 127.2, 127.0 (arom. CH), 87.5 (*C*Ph$_3$), 76.3 (NO*C*H$_2$Ph), 74.0 (C-3), 73.1, 72.5 (2×O*C*H$_2$Ph), 71.2 (C-4), 62.0 (C-1). Anal. calcd for $C_{44}H_{41}NO_4$: C, 81.58; H, 6.38; N, 2.16. Found: C, 81.66; H, 6.40; N, 2.23.

(*E*)-**2d**: oil, $[\alpha]_D$ −15.5 ($CHCl_3$, *c* 2.4); IR ν_{max} cm^{-1}: 3062, 3033, 1597 (C=N); FABMS, *m/z* 648.3116 (M+H$^+$). Calcd for $C_{44}H_{42}NO_4$, M=644.3114; ^{1}H NMR: δ 7.45–7.40 (6H, *m*, arom.), 7.40–7.20 (24H, *m*, arom.), 5.11, 5.09 (2H, AB system, J=12 Hz, NOC*H*$_2$Ph), 4.57 (1H, *dd*, J=7.2, 4.4 Hz, H-3), 4.57, 4.50 (2H, AB system, J=12 Hz, OC*H*$_2$Ph), 4.52, 4.48 (2H, AB system, J=12 Hz, OC*H*$_2$Ph), 4.06 (1H, *d*, J=12.6 Hz, H-1), 3.89 (1H, *d*, J=12.6 Hz, H-1′), 3.77 (1H, *dd*, J=10.5, 7.5 Hz, H-4), 3.71 (1H, *dd*, J=10.5, 4.5 Hz, H-4′); ^{13}C NMR: δ 155.7 (C-2), 143.4, 138.3, 138.2, 137.7 (arom. C), 128.7, 128.3, 128.2, 128.0, 127.8, 127.7, 127.6, 127.4, 127.0 (arom. CH), 87.4 (*C*Ph$_3$), 77.5 (C-3), 76.1 (NO*C*H$_2$Ph), 73.2, 71.4 (2×O*C*H$_2$Ph), 71.5 (C-4), 56.8 (C-1). Anal. calcd for $C_{44}H_{41}NO_4$: C, 81.58; H, 6.38; N, 2.16. Found: C, 81.75; H, 6.44; N, 2.28.

3.6. General experimental procedure for organolithium additions to oximes **2a–d**

Substrate, temperature, reaction time and yield are indicated in Tables 1 and 2. Careful exclusion of oxygen and moisture is assumed in all cases. Allyllithium was generated according to a described procedure[25] and used immediately in situ.

A solution of the appropriate oxime (1 mmol) in dry Et_2O (5 ml) was cooled to the indicated temperature. The required organolithium reagent (2 mmol) was then added dropwise, and the reaction mixture was stirred for 1 h. Work-up (Et_2O) and column chromatography (hexane:EtOAc=9:1) yielded the expected addition product with the indicated yield and diastereoisomeric composition. In the case of allyllithium, a solution of the oxime in dry Et_2O was added to a solution of the freshly generated reagent.

The mixtures of diastereoisomers **3**/**4** formed in these reactions are practically inseparable with normal chromatographic systems based on silica gel. For this reason, spectral data and optical rotations are given below only for diastereoisomers **3** in such cases where a high stereoisomeric purity (>95% d.r.) was achieved.

3.6.1. (2R,3R)-1-*O*-t-Butyldiphenylsilyl-3,4-*O*-isopropylidene-2-(*N*-benzyloxyamino)-2-methylbutane-1,3,4-triol (**3a**, R=Me)

Oil, $[\alpha]_D$ −6.2 ($CHCl_3$, *c* 6.8); IR ν_{max} cm^{-1}: 3350 (br, NH); CIMS, *m/z* (% rel. int.): 520.2888 ($M+H^+$). Calcd for $C_{31}H_{42}NO_4Si$, M=520.2883; ^{1}H NMR: δ 7.75–7.70 (4H, *m*, arom.), 7.45–7.30 (11H, *m*, arom.), 4.67 (2H, *s*, NOCH_2Ph), 4.23 (1H, *t*, J=6.9 Hz, H-3), 4.03 (1H, *dd*, J=8.5, 6.9 Hz, H-4), 3.96 (1H, *dd*, J=8.5, 6.9 Hz, H-4′), 3.83 (1H, *d*, J=9.7 Hz, H-1), 3.63 (1H, *d*, J=9.7 Hz, H-1′), 1.40, 1.34 (2×3H, 2×acetonide Me), 1.06 (9H, *s*, Si*t*Bu), 1.05 (3H, s, *Me*C_2); ^{13}C NMR: δ 137.8, 133.4, 134.3 (arom. C), 135.7, 135.6, 129.6, 129.5, 128.3, 128.2, 127.7, 127.6, 127.5 (arom. CH), 108.5 (acetonide C), 76.7 (NO*C*H_2Ph), 76.1 (C-3), 65.4 (C-4), 64.8 (C-1), 62.2 (C-2), 26.8 (SiC*Me*$_3$), 26.3, 24.9 (2×acetonide Me), 19.4 (Si*C*Me_3), 13.9 (*Me*C_2). Anal. calcd for $C_{31}H_{41}NO_4Si$: C, 71.64; H, 7.95; N, 2.69. Found: C, 71.77; H, 8.05; N, 2.61.

3.6.2. (2S,3S)-1-*O*-t-Butyldiphenylsilyl-3,4-*O*-isopropylidene-2-(*N*-benzyloxyamino)-2-methylbutane-1,3,4-triol (ent-**3a**, R=Me)

Oil, $[\alpha]_D$ +6.0 ($CHCl_3$, *c* 1.6). Other physical properties identical to those of **3a** (R=Me). Anal. calcd for $C_{31}H_{41}NO_4Si$: C, 71.64; H, 7.95; N, 2.69. Found: C, 71.80; H, 7.90; N, 2.57.

3.6.3. (2R,3R)-1-*O*-t-Butyldiphenylsilyl-3,4-*O*-isopropylidene-2-(*N*-benzyloxyamino)-2-n-butylbutane-1,3,4-triol (**3a**, R=n*Bu*)

Oil, $[\alpha]_D$ −7.0 ($CHCl_3$, *c* 1.2); IR ν_{max} cm^{-1}: 3350 (br, NH), 3051; FABMS, *m/z* 562.3372 ($M+H^+$). Calcd for $C_{34}H_{48}NO_4Si$, M=562.3352; ^{1}H NMR: δ 7.75–7.65 (4H, *m*, arom.), 7.45–7.25 (11H, *m*, arom.), 4.64 (2H, *s*, NOCH_2Ph), 4.32 (1H, *dd*, J=8.2, 7 Hz, H-3), 4.09 (1H, *t*, J=8.2 Hz, H-4), 3.95 (1H, *dd*, J=8.2, 7.0 Hz, H-4′), 3.77 (1H, *d*, J=10 Hz, H-1), 3.69 (1H, *d*, J=10 Hz, H-1′), 1.60–1.50 (2H, *m*, CH_2-C_3H_7), 1.39, 1.35 (2×3H, 2×acetonide Me), 1.35–1.20 (4H, *m*, CH_2CH_2Me), 1.04 (9H, *s*, Si*t*Bu), 0.88 (3H, *t*, J=7 Hz, CH_2*Me*); ^{13}C NMR: δ 137.8, 133.3, 133.1 (arom. C), 135.7, 135.6, 129.7, 129.6, 128.3, 128.2, 127.7, 127.6, 127.5 (arom. CH), 107.9 (acetonide C), 77.5 (C-3), 76.7 (NO*C*H_2Ph), 65.6 (C-4), 63.9 (C-1), 63.2 (C-2), 29.5 (*C*H_2–C_3H_7), 26.8 (SiC*Me*$_3$), 26.3, 25.1 (2×acetonide Me), 25.4, 23.8 (*C*H_2*C*H_2Me), 19.3 (Si*C*Me_3), 14.1 (CH_2*Me*). Anal. calcd for $C_{34}H_{47}NO_4Si$: C, 72.69; H, 8.43; N, 2.49. Found: C, 72.77; H, 8.25; N, 2.60.

*3.6.4. (2*S,*3*S*)-1-O-*t*-Butyldiphenylsilyl-3,4-O-isopropylidene-2-(N-benzyloxyamino)-2-*n*-butylbutane-1,3,4-triol (*ent-***3a**, *R*=n*Bu)*

Oil, $[\alpha]_D$ +6.5 ($CHCl_3$, *c* 1.4). Other physical properties identical to those of **3a** (R=*n*Bu). Anal. calcd for $C_{34}H_{47}NO_4Si$: C, 72.69; H, 8.43; N, 2.49. Found: C, 72.82; H, 8.35; N, 2.44.

*3.6.5. (2*R,*3*R*)-1-O-*t*-Butyldiphenylsilyl-3,4-O-isopropylidene-2-(N-benzyloxyamino)-2-*t*-butylbutane-1,3,4-triol (***3a**, *R*=t*Bu)*

Oil, $[\alpha]_D$ −8.8 ($CHCl_3$, *c* 2.9); IR ν_{max} cm^{-1}: 3400 (br, NH), 3071; FABMS, *m/z* 562.3343 ($M+H^+$). Calcd for $C_{34}H_{48}NO_4Si$, M=562.3352; ^1H NMR: δ 7.65–7.60 (4H, *m*, arom.), 7.50–7.10 (11H, *m*, arom.), 4.48 (1H, *dd*, J=8.5, 6.3 Hz, H-3), 4.42 (2H, *s*, NOC*H*$_2$Ph), 3.97 (1H, *dd*, J=8.5, 7.5 Hz, H-4), 3.96 (1H, *d*, J=10.7 Hz, H-1), 3.62 (1H, *dd*, J=7.5, 6.3 Hz, H-4′), 3.56 (1H, *d*, J=10.7 Hz, H-1′), 1.32, 1.30 (2×3H, 2×acetonide Me), 1.12 (9H, *s*, *t*Bu), 1.08 (9H, *s*, Si*t*Bu); ^{13}C NMR: δ 137.8, 133.0, 132.8 (arom. C), 136.0, 135.9, 129.8, 129.7, 128.4, 128.1, 127.7, 127.6, 127.5 (arom. CH), 107.7 (acetonide C), 77.6 (C-3), 76.8 (NO*C*H$_2$Ph), 66.2 (C-4), 64.7 (C-1), 64.5 (C-2), 37.5 (*C*Me$_3$), 28.1 (C*Me*$_3$), 27.1 (SiC*Me*$_3$), 26.4, 25.5 (2×acetonide Me), 19.1 (Si*C*Me$_3$). Anal. calcd for $C_{34}H_{47}NO_4Si$: C, 72.69; H, 8.43; N, 2.49. Found: C, 72.80; H, 8.30; N, 2.45.

*3.6.6. (2*S,*3*S*)-1-O-*t*-Butyldiphenylsilyl-3,4-O-isopropylidene-2-(N-benzyloxyamino)-2-*t*-butylbutane-1,3,4-triol (*ent-***3a**, *R*=t*Bu)*

Oil, $[\alpha]_D$ +8.0 ($CHCl_3$, *c* 2). Other physical properties identical to those of **3a** (R=*t*Bu). Anal. calcd for $C_{34}H_{47}NO_4Si$: C, 72.69; H, 8.43; N, 2.49. Found: C, 72.77; H, 8.55; N, 2.61.

*3.6.7. (2*R,*3*R*)-1-O-*t*-Butyldiphenylsilyl-3,4-O-isopropylidene-2-(N-benzyloxyamino)-2-phenylbutane-1,3,4-triol (***3a**, *R=Ph)*

Oil, $[\alpha]_D$ +1.1 ($CHCl_3$, *c* 1.3); IR ν_{max} cm^{-1}: 3400 (br, NH), 3054; FABMS, *m/z* 582.3036 ($M+H^+$). Calcd for $C_{36}H_{44}NO_4Si$, M=582.3040; ^1H NMR: δ 7.75–7.50 (6H, *m*, arom.), 7.45–7.25 (14H, *m*, arom.), 6.50 (1H, *br s*, NH), 4.84 (2H, *s*, NOC*H*$_2$Ph), 4.54 (1H, *dd*, J=8.2, 6.7 Hz, H-3), 4.35 (1H, *d*, J=9.6 Hz, H-1), 4.04 (1H, *d*, J=9.6 Hz, H-1′), 3.97 (1H, *dd*, J=8.2, 6.7 Hz, H-4), 3.67 (1H, *t*, J=8.2 Hz, H-4′), 1.35, 1.13 (2×3H, 2×acetonide Me), 0.98 (9H, *s*, Si*t*Bu); ^{13}C NMR: δ 137.7, 137.6, 133.3, 133.1 (arom. C), 135.7, 135.6, 129.7, 129.6, 128.5, 128.4, 128.1, 127.9, 127.6, 127.5, 127.2 (arom. CH), 108.5 (acetonide C), 76.1 (C-3, NO*C*H$_2$Ph), 67.6 (C-2), 66.1 (C-4), 63.7 (C-1), 26.7 (SiC*Me*$_3$), 26.0, 25.2 (2×acetonide Me), 19.3 (Si*C*Me$_3$). Anal. calcd for $C_{36}H_{45}NO_4Si$: C, 74.06; H, 7.77; N, 2.40. Found: C, 73.97; H, 7.90; N, 2.48.

*3.6.8. (2*S,*3*S*)-1-O-*t*-Butyldiphenylsilyl-3,4-O-isopropylidene-2-(N-benzyloxyamino)-2-phenylbutane-1,3,4-triol (*ent-***3a**, *R=Ph)*

Oil, $[\alpha]_D$ −1.5 ($CHCl_3$, *c* 2.1). Other physical properties identical to those of **3a** (R=Ph). Anal. calcd for $C_{36}H_{45}NO_4Si$: C, 74.06; H, 7.77; N, 2.40. Found: C, 74.10; H, 7.88; N, 2.51.

*3.6.9. (2*R,*3*R*)-1-O-*t*-Butyldiphenylsilyl-3,4-di-O-benzyl-2-(N-benzyloxyamino)-2-methylbutane-1,3,4-triol (***3b**, *R=Me)*

Oil, $[\alpha]_D$ −4.2 ($CHCl_3$, *c* 2.6); IR ν_{max} cm^{-1}: 3400 (br, NH), 3058, 3031; FABMS, *m/z* 660.3521 ($M+H^+$). Calcd for $C_{42}H_{50}NO_4Si$, M=660.3509; ^1H NMR: δ 7.70–7.60 (4H, *m*, arom.), 7.40–7.15 (21H, *m*, arom.), 4.90, 4.52 (2H, AB system, J=11.5 Hz, OC*H*$_2$Ph), 4.68, 4.62 (2H, AB system, J=11.5 Hz, NOC*H*$_2$Ph), 4.58 (2H, *s*, OC*H*$_2$Ph), 4.09 (1H, *dd*, J=10, 1.5 Hz, H-4), 3.84 (1H, *dd*, J=7.5, 1.5 Hz, H-3), 3.77 (1H, *d*, J=9.5 Hz, H-1), 3.75 (1H, *dd*, J=10, 7.5 Hz, H-4′), 3.70 (1H, *d*, J=9.5 Hz, H-1′), 1.05 (9H, *s*,

Si*t*Bu), 1.03 (3H, s, *Me*C_2); ^{13}C NMR: δ 139.0, 138.7, 138.1, 133.3, 133.2 (arom. C), 135.7, 135.6, 129.6, 129.5, 128.4, 128.3, 128.2, 128.1, 127.6, 127.5, 127.4, 127.2 (arom. CH), 79.4 (C-3), 76.6 (NO*C*H_2Ph), 74.0, 73.3 (2×O*C*H_2Ph), 72.9 (C-4), 64.0 (C-1), 63.6 (C-2), 26.9 (SiC*Me*$_3$), 19.3 (Si*C*Me$_3$), 15.0 (*Me*C_2). Anal. calcd for $C_{42}H_{49}NO_4Si$: C, 76.44; H, 7.48; N, 2.12. Found: C, 76.80; H, 7.31; N, 2.15.

*3.6.10. (2*R,*3*R*)-1-O*-t-*Butyldiphenylsilyl-3,4-di-O-benzyl-2-(N-benzyloxyamino)-2*-n-*butylbutane-1,3,4-triol (**3b**, R*=n*Bu)*

Oil, $[\alpha]_D$ +5.1 ($CHCl_3$, *c* 1.3); IR ν_{max} cm^{-1}: 3350 (br, NH), 3067, 3031; CIMS, *m/z* (% rel. int.): 702.3960 (M+H$^+$). Calcd for $C_{45}H_{56}NO_4Si$, M=702.3978; ^{1}H NMR: δ 7.70–7.60 (4H, *m*, arom.), 7.40–7.20 (21H, *m*, arom.), 4.95, 4.55 (2H, AB system, J=11.5 Hz, OC*H*$_2$Ph), 4.66, 4.59 (2H, AB system, J=11.5 Hz, NOC*H*$_2$Ph), 4.56 (2H, *s*, OC*H*$_2$Ph), 4.06 (1H, *dd*, J=10, 1 Hz, H-4), 3.93 (1H, *d*, J=7.5, 1 Hz, H-3), 3.84 (1H, *dd*, J=10, 7.5 Hz, H-4′), 3.75 (1H, *d*, J=10 Hz, H-1), 3.66 (1H, *d*, J=10 Hz, H-1′), 1.50 (2H, *m*, C*H*$_2$C$_3$H$_7$), 1.45–1.20 (4H, *m*, C*H*$_2$C*H*$_2$Me), 1.04 (9H, *s*, Si*t*Bu), 0.89 (3H, *t*, J=7 Hz, CH$_2$*Me*); ^{13}C NMR: δ 139.3, 138.6, 138.0, 133.3, 133.2 (arom. C), 135.7, 129.6, 129.5, 128.3, 128.2, 128.1, 127.7, 127.6, 127.5, 127.4, 127.1 (arom. CH), 80.4 (C-3), 76.3 (NO*C*H_2Ph), 74.1, 73.5 (2×O*C*H_2Ph), 73.3 (C-4), 65.3 (C-2), 62.4 (C-1), 29.9 (*C*H_2C$_3$H$_7$), 26.9 (SiC*Me*$_3$), 25.8, 23.8 (*C*H_2*C*H_2Me), 19.3 (Si*C*Me$_3$), 14.1 (CH$_2$*Me*). Anal. calcd for $C_{45}H_{55}NO_4Si$: C, 76.99; H, 7.90; N, 2.00. Found: C, 76.88; H, 7.71; N, 2.10.

*3.6.11. (2*R,*3*R*)-1-O*-t-*Butyldiphenylsilyl-3,4-di-O-benzyl-2-(N-benzyloxyamino)-2-phenylbutane-1,3,4-triol (**3b**, R=Ph)*

Oil, $[\alpha]_D$ −8.5 ($CHCl_3$, *c* 3.1); IR ν_{max} cm^{-1}: 3350 (br, NH), 3065, 3031; CIMS, *m/z* (% rel. int.): 722.3667 (M+H$^+$). Calcd for $C_{47}H_{52}NO_4Si$, M=722.3665; ^{1}H NMR: δ 7.60–7.45 (6H, *m*, arom.), 7.40–7.15 (24H, *m*, arom.), 4.90, 4.57 (2H, AB system, J=11.5 Hz, OC*H*$_2$Ph), 4.76 (2H, *s*, NOC*H*$_2$Ph), 4.44, 4.41 (2H, AB system, J=12 Hz, OC*H*$_2$Ph), 4.30 (1H, *d*, J=10 Hz, H-1), 4.19 (1H, *d*, J=10 Hz, H-1′), 4.18 (1H, *dd*, J=7.5, 1.5 Hz, H-3), 4.02 (1H, *dd*, J=10.5, 1.5 Hz, H-4), 3.24 (1H, *dd*, J=10.5, 7.5 Hz, H-4′), 0.92 (9H, *s*, Si*t*Bu); ^{13}C NMR: δ 139.0, 138.7, 138.6, 137.8, 133.4, 133.1 (arom. C), 135.8, 135.6, 129.5, 128.5, 128.4, 128.1, 127.7, 127.6, 127.5, 127.4, 127.2, 127.1, 126.9 (arom. CH), 79.7 (C-3), 76.4 (NO*C*H_2Ph), 74.2, 74.0 (2×O*C*H_2Ph), 73.2 (C-4), 68.1 (C-2), 63.2 (C-1), 26.8 (SiC*Me*$_3$), 19.3 (Si*C*Me$_3$). Anal. calcd for $C_{47}H_{51}NO_4Si$: C, 78.19; H, 7.12; N, 1.94. Found: C, 78.00; H, 7.31; N, 2.00.

*3.6.12. (2*R,*3*R*)-1-O*-t-*Butyldiphenylsilyl-3,4-di-O-benzyl-2-(N-benzyloxyamino)-2-allylbutane-1,3,4-triol (**3b**, R=allyl)*

Oil, $[\alpha]_D$ +7.0 ($CHCl_3$, *c* 2.9); IR ν_{max} cm^{-1}: 3350 (br, NH), 3067; FABMS, *m/z* 686.3674 (M+H$^+$). Calcd for $C_{44}H_{52}NO_4Si$, M=686.3665; ^{1}H NMR: δ 7.65–7.60 (4H, *m*, arom.), 7.40–7.20 (21H, *m*, arom.), 5.94 (1H, *ddt*, J=17.3, 10.2, 7.5 Hz, C*H*=CH$_2$), 5.02 (1H, *br dd*, J=17.3, 2 Hz, CH=C*H*$_2$), 4.99 (1H, *br dd*, J=10.2, 2 Hz, CH=C*H*$_2$), 4.92, 4.52 (2H, AB system, J=11.5 Hz, OC*H*$_2$Ph), 4.63, 4.59 (2H, AB system, J=11.5 Hz, NOC*H*$_2$Ph), 4.51 (2H, *s*, OC*H*$_2$Ph), 4.00 (1H, *dd*, J=10, 1 Hz, H-4), 3.90 (1H, *dd*, J=8, 1 Hz, H-3), 3.83 (1H, *dd*, J=10, 8 Hz, H-4′), 3.72 (1H, *d*, J=10 Hz, H-1), 3.62 (1H, *d*, J=10 Hz, H-1′), 2.35 (2H, *br d*, J=7.5 Hz, CH$_2$C=C), 1.01 (9H, *s*, Si*t*Bu); ^{13}C NMR: δ 139.2, 138.6, 137.8, 133.2, 133.1 (arom. C), 134.6 (*C*H=CH$_2$), 135.7, 129.5, 128.3, 128.2, 128.1, 127.6, 127.5, 127.4, 127.1 (arom. CH), 117.0 (CH=*C*H$_2$), 80.2 (C-3), 76.3 (NO*C*H_2Ph), 74.1, 73.2 (2×O*C*H_2Ph), 73.1 (C-4), 65.5 (C-2), 62.7 (C-1), 34.9 (*C*H_2C=C), 26.9 (SiC*Me*$_3$), 19.2 (Si*C*Me$_3$). Anal. calcd for $C_{44}H_{51}NO_4Si$: C, 77.04; H, 7.49; N, 2.04. Found: C, 77.00; H, 7.32; N, 1.92.

*3.6.13. (2*R,*3*R*)-1-O-Trityl-3,4-O-isopropylidene-2-(N-benzyloxyamino)-2-methylbutane-1,3,4-triol (**3c**, R=Me)*

Oil, $[\alpha]_D$ −4.7 ($CHCl_3$, *c* 7.2); IR ν_{max} cm^{-1}: 3400 (br, NH), 3060, 3030; CIMS, *m/z* (% rel. int.): 524.2807 ($M+H^+$). Calcd for $C_{34}H_{38}NO_4$, M=524.2800; ^1H NMR (200 MHz): δ 7.60–7.50 (6H, *m*, arom.), 7.50–7.20 (14H, *m*, arom.), 6.10 (1H, *br s*, NH), 4.70 (2H, *s*, NOCH_2Ph), 4.34 (1H, *t*, J=7 Hz, H-3), 4.10–3.90 (2H, *m*, H-4, H-4′), 3.45 (1H, *d*, J=8.8 Hz, H-1), 3.18 (1H, *d*, J=8.8 Hz, H-1′), 1.40 (6H, 2×acetonide Me), 1.17 (3H, s, *Me*C_2); ^{13}C NMR: δ 144.1, 137.9 (arom. C), 129.2, 129.1, 129.0, 128.4, 128.3, 128.0, 127.9, 127.4, 127.1 (arom. CH), 108.6 (acetonide C), 86.6 (*C*Ph_3), 77.3 (C-3), 76.8 (NO*C*H_2Ph), 65.4 (C-4), 64.3 (C-1), 61.7 (C-2), 26.4, 25.2 (2×acetonide Me), 15.6 (*Me*C_2). Anal. calcd for $C_{34}H_{37}NO_4$: C, 77.98; H, 7.12; N, 2.67. Found: C, 78.11; H, 7.30; N, 2.42.

*3.6.14. (2*R,*3*R*)-1-O-Trityl-3,4-O-isopropylidene-2-(N-benzyloxyamino)-2-*n*-butylbutane-1,3,4-triol (**3c**, R=n-Bu)*

Oil, $[\alpha]_D$ −9.6 ($CHCl_3$, *c* 2.2); IR ν_{max} cm^{-1}: 3300 (br, NH), 3061, 3031; FABMS, *m/z* 566.3257 ($M+H^+$). Calcd for $C_{37}H_{44}NO_4$, M=566.3270; ^1H NMR: δ 7.50–7.40 (6H, *m*, arom.), 7.40–7.20 (14H, *m*, arom.), 4.57 (2H, *s*, NOCH_2Ph), 4.30 (1H, *dd*, J=8.2, 6.8 Hz, H-3), 3.98 (1H, *t*, J=8.2 Hz, H-4), 3.83 (1H, *dd*, J=8.2, 6.8 Hz, H-4′), 3.33 (1H, *d*, J=9 Hz, H-1), 3.12 (1H, *d*, J=9 Hz, H-1′), 1.60–1.50 (2H, *m*, C$H_2C_3H_7$), 1.33, 1.32 (2×3H, 2×acetonide Me), 1.30–1.10 (4H, *m*, CH_2CH_2Me), 0.83 (3H, *t*, J=7 Hz, CH_2*Me*); ^{13}C NMR: δ 143.8, 137.8 (arom. C), 128.8, 128.3, 128.2, 128.0, 127.9, 127.7, 127.0 (arom. CH), 108.0 (acetonide C), 86.7 (*C*Ph_3), 78.2 (C-3), 76.7 (NO*C*H_2Ph), 65.5 (C-4), 63.0 (C-2), 62.8 (C-1), 30.9 (*C*$H_2C_3H_7$), 26.3, 25.2 (2×acetonide Me), 25.2, 23.7 (*C*H_2*C*H_2Me), 14.1 (CH_2*Me*). Anal. calcd for $C_{37}H_{43}NO_4$: C, 78.55; H, 7.66; N, 2.48. Found: C, 78.43; H, 7.39; N, 2.41.

*3.6.15. (2*R,*3*R*)-1-O-Trityl-3,4-O-isopropylidene-2-(N-benzyloxyamino)-2-*t*-butylbutane-1,3,4-triol (**3c**, R=t-Bu)*

Oil, $[\alpha]_D$ −2.5 ($CHCl_3$, *c* 1.7); IR ν_{max} cm^{-1}: 3400 (br, NH), 3060, 3029; FABMS, *m/z* 566.3257 ($M+H^+$). Calcd for $C_{37}H_{44}NO_4$, M=566.3270; ^1H NMR: δ 7.50–7.40 (6H, *m*, arom.), 7.35–7.20 (14H, *m*, arom.), 4.47 (2H, *s*, NOCH_2Ph), 4.44 (1H, *dd*, J=8.2, 6.5 Hz, H-3), 3.93 (1H, *t*, J=8.2 Hz, H-4), 3.57 (1H, *dd*, J=8.2, 6.5 Hz, H-4′), 3.46 (1H, *d*, J=10 Hz, H-1), 3.33 (1H, *d*, J=10 Hz, H-1′), 1.31 (6H, 2×acetonide Me), 1.05 (9H, *s*, *t*Bu); ^{13}C NMR: δ 143.4, 137.9 (arom. C), 129.1, 128.7, 128.6, 128.3, 128.1, 127.9, 127.8, 127.7, 127.4, 127.2, 127.1, 126.8 (arom. CH), 107.6 (acetonide C), 87.8 (*C*Ph_3), 77.9 (C-3), 76.7 (NO*C*H_2Ph), 66.3 (C-4), 64.9 (C-2), 63.5 (C-1), 37.8 (*C*Me_3), 27.9 (C*Me*$_3$), 26.4, 25.4 (2×acetonide Me). Anal. calcd for $C_{37}H_{43}NO_4$: C, 78.55; H, 7.66; N, 2.48. Found: C, 78.62; H, 7.49; N, 2.61.

*3.6.16. (2*R,*3*R*)-1-O-Trityl-3,4-O-isopropylidene-2-(N-benzyloxyamino)-2-phenylbutane-1,3,4-triol (**3c**, R=Ph)*

Oil, $[\alpha]_D$ −16.0 ($CHCl_3$, *c* 4.3); IR ν_{max} cm^{-1}: 3400 (br, NH), 3060, 3030; FABMS, *m/z* 586.2960 ($M+H^+$). Calcd for $C_{39}H_{40}NO_4$, M=586.2957; ^1H NMR: δ 7.40–7.20 (25H, *m*, arom.), 4.72 (2H, *s*, NOCH_2Ph), 4.51 (1H, *t*, J=7.2 Hz, H-3), 3.83 (1H, *dd*, J=8, 7.2 Hz, H-4), 3.82 (1H, *d*, J=8.8 Hz, H-1), 3.61 (1H, *t*, J=8 Hz, H-4′), 3.49 (1H, *d*, J=8.8 Hz, H-1′), 1.26, 1.01 (2×3H, 2×acetonide Me); ^{13}C NMR: δ 143.7, 138.0, 137.6 (arom. C), 128.8, 128.3, 128.2, 127.9, 127.7, 127.6, 127.4, 127.1, 126.9 (arom. CH), 108.5 (acetonide C), 86.5 (*C*Ph_3), 76.7 (C-3), 76.1 (NO*C*H_2Ph), 66.9 (C-2), 65.8 (C-4), 62.9 (C-1), 25.8, 25.2 (2×acetonide Me). Anal. calcd for $C_{39}H_{39}NO_4$: C, 79.97; H, 6.71; N, 2.39. Found: C, 80.08; H, 6.72; N, 2.63.

*3.6.17. (2*R,*3*R*)-1-O-Trityl-3,4-di-O-benzyl-2-(N-benzyloxyamino)-2-methylbutane-1,3,4-triol (**3d**, R=Me)*

Oil, $[\alpha]_D$ −10.6 ($CHCl_3$, *c* 0.4); IR ν_{max} cm^{-1}: 3400 (br, NH), 3061, 3030; FABMS, *m/z* 664.3398 ($M+H^+$). Calcd for $C_{45}H_{46}NO_4$, M=664.3426; ^1H NMR: δ 7.40–7.20 (30H, *m*, arom.), 4.79, 4.38 (2H, AB system, J=11.5 Hz, OC*H*$_2$Ph), 4.63, 4.58 (2H, AB system, J=11.5 Hz, NOC*H*$_2$Ph), 4.48 (2H, *s*, OC*H*$_2$Ph), 3.91 (1H, *dd*, J=10.2, 1.8 Hz, H-4), 3.82 (1H, *dd*, J=7.7, 1.8 Hz, H-3), 3.61 (1H, *dd*, J=10.2, 7.7 Hz, H-4′), 3.27 (1H, *d*, J=8.8 Hz, H-1), 3.18 (1H, *d*, J=8.8 Hz, H-1′), 1.02 (3H, s, *Me*C_2); ^{13}C NMR: δ 144.0, 139.0, 138.6, 137.9 (arom. C), 129.8, 128.3, 128.2, 128.1, 128.0, 127.7, 127.6, 127.5, 127.4, 127.1, 126.8 (arom. CH), 86.4 (*C*Ph_3), 80.1 (C-3), 76.6 (NO*C*H_2Ph), 74.0, 73.2 (2×O*C*H_2Ph), 72.5 (C-4), 63.5 (C-1), 63.1 (C-2), 16.3 (*Me*C_2). Anal. calcd for $C_{45}H_{45}NO_4$: C, 81.42; H, 6.83; N, 2.11. Found: C, 81.28; H, 6.72; N, 2.23.

*3.6.18. (2*R,*3*R*)-1-O-Trityl-3,4-di-O-benzyl-2-(N-benzyloxyamino)-2-*n*-butylbutane-1,3,4-triol (**3d**, R=n*Bu)*

Oil, $[\alpha]_D$ −1.6 ($CHCl_3$, *c* 3.8); IR ν_{max} cm^{-1}: 3400 (br, NH), 3088, 3061, 3032; FABMS, *m/z* 706.3878 ($M+H^+$). Calcd for $C_{48}H_{52}NO_4$, M=706.3896; ^1H NMR: δ 7.45–7.20 (30H, *m*, arom.), 4.90, 4.50 (2H, AB system, J=11.5 Hz, OC*H*$_2$Ph), 4.68, 4.62 (2H, AB system, J=11.5 Hz, NOC*H*$_2$Ph), 4.52 (2H, *s*, OC*H*$_2$Ph), 3.93 (2H, *m*, H-3, H-4), 3.73 (1H, *dd*, J=10.5, 8 Hz, H-4′), 3.24 (2H, *s*, H-1, H-1′), 1.50–1.40 (2H, *m*, C*H*$_2$$C_3H_7$), 1.30–1.00 (4H, *m*, C*H*$_2$C*H*$_2$Me), 0.83 (3H, *t*, J=7 Hz, CH_2*Me*); ^{13}C NMR: δ 143.9, 139.3, 138.6, 138.0 (arom. C), 128.9, 128.8, 128.3, 128.2, 128.1, 128.0, 127.7, 127.6, 127.5, 127.4, 127.3, 127.0, 126.8 (arom. CH), 86.6 (*C*Ph_3), 80.8 (C-3), 76.4 (NO*C*H_2Ph), 74.2, 73.2 (2×O*C*H_2Ph), 73.1 (C-4), 64.9 (C-2), 61.6 (C-1), 30.6 (*C*$H_2$$C_3H_7$), 25.5, 23.7 (*C*$H_2$*C*$H_2$Me), 14.0 ($CH_2$*Me*). Anal. calcd for $C_{48}H_{51}NO_4$: C, 81.67; H, 7.28; N, 1.98. Found: C, 81.48; H, 7.44; N, 2.13.

*3.6.19. (2*R,*3*R*)-1-O-Trityl-3,4-di-O-benzyl-2-(N-benzyloxyamino)-2-phenylbutane-1,3,4-triol (**3d**, R=Ph)*

Oil, $[\alpha]_D$ −18.8 ($CHCl_3$, *c* 2.6); IR ν_{max} cm^{-1}: 3350 (br, NH), 3060, 3030; FABMS, *m/z* 726.3617 ($M+H^+$). Calcd for $C_{50}H_{48}NO_4$, M=726.3583; ^1H NMR: δ 7.60–7.20 (35H, *m*, arom.), 6.70 (1H, *br s*, NH), 4.78, 4.42 (2H, AB system, J=11.5 Hz, OC*H*$_2$Ph), 4.69, 4.66 (2H, AB system, J=11.5 Hz, NOC*H*$_2$Ph), 4.37, 4.34 (2H, AB system, J=12 Hz, OC*H*$_2$Ph), 4.15 (1H, *dd*, J=7.7, 1.5 Hz, H-3), 3.88 (1H, *br d*, J=10.2 Hz, H-4), 3.74 (2H, *s*, H-1, H-1′), 3.18 (1H, *dd*, J=10.2, 7.7 Hz, H-4′); ^{13}C NMR: δ 143.7, 138.9, 138.6, 137.8 (arom. C), 128.9, 128.3, 128.0, 127.6, 127.5, 127.4, 127.3, 127.1, 127.0, 126.8 (arom. CH), 86.5 (*C*Ph_3), 80.5 (C-3), 76.4 (NO*C*H_2Ph), 74.2, 73.1 (2×O*C*H_2Ph), 73.4 (C-4), 67.5 (C-2), 62.5 (C-1). Anal. calcd for $C_{50}H_{47}NO_4$: C, 82.73; H, 6.53; N, 1.93. Found: C, 82.49; H, 6.44; N, 2.15.

3.7. General desilylation procedure

A solution of the substrate (1 mmol) in dry THF (15 ml) was treated with solid tetra-*n*-butylammonium fluoride trihydrate (331 mg, 1.05 mmol) and stirred at room temperature for 2 h. After adding water (1 ml), the volatiles were totally eliminated at reduced pressure. Column chromatography of the residue (hexane/EtOAc mixtures) provided the desilylation product with yields in the range 75–95%.

3.8. General benzylation procedure

An 80% suspension of NaH in mineral oil (45 mg, ca. 1.5 mmol of sodium hydride) was washed three times under Ar with dry hexane. Dry THF (1 ml) was then added, followed by a solution of the substrate

(1 mmol) in dry THF (3 ml). The solution was stirred at room temperature for 30 min. Benzyl bromide (0.15 ml, 1.2 mmol) was then added dropwise, followed by nBu$_4$N$^+$I$^-$ (37 mg, 0.1 mmol). The reaction mixture was then heated at reflux for 3 h. Work-up (Et_2O) and column chromatography (hexane/EtOAc mixtures) furnished the desired benzylation product. For compounds having three free hydroxyl groups, the proportions of NaH and benzyl bromide were increased to 4.5 and 3.5 equiv., respectively. Yields were usually about 80–85% in the monobenzylations and about 50–55% in the tribenzylations.

3.9. General acetonide hydrolysis procedure

The substrate (1 mmol) was dissolved in a MeOH:H_2O (9:1) mixture (5 ml). After addition of PPTS (25 mg, 0.1 mmol), the solution was heated at reflux for 12 h. After cooling the reaction mixture to room temperature, solid Na_2CO_3 (15 mg) was added. The reaction mixture was then filtered through Celite, the reaction flask and the Celite were washed two times with EtOAc. The organic phases were evaporated at reduced pressure and the oily residue was chromatographed on silica gel (hexane/EtOAc mixtures) to afford the desired hydrolysis product with yields in the range 70–90%.

3.10. General detritylation procedure[26]

A 1.8 M solution of trifluoroacetic acid/trifluoroacetic anhydride was prepared by dissolving these reagents in the appropriate amount of dry CH_2Cl_2. The substrate (1 mmol) was then dissolved under Ar in dry CH_2Cl_2 (2 ml) and treated dropwise at room temperature with the aforementioned solution (1.6 ml, ca. 7.5 equiv.). The reaction mixture turned yellow and was then cooled to 0°C, followed by addition of triethylamine (1.25 ml, 9 mmol). After stirring for 5 min, the reaction mixture was poured into MeOH (25 ml). Stirring was continued for 30 min at room temperature. After removal of all solvents at reduced pressure, the residue was chromatographed (hexane/EtOAc mixtures) to yield the desired detritylation product with yields in the range 70–80%.

3.11. Formation of oxazolidinones ***6***

A solution of the appropriate amino alcohol (0.2 mmol) in dry CH_2Cl_2 (2 ml) was successively treated under Ar with Et_3N (80 μl, ca. 0.6 mmol) and triphosgene (60 mg, ca. 0.2 mmol). The reaction mixture was then stirred at room temperature for 2 days. Work-up (CH_2Cl_2) and column chromatography (hexane/EtOAc mixtures) furnished oxazolidinones **6** with yields in the range 40–50%.

*3.11.1. (2*R*,3*R*)-3,4-O-Isopropylidene-2-(N-benzyloxyamino)-2-methylbutane-1,3,4-triol (**5**, R=Me)*

Oil, $[\alpha]_D$ −8.2 ($CHCl_3$, *c* 5); IR ν_{max} cm^{-1}: 3450 (br, OH), 3088, 3064, 3031; FABMS, *m/z* 282.1703 (M+H$^+$). Calcd for $C_{15}H_{24}NO_4$, M=282.1705; ^{1}H NMR: δ 7.40–7.30 (5H, *m*, arom.), 4.64 (2H, *s*, NOC*H*$_2$Ph), 4.18 (1H, *t*, J=6.8 Hz, H-3), 3.91 (1H, *dd*, J=8.5, 6.8 Hz, H-4), 3.89 (1H, *dd*, J=8.5, 6.8 Hz, H-4′), 3.65 (1H, *d*, J=11.5 Hz, H-1), 3.57 (1H, *d*, J=11.5 Hz, H-1′), 1.40, 1.31 (2×3H, 2×acetonide Me), 0.99 (3H, s, *Me*C$_2$); ^{13}C NMR: δ 137.4 (arom. C), 128.6, 128.4, 128.0 (arom. CH), 108.9 (acetonide C), 77.5 (C-3), 77.1 (NO*C*H$_2$Ph), 65.2, 65.1 (C-1, C-4), 61.4 (C-2), 26.2, 24.8 (2×acetonide Me), 15.1 (*Me*C$_2$). Anal. calcd for $C_{15}H_{23}NO_4$: C, 64.04; H, 8.24; N, 4.98. Found: C, 64.39; H, 8.44; N, 5.14.

*3.11.2. (2*R*,3*R*)-3,4-O-Isopropylidene-2-(N-benzyloxyamino)-2-*n*-butylbutane-1,3,4-triol (**5**, R=n*Bu)*

Oil, $[\alpha]_D$ −16.0 ($CHCl_3$, *c* 0.7); IR ν_{max} cm^{-1}: 3450 (br, OH), 3088, 3064, 3031; CIMS, *m/z* (% rel. int.): 324.2168 (M+H$^+$). Calcd for $C_{18}H_{30}NO_4$, M=324.2174; ^{1}H NMR: δ 7.40–7.30 (5H, *m*, arom.),

6.00 (1H, *br s*, NH), 4.66 (2H, *s*, NOC*H*$_2$Ph), 4.22 (1H, *dd*, J=7.7, 6.6 Hz, H-3), 3.93 (2H, *m*, H-4, H-4′), 3.62 (2H, *br s*, H-1, H-1′), 2.50 (1H, *br s*, OH), 1.60–1.20 (6H, *m*, C*H*$_2$C*H*$_2$C*H*$_2$), 1.40, 1.31 (2×3H, 2×acetonide Me), 0.90 (3H, *t*, J=7.5 Hz, Me); ^{13}C NMR: δ 137.5 (arom. C), 128.5, 128.4, 127.9 (arom. CH), 108.5 (acetonide C), 78.3 (C-3), 76.7 (NO*C*H$_2$Ph), 65.2 (C-4), 64.2 (C-1), 62.6 (C-2), 29.9 (*C*H$_2$–C$_3$H$_7$), 26.3, 24.9 (2×acetonide Me), 25.2, 23.5 (*C*H$_2$*C*H$_2$Me), 14.1 (CH$_2$*Me*). Anal. calcd for $C_{18}H_{29}NO_4$: C, 66.84; H, 9.04; N, 4.33. Found: C, 66.55; H, 8.93; N, 4.13.

*3.11.3. (2*R,*3*R*)-3,4-O-Isopropylidene-2-(N-benzyloxyamino)-2-*t*-butylbutane-1,3,4-triol (**5**, R=t*Bu)*

Oil, $[\alpha]_D$ −40.0 ($CHCl_3$, *c* 0.7); IR ν_{max} cm^{-1}: 3440 (br, OH), 3086, 3065, 3030; CIMS, *m/z* (% rel. int.): 324.2177 (M+H$^+$). Calcd for $C_{18}H_{30}NO_4$, M=324.2174; ^{1}H NMR: δ 7.40–7.30 (5H, *m*, arom.), 4.71, 4.69 (2H, AB system, J=11.5 Hz, NOC*H*$_2$Ph), 4.34 (1H, *dd*, J=9, 5.7 Hz, H-3), 4.09 (1H, *dd*, J=8.5, 5.7 Hz, H-4), 4.00 (1H, *dd*, J=9, 8.5 Hz, H-4′), 3.84 (1H, *br d*, J=12 Hz, H-1), 3.58 (1H, *br dd*, J=12, 7 Hz, H-1′), 2.20 (1H, *br s*, OH), 1.36, 1.33 (2×3H, 2×acetonide Me), 1.02 (9H, *s*, *t*Bu); ^{13}C NMR: δ 137.3 (arom. C), 128.7, 128.5, 128.1 (arom. CH), 106.6 (acetonide C), 78.4 (C-3), 76.7 (NO*C*H$_2$Ph), 66.8 (C-4), 65.6 (C-2), 63.2 (C-1), 37.4 (*C*Me$_3$), 27.2 (C*Me*$_3$), 26.5, 25.7 (2×acetonide Me). Anal. calcd for $C_{18}H_{29}NO_4$: C, 66.84; H, 9.04; N, 4.33. Found: C, 66.63; H, 9.15; N, 4.29.

*3.11.4. (2*R,*3*R*)-3,4-O-Isopropylidene-2-(N-benzyloxyamino)-2-phenylbutane-1,3,4-triol (**5**, R=Ph)*

Oil, $[\alpha]_D$ −22.0 ($CHCl_3$, *c* 2.9); IR ν_{max} cm^{-1}: 3330 (br, OH), 3085, 3066, 3030; FABMS, *m/z* 344.1855 (M+H$^+$). Calcd for $C_{20}H_{26}NO_4$, M=344.1862; ^{1}H NMR: δ 7.55 (2H, *m*, arom.), 7.40–7.20 (8H, *m*, arom.), 6.50 (1H, *br s*, NH), 4.66 (2H, *s*, NOC*H*$_2$Ph), 4.38 (1H, *t*, J=7.2 Hz, H-3), 4.28 (1H, *br d*, J=11.5 Hz, H-1), 4.14 (1H, *br d*, J=11.5 Hz, H-1′), 3.70–3.60 (2H, *m*, H-4, H-4′), 2.50 (1H, *br s*, OH), 1.28, 1.27 (2×3H, 2×acetonide Me); ^{13}C NMR: δ 138.0, 137.4 (arom. C), 128.5, 128.4, 128.1, 127.9, 127.4 (arom. CH), 109.5 (acetonide C), 78.3 (C-3), 76.7 (NO*C*H$_2$Ph), 66.6 (C-2), 65.7 (C-4), 63.2 (C-1), 26.0, 24.8 (2×acetonide Me). Anal. calcd for $C_{20}H_{25}NO_4$: C, 69.95; H, 7.34; N, 4.08. Found: C, 69.65; H, 7.53; N, 4.15.

*3.11.5. (4*R,*5*R*)-3-Benzyloxy-4-methyl-4,5-bis(trityloxymethyl)-1,3-oxazolidin-2-one (**6**, R=Me, R′=R″=Tr, P=Bn)*

Colourless needles (from hexane/CH_2Cl_2), mp 242–246°C (dec.), $[\alpha]_D$ +5.8 ($CHCl_3$, *c* 0.4); IR ν_{max} cm^{-1}: 3059, 3031, 1787 (C=O); EIMS, *m/z* (% rel. int.): 751 (M$^+$, 0.5), 478 (M$^+$−CH$_2$OTr, 20), 243 (Ph$_3$C$^+$, 100). Calcd for $C_{51}H_{45}NO_5$, M=751; ^{1}H NMR: δ 7.50–7.10 (35H, *m*, arom.), 5.24, 4.85 (2H, AB system, J=10.2 Hz, NOC*H*$_2$Ph), 4.03 (1H, *dd*, J=8.7, 3.3 Hz, H-5), 3.52 (1H, *dd*, J=10.6, 8.7 Hz, C$_5$–C*H*$_2$OTr), 3.42 (1H, *d*, J=10.2 Hz, C$_4$–C*H*$_2$OTr), 2.66 (1H, *dd*, J=10.6, 3.3 Hz, C$_5$–C*H*$_2$OTr), 2.52 (1H, *d*, J=10.2 Hz, C$_4$–C*H*$_2$OTr), 0.82 (3H, *s*, *Me*–C$_4$); ^{13}C NMR: δ 158.7 (C=O), 143.3, 142.8, 135.3 (arom. C), 129.8, 128.9, 128.7, 128.6, 128.4, 127.8, 127.7, 127.0, 126.8 (arom. CH), 87.7, 86.9 (2×*C*Ph$_3$), 80.3 (C-5), 79.1 (NO*C*H$_2$Ph), 64.6 (C-4), 61.7 (C$_4$–*C*H$_2$OTr), 60.3 (C$_5$–*C*H$_2$OTr), 19.8 (*Me*–C$_4$). Anal. calcd for $C_{51}H_{45}NO_5$: C, 81.47; H, 6.03; N, 1.86. Found: C, 81.65; H, 6.20; N, 2.01.

*3.11.6. (4*R,*5*R*)-3-Benzyloxy-4-*n*-butyl-4,5-bis(trityloxymethyl)-1,3-oxazolidin-2-one (**6**, R=n*Bu, R′=R″=Tr, P=Bn)*

Colourless needles (from hexane/Et_2O), mp 270–275°C (dec.), $[\alpha]_D$ +18.7 ($CHCl_3$, *c* 1.2); IR ν_{max} cm^{-1}: 3059, 3031, 2930, 1785 (C=O); FABMS, *m/z* 794.3881 (M+H$^+$). Calcd for $C_{54}H_{52}NO_5$, M=794.3846; ^{1}H NMR: δ 7.50–7.00 (35H, *m*, arom.), 5.30, 4.85 (2H, AB system, J=10 Hz, NOC*H*$_2$Ph), 4.28 (1H, *dd*, J=8.6, 2 Hz, H-5), 3.58 (1H, *dd*, J=10.2, 8.6 Hz, C$_5$–C*H*$_2$OTr), 3.42 (1H, *d*, J=10 Hz, C$_4$–C*H*$_2$OTr), 2.54 (1H, *dd*, J=10.2, 2 Hz, C$_5$–C*H*$_2$OTr), 2.51 (1H, *d*, J=10 Hz, C$_4$–C*H*$_2$OTr),

1.30–1.10 (2H, *m*, C*H*$_2$–C$_3$H$_7$), 1.00–0.75 (4H, *m*, C*H*$_2$C*H*$_2$Me), 0.69 (3H, *t*, J=7.4 Hz, CH$_2$*Me*); ^{13}C NMR: δ 159.1 (C=O), 143.3, 142.7, 135.2 (arom. C), 129.7, 128.9, 128.7, 128.6, 128.5, 127.9, 127.7, 127.6, 126.9, 126.8 (arom. CH), 87.7, 86.8 (2×*C*Ph$_3$), 78.7 (C-5), 78.6 (NO*C*H$_2$Ph), 67.1 (C-4), 615 (C$_4$–*C*H$_2$OTr), 60.7 (C$_5$–*C*H$_2$OTr), 32.8 (*C*H$_2$–C$_3$H$_7$), 25.1, 22.9 (*C*H$_2$*C*H$_2$Me), 13.7 (CH$_2$*Me*). Anal. calcd for $C_{54}H_{51}NO_5$: C, 81.69; H, 6.47; N, 1.76. Found: C, 81.61; H, 6.27; N, 1.63.

*3.11.7. (4*R,*5*R*)-3-Benzyloxy-4-*t*-butyl-4-(*t*-butyldiphenylsilyloxymethyl)-5-(trityloxymethyl)-1,3-oxazolidin-2-one (**6**, R=t*Bu*, R′=Tr, R″=TPS, P=Bn)*

Colourless needles (from hexane/CH_2Cl_2), mp 251–255°C (dec.), $[\alpha]_D$ +39.1 ($CHCl_3$, *c* 2.5); IR ν_{max} cm^{-1}: 3058, 2957, 2858, 1785 (C=O); CIMS, *m/z* (% rel. int.): 790.3938 (M+H$^+$). Calcd for $C_{51}H_{56}NO_5Si$, M=790.3928; ^{1}H NMR: δ 7.50–7.10 (30H, *m*, arom.), 5.46, 4.90 (2H, AB system, J=8.8 Hz, NOC*H*$_2$Ph), 4.46 (1H, *d*, J=7.5 Hz, H-5), 4.00 (1H, *d*, J=11 Hz, C*H*$_2$OTPS), 3.96 (1H, *dd*, J=11, 7.5 Hz, C*H*$_2$OTr), 3.01 (1H, *d*, J=11 Hz, C*H*$_2$OTPS), 2.80 (1H, *d*, J=11 Hz, C*H*$_2$OTr), 0.94 (9H, *s*, Si*t*Bu), 0.66 (9H, *s*, C$_4$-*t*Bu); ^{13}C NMR δ 159.8 (C=O), 143.5, 135.0, 132.7, 131.7 (arom. C), 136.2, 135.8, 130.0, 129.6, 127.9, 127.8, 127.7, 127.3, 127.1, 127.0 (arom. CH), 86.5 (*C*Ph$_3$), 78.8 (C-5), 76.9 (NO*C*H$_2$Ph), 72.6 (C-4), 63.5, 58.4 (*C*H$_2$OTr, *C*H$_2$OTPS), 34.8 (C$_4$–*C*Me$_3$), 26.8 (C$_4$–C*Me*$_3$), 26.4 (Si*CMe*$_3$), 18.7 (Si*C*Me$_3$). Anal. calcd for $C_{51}H_{55}NO_5Si$: C, 77.53; H, 7.02; N, 1.77. Found: C, 77.66; H, 7.24; N, 1.88.

*3.11.8. (4*R,*5*R*)-3-Benzyloxy-4-phenyl-4,5-bis(*t*-butyldimethylsilyloxymethyl)-1,3-oxazolidin-2-one (**6**, R=Ph, R′=R″=TBS, P=Bn)*

Colourless needles (from hexane/CH_2Cl_2), mp 110–112°C, $[\alpha]_D$ +55.3 ($CHCl_3$, *c* 0.9); IR ν_{max} cm^{-1}: 3065, 3034, 2950, 2928, 2887, 2856, 1788 (C=O); FABMS, *m/z* 558.3064 (M+H$^+$). Calcd for $C_{30}H_{48}NO_5Si_2$, M=558.3071; ^{1}H NMR: δ 7.50–7.20 (10H, *m*, arom.), 5.20, 4.74 (2H, AB system, J=10 Hz, NOC*H*$_2$Ph), 4.49 (1H, *t*, J=6.3 Hz, H-5), 4.25, 4.23 (2H, AB system, J=10.5 Hz, C$_4$–C*H*$_2$OTBS), 4.08 (2H, *m*, C$_5$–C*H*$_2$OTBS), 0.89, 0.80 (2×9H, 2×*s*, 2×Si*t*Bu), 0.03, 0.01, −0.01, −0.03 (4×3H, 4×*s*, SiMe); ^{13}C NMR: δ 158.9 (C=O), 138.2. 135.3 (arom. C), 129.0, 128.6, 128.4, 128.3, 128.1, 126.4 (arom. CH), 82.2 (C-5), 78.0 (NO*C*H$_2$Ph), 70.2 (C-4), 61.0, 60.6 (2×*C*H$_2$OTBS), 25.7 (2×SiC*Me*$_3$), 18.2 (2×Si*C*Me$_3$), −5.4, −5.6, −5.7, −6.0 (4×SiMe). Anal. calcd for $C_{30}H_{47}NO_5Si_2$: C, 64.59; H, 8.49; N, 2.51. Found: C, 64.64; H, 8.34; N, 2.80.

*3.12. Hydrogenolysis of **6** (R=Ph, R′=R″=TBS, P=Bn)*

A 10% Pd/C hydrogenation catalyst (15 mg) was suspended in MeOH (1 ml) and stirred for 10 min under an H_2 atmosphere. The substrate (0.1 mmol) was dissolved in MeOH (2 ml) and added via syringe to the catalyst suspension. The reaction mixture was then stirred for 48 h at room temperature. After this time, the mixture was filtered through Celite, the reaction flask and the Celite were washed two times with EtOAc, and the organic layers were concentrated at reduced pressure. Column chromatography of the oily residue (hexane:EtOAc=4:1) furnished the hydrogenolysis product **6** (R=Ph, R′=R″=TBS, P=H) as an oil, $[\alpha]_D$ +20.4 ($CHCl_3$, *c* 0.5); IR ν_{max} cm^{-1}: 3220 (br, OH), 1764 (C=O); FABMS, *m/z* 468.2596 (M+H$^+$). Calcd for $C_{23}H_{42}NO_5Si_2$, M=468.2601; ^{1}H NMR: δ 7.50–7.30 (5H, *m*, arom.), 4.40 (1H, *dd*, J=6.5, 6 Hz, H-5), 4.26 (1H, *dd*, J=11, 6 Hz, C$_5$–C*H*$_2$OTBS), 4.20 (1H, *d*, J=10.8 Hz, C$_4$–C*H*$_2$OTBS), 4.17 (1H, *dd*, J=11, 6.5 Hz, C$_5$–C*H*$_2$OTBS), 4.12 (1H, *d*, J=10.8 Hz, C$_4$–C*H*$_2$OTBS), 0.90, 0.87 (2×9H, 2×*s*, 2×Si*t*Bu), 0.10, 0.08, 0.07, 0.05 (4×3H, 4×*s*, SiMe); ^{13}C NMR: δ 161.3 (C=O), 137.8 (arom. C), 128.9, 128.2, 125.9 (arom. CH), 82.3 (C-5), 71.4 (C-4), 61.2 (2×*C*H$_2$OTBS), 25.8, 25.7 (2×SiC*Me*$_3$), 18.3, 18.1 (2×Si*C*Me$_3$), −5.4, −5.5, −5.6, −6.0 (4×SiMe). Anal. calcd for $C_{23}H_{41}NO_5Si_2$: C, 59.06;

H, 8.83; N, 2.99. Found: C, 58.88; H, 8.84; N, 3.11. The NOE measurements described in the text were performed on this debenzylation product.

*3.12.1. (4*R,*5*R*)-3-Benzyloxy-4-allyl-4-(*t*-butyldiphenylsilyloxymethyl)-5-(*t*-butyldimethylsilyloxymethyl)-1,3-oxazolidin-2-one (**6**, R=allyl, R′=TBS, R′′=TPS, P=Bn)*

Oil, IR ν_{max} cm^{-1}: 1791 (C=O); FABMS, *m/z* 588.2606 $(M-tBu)^+$. Calcd for $C_{33}H_{42}NO_5Si_2$, M=588.2601; ^{1}H NMR: δ 7.70–7.20 (15H, *m*, arom.), 5.76 (1H, *dddd*, J=17.5, 10, 8.5, 6 Hz, C*H*=CH_2), 5.26, 4.89 (2H, AB system, J=9.8 Hz, NOCH_2Ph), 5.14 (1H, *br d*, J=10 Hz, CH=CH_2), 5.06 (1H, *br d*, J=17.5 Hz, CH=CH_2), 4.34 (1H, *t*, J=6.5 Hz, H-5), 4.00–3.85 (3H, *m*, C_5–CH_2OTBS, C_4–CH_2OTPS), 3.44 (1H, *d*, J=11 Hz, CH_2OTPS), 2.28 (1H, *dd*, J=15, 6 Hz, CH_2C=C), 2.14 (1H, *dd*, J=15, 8.5 Hz, CH_2C=C), 1.04 (9H, *s*, Si*t*Bu), 0.79 (9H, *s*, Si*t*Bu), −0.02, −0.11 (2×3H, 2×*s*, SiMe); ^{13}C NMR: δ 158.8 (C=O), 135.0. 132.7, 131.9 (arom. C), 136.0, 135.7, 129.9, 129.6, 129.5, 128.6, 128.5, 127.8, 127.3 (arom. CH), 131.6 (*C*H=CH_2), 119.8 (CH=*C*H_2), 78.4 (NO*C*H_2Ph), 77.3 (C-5), 68.1 (C-4), 62.4 (C_4–*C*H_2OTPS), 60.9 (C_5–*C*H_2OTBS), 36.3 (*C*H_2C=C), 26.6, 25.8 (2×SiC*Me*$_3$), 18.8, 18.1 (2×Si*C*Me_3), −5.6, −5.7 (2×SiMe). Anal. calcd for $C_{37}H_{51}NO_5Si_2$: C, 68.80; H, 7.96; N, 2.17. Found: C, 68.81; H, 7.89; N, 2.01.

*3.12.2. (2*R,*3*R*)-3,4-Di-O-benzyl-2-(N-benzyloxyamino)-2-methylbutane-1,3,4-triol (**7**, R=Me)*

Oil, $[\alpha]_D$ +24.4 ($CHCl_3$, *c* 1); IR ν_{max} cm^{-1}: 3400 (br, OH), 3088, 3063, 3031; FABMS, *m/z* 422.2342 $(M+H^+)$. Calcd for $C_{26}H_{32}NO_4$, M=422.2331; ^{1}H NMR: δ 7.40–7.20 (15H, *m*, arom.), 4.78, 4.57 (2H, AB system, J=11.3 Hz, NOCH_2Ph), 4.66 (2H, *br s*, OCH_2Ph), 4.53 (2H, *s*, OCH_2Ph), 3.90 (1H, *dd*, J=5.8, 4 Hz, H-3), 3.82 (1H, *dd*, J=10.3, 4 Hz, H-4), 3.66 (1H, *d*, J=11 Hz, H-1′), 3.64 (1H, *dd*, J=10.3, 5.8 Hz, H-4′), 3.58 (1H, *d*, J=11 Hz, H-1′), 1.02 (3H, s, *Me*C_2); ^{13}C NMR: δ 138.3, 137.8, 137.5 (arom. C), 128.4, 128.3, 128.2, 128.1, 128.0, 127.8, 127.7, 127.6 (arom. CH), 79.6 (C-3), 77.0 (NO*C*H_2Ph), 73.8, 73.5 (2×O*C*H_2Ph), 70.3 (C-4), 65.4 (C-1), 63.2 (C-2), 16.2 (*Me*C_2). Anal. calcd for $C_{26}H_{31}NO_4$: C, 74.08; H, 7.41; N, 3.32. Found: C, 73.96; H, 7.59; N, 3.16.

*3.12.3. (2*R,*3*R*)-3,4-Di-O-benzyl-2-(N-benzyloxyamino)-2-*n*-butylbutane-1,3,4-triol (**7**, R=n*Bu)*

Oil, $[\alpha]_D$ +16.1 ($CHCl_3$, *c* 2.1); IR ν_{max} cm^{-1}: 3440 (br, OH), 3088, 3063, 3030; FABMS, *m/z* 464.2778 $(M+H^+)$. Calcd for $C_{29}H_{38}NO_4$, M=464.2800; ^{1}H NMR: δ 7.40–7.25 (15H, *m*, arom.), 4.80, 4.56 (2H, AB system, J=11.3 Hz, OCH_2Ph), 4.68, 4.65 (2H, AB system, J=11.5 Hz, NOCH_2Ph), 4.57, 4.53 (2H, AB system, J=11.5 Hz, OCH_2Ph), 3.94 (1H, *dd*, J=5.5, 3.4 Hz, H-3), 3.84 (1H, *dd*, J=10.5, 3.4 Hz, H-4), 3.68 (1H, *dd*, J=10.5, 5.5 Hz, H-4′), 3.64 (2H, *br s*, H-1, H-1′), 3.00 (1H, *br s*, OH), 1.50–1.20 (6H, *m*, CH_2CH_2CH_2), 0.89 (3H, *t*, J=7.5 Hz, Me); ^{13}C NMR: δ 138.4, 137.9, 137.8 (arom. C), 128.5, 128.4, 128.3, 127.8, 127.7, 127.6 (arom. CH), 80.3 (C-3), 76.5 (NO*C*H_2Ph), 73.9, 73.5 (2×O*C*H_2Ph), 70.4 (C-4), 64.6 (C-2), 64.1 (C-1), 30.2 (*C*$H_2$$C_3H_7$), 25.3, 23.5 (*C*$H_2$*C*$H_2$Me), 14.1 (Me). Anal. calcd for $C_{29}H_{37}NO_4$: C, 75.13; H, 8.04; N, 3.02. Found: C, 74.99; H, 8.19; N, 3.11.

*3.12.4. (2*R,*3*R*)-3,4-Di-O-benzyl-2-(N-benzyloxyamino)-2-phenylbutane-1,3,4-triol (**7**, R=Ph)*

Oil, $[\alpha]_D$ −1.0 ($CHCl_3$, *c* 0.7); IR ν_{max} cm^{-1}: 3440 (br, OH), 3088, 3062, 3030; FABMS, *m/z* 484.2493 $(M+H^+)$. Calcd for $C_{31}H_{34}NO_4$, M=484.2487; ^{1}H NMR: δ 7.50 (5H, *m*, arom.), 7.40–7.20 (15H, *m*, arom.), 4.76, 4.55 (2H, AB system, J=11.3 Hz, OCH_2Ph), 4.60 (2H, *s*, NOCH_2Ph), 4.37, 4.34 (2H, AB system, J=12 Hz, OCH_2Ph), 4.26 (1H, *dd*, J=11.3, 5 Hz, H-1), 4.15 (1H, *dd*, J=11.3, 7 Hz, H-1′), 4.05 (1H, *dd*, J=6, 3.8 Hz, H-3), 3.55 (1H, *dd*, J=10.3, 3.8 Hz, H-4), 3.37 (1H, *dd*, J=10.3, 6 Hz, H-4′), 2.60 (1H, *br t*, J=6.5 Hz, 1-OH); ^{13}C NMR: δ 139.0, 138.2, 137.8, 137.5 (arom. C), 128.4, 128.3, 128.2, 128.1, 128.0, 127.8, 127.7, 127.6, 127.5, 127.4, 127.2 (arom. CH), 81.0 (C-3), 76.5 (NO*C*H_2Ph), 74.1,

73.3 (2×O*C*H$_2$Ph), 70.9 (C-4), 67.8 (C-2), 63.5 (C-1). Anal. calcd for $C_{31}H_{33}NO_4$: C, 76.99; H, 6.88; N, 2.90. Found: C, 77.10; H, 7.00; N, 2.77.

*3.12.5. (2*R,*3*R*)-3,4-O-Di-O-benzyl-2-(N-benzyloxyamino)-2-allylbutane-1,3,4-triol (**7**, R=allyl)*

Oil, $[\alpha]_D$ +19.5 ($CHCl_3$, *c* 1.6); IR ν_{max} cm^{-1}: 3440 (br, OH), 3064, 3030; FABMS, *m/z* 448.2495 (M+H$^+$). Calcd for $C_{28}H_{34}NO_4$, M=448.2487; ^{1}H NMR: δ 7.40–7.20 (15H, *m*, arom.), 5.94 (1H, *ddt*, J=17.5, 10, 7 Hz, C*H*=CH$_2$), 5.06 (1H, *br d*, J=10 Hz, CH=C*H*$_2$), 5.03 (1H, *br d*, J=17.5 Hz, CH=C*H*$_2$), 4.80, 4.56 (2H, AB system, J=11 Hz, OC*H*$_2$Ph), 4.69, 4.65 (2H, AB system, J=11.5 Hz, NOC*H*$_2$Ph), 4.54 (2H, *s*, OC*H*$_2$Ph), 3.93 (2H, *dd*, J=5.5, 3.4 Hz, H-3), 3.86 (1H, *dd*, J=10.5, 3.4 Hz, H-4), 3.67 (1H, *dd*, J=10.5, 5.5 Hz, H-4′), 3.66 (2H, *s*, H-1, H-1′), 2.80 (1H, *br s*, OH), 2.34 (1H, *dd*, J=14, 7 Hz, CH$_2$C=C), 2.20 (1H, *dd*, J=14, 7 Hz, CH$_2$C=C); ^{13}C NMR: δ 138.3, 137.8, 137.6 (arom. C), 133.9 (*C*H=CH$_2$), 128.5, 128.4, 128.3, 127.8, 127.7, 127.6 (arom. CH), 117.8 (CH=*C*H$_2$), 80.0 (C-3), 76.6 (NO*C*H$_2$Ph), 73.8, 73.5 (2×O*C*H$_2$Ph), 70.2 (C-4), 64.7 (C-2), 64.2 (C-1), 35.1 (*C*H$_2$C=C). Anal. calcd for $C_{28}H_{33}NO_4$: C, 75.14; H, 7.43; N, 3.13. Found: C, 75.10; H, 7.60; N, 3.22.

*3.12.6. (2*R,*3*R*)-1,3,4-Tri-O-benzyl-2-(N-benzyloxyamino)-2-methylbutane-1,3,4-triol (**8**, R=Me)*

Oil, $[\alpha]_D$ +7.3 ($CHCl_3$, *c* 1.7); IR ν_{max} cm^{-1}: 3320 (br, NH), 3063, 3030; FABMS, *m/z* 512.2794 (M+H$^+$). Calcd for $C_{33}H_{38}NO_4$, M=512.2801; ^{1}H NMR: δ 7.40–7.20 (20H, *m*, arom.), 4.88, 4.55 (2H, AB system, J=11.5 Hz, OC*H*$_2$Ph), 4.63, 4.60 (2H, AB system, J=11.5 Hz, NOC*H*$_2$Ph), 4.53, 4.52 (2H, AB system, J=12 Hz, OC*H*$_2$Ph), 4.50 (2H, *s*, OC*H*$_2$Ph), 3.95 (1H, *dd*, J=10.5, 2 Hz, H-4), 3.80 (1H, *dd*, J=7.5, 2 Hz, H-3), 3.68 (1H, *dd*, J=10.5, 7.5 Hz, H-4′), 3.54, 3.50 (2H, AB system, J=9 Hz, H-1, H-1′), 1.04 (3H, s, *Me*C$_2$); ^{13}C NMR: δ 139.1, 138.5, 138.0 (arom. C), 128.4, 128.3, 128.2, 128.1, 127.6, 127.5, 127.4, 127.3 (arom. CH), 79.6 (C-3), 76.6 (NO*C*H$_2$Ph), 74.1, 73.3, 73.2 (4×O*C*H$_2$Ph), 72.4 (C-4), 70.8 (C-1), 63.0 (C-2), 15.6 (*Me*C$_2$). Anal. calcd for $C_{33}H_{37}NO_4$: C, 77.47; H, 7.29; N, 2.74. Found: C, 77.30; H, 7.41; N, 2.90.

*3.12.7. (2*R,*3*R*)-1,3,4-Tri-O-benzyl-2-(N-benzyloxyamino)-2-*n*-butylbutane-1,3,4-triol (**8**, R=n*Bu)*

Oil, $[\alpha]_D$ +5.8 ($CHCl_3$, *c* 0.8); IR ν_{max} cm^{-1}: 3350 (br, NH), 3063, 3030; FABMS, *m/z* 554.3276 (M+H$^+$). Calcd for $C_{36}H_{44}NO_4$, M=554.3270; ^{1}H NMR: δ 7.40–7.25 (20H, *m*, arom.), 4.96, 4.60 (2H, AB system, J=11.5 Hz, OC*H*$_2$Ph), 4.66, 4.63 (2H, AB system, J=11.5 Hz, NOC*H*$_2$Ph), 4.58, 4.53 (2H, AB system, J=12 Hz, OC*H*$_2$Ph), 4.49 (2H, *s*, OC*H*$_2$Ph), 3.98 (1H, *dd*, J=10.2, 2 Hz, H-4), 3.91 (1H, *dd*, J=7.5, 2 Hz, H-3), 3.80 (1H, *dd*, J=10.2, 7.5 Hz, H-4′), 3.56, 3.51 (2H, AB system, J=8.8 Hz, H-1, H-1′), 1.60–1.20 (6H, *m*, C*H*$_2$C*H*$_2$C*H*$_2$), 0.91 (3H, *t*, J=7.5 Hz, Me); ^{13}C NMR: δ 139.3, 138.7, 138.6, 138.1 (arom. C), 128.3, 128.2, 128.1, 127.6, 127.5, 127.4, 127.3 (arom. CH), 80.5 (C-3), 76.5 (NO*C*H$_2$Ph), 74.3 (C-1), 73.3, 73.2, 73.1 (3×O*C*H$_2$Ph), 69.3 (C-4), 64.7 (C-2), 30.3 (*C*H$_2$–C$_3$H$_7$), 25.7, 23.6 (*C*H$_2$*C*H$_2$Me), 14.1 (Me). Anal. calcd for $C_{36}H_{43}NO_4$: C, 78.09; H, 7.83; N, 2.53. Found: C, 78.00; H, 7.91; N, 2.60.

*3.12.8. (2*R,*3*R*)-1,3,4-Tri-O-benzyl-2-(N-benzyloxyamino)-2-phenylbutane-1,3,4-triol (**8**, R=Ph)*

Oil, $[\alpha]_D$ −12.5 ($CHCl_3$, *c* 2.2); IR ν_{max} cm^{-1}: 3350 (br, NH), 3064, 3031; FABMS, *m/z* 574.2947 (M+H$^+$). Calcd for $C_{38}H_{40}NO_4$, M=574.2957; ^{1}H NMR: δ 7.50 (5H, *m*, arom.), 7.40–7.20 (25H, *m*, arom.), 4.87, 4.57 (2H, AB system, J=11.5 Hz, OC*H*$_2$Ph), 4.67 (2H, *s*, NOC*H*$_2$Ph), 4.55, 4.45 (2H, AB system, J=12.0 Hz, OC*H*$_2$Ph), 4.40, 4.35 (2H, AB system, J=12.0 Hz, OC*H*$_2$Ph), 4.15–3.95 (3H, *m*, H-1, H-1′, H-3), 3.85 (1H, *dd*, J=10.5, 2 Hz, H-4), 3.25 (1H, *dd*, J=10.5, 7.7 Hz, H-4′); ^{13}C NMR: δ 139.2, 139.0, 138.6, 138.4, 138.0 (arom. C), 128.3, 128.2, 128.1, 128.0, 127.9, 127.8, 127.7, 127.6, 127.5, 127.3, 127.2, 127.0 (arom. CH), 80.2 (C-3), 76.2 (NO*C*H$_2$Ph), 74.4, 73.5, 73.3, 73.2 (C-1, 3×O*C*H$_2$Ph), 69.6

(C-4), 67.7 (C-2). Anal. calcd for $C_{38}H_{39}NO_4$: C, 79.55; H, 6.85; N, 2.44. Found: C, 79.76; H, 7.00; N, 2.50.

*3.12.9. (2*R,*3*R*)-1,3,4-Tri-O-benzyl-2-(N-benzyloxyamino)-2-allylbutane-1,3,4-triol (**8**, R=allyl)*

Oil, $[\alpha]_D$ +2.0 ($CHCl_3$, *c* 0.6); IR ν_{max} cm^{-1}: 3350 (br, NH), 3064, 3031; FABMS, *m/z* 538.2963 ($M+H^+$). Calcd for $C_{35}H_{40}NO_4$, M=538.2957; ^{1}H NMR: δ 7.40–7.20 (20H, *m*, arom.), 5.95 (1H, *ddt*, J=17.5, 10, 7 Hz, C*H*=CH_2), 5.05 (1H, *br d*, J=10 Hz, CH=CH_2), 5.03 (1H, *br d*, J=17.5 Hz, CH=CH_2), 4.92, 4.56 (2H, AB system, J=11 Hz, OCH_2Ph), 4.66, 4.62 (2H, AB system, J=11.5 Hz, NOCH_2Ph), 4.51, 4.49 (2H, AB system, J=11 Hz, OCH_2Ph), 4.44 (2H, *s*, OCH_2Ph), 3.95–3.85 (2H, *m*, H-3, H-4), 3.78 (1H, *dd*, J=10.5, 7.5 Hz, H-4′), 3.50 (2H, AB system, J=9 Hz, H-1, H-1′), 2.35 (2H, *d*, J=7 Hz, CH_2C=C); ^{13}C NMR: δ 139.4, 138.7, 138.0 (arom. C), 134.7 (*C*H=CH_2), 128.5, 128.4, 128.3, 127.7, 127.6, 127.5, 127.4 (arom. CH), 117.2 (CH=*C*H_2), 80.2 (C-3), 76.4 (NO*C*H_2Ph), 74.3, 73.2 (3×O*C*H_2Ph), 72.8 (C-1), 69.6 (C-4), 64.9 (C-2), 35.4 (*C*H_2C=C). Anal. calcd for $C_{35}H_{39}NO_4$: C, 78.18; H, 7.31; N, 2.60. Found: C, 78.05; H, 7.21; N, 2.48.

3.13. Photochemical conversion of (Z)-***2a–d*** *to* (E)-***2a–d***

An ice-cooled solution of any of the oximes (*Z*)-**2** (1 mmol) in MeOH (30 ml) was irradiated for 6 h with a UV lamp. Solvent removal *in vacuo* afforded an oil which was found by NMR to be a ca. 1:1 mixture of (*E*)- and (*Z*)-**2**. Column chromatography on silica gel (hexane:EtOAc=19:1) afforded both isomeric oximes in almost 50% yield each.

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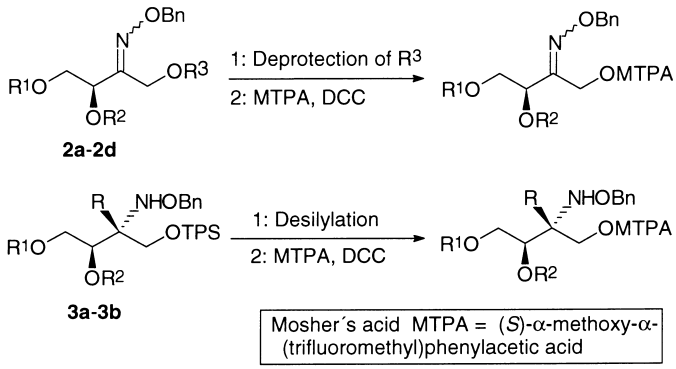
9. In order to ascertain whether partial racemization took place during either the formation of the oximes or their reactions with organolithium reagents, we have prepared the Mosher derivatives of the 1-O-deprotected oximes **2a–d** and addition products **3a–b**.



The Mosher derivatives obtained in this way were at least 98% diastereoisomerically pure, as judged by high-field ^{1}H and ^{13}C NMR measurements. Consequently, no detectable racemization took place in either step.

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19. This result is to be compared with those observed for ketones **1b**,**d** with organomagnesium reagents, where *three* equivalents of the latter were necessary for a fast reaction.[8d] We have interpreted this behaviour by assuming that two molecules of the Grignard reagent participate in the transition state, one of them forming the chelate and the second one adding to the C=O bond.

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