Anionic Hetero[3,3] and [3,5] Rearrangements of Hydroxylamine Derivatives Accompanied with N–O Bond Cleavage

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Aromatic and aliphatic *N,O*-divinylhydroxylamine systems generated in situ from hydroxylamine derivatives smoothly undergo [3,3] rearrangement. The base-catalyzed formation and rearrangement of enolates or dienolates of *N*-aryl-*O*-acylhydroxylamines, *N,O*-diacylhydroxylamines and *N*-acylhydroxylamine-*O*-carbamates result in C–C or C–N bond formation with cleavage of the N–O bond.

The usefulness of [3,3] sigmatropic rearrangement in systems containing heteroatom(s) is well documented.[1] An aliphatic version of the Claisen rearrangement has been developed by means of in situ formation of the [3,3] rearrangement precursors, allyl vinyl ethers. Examples include the exchange of amide acetals[2] or ethyl orthoacetate[3] with allyl alcohols and subsequent formation of α,β-unsaturated amides or esters upon rearrangement. An important example was reported by Ireland and Mueller, who demonstrated the Claisen rearrangement of acylated allyl alcohols by the use of bases for the generation of ester enolates.[4] On the other hand, a typical example of [3,3] rearrangement by cleavage of the bond between heteroatoms is the Fischer indole synthesis, which involves 3,4-diaza[3,3] sigmatropic shifts[5] of the ene–hydrazines.[6] We have reported the aliphatic version of 3,4-diaza[3,3] rearrangements, i.e., the anionic rearrangement of *N,N'*-diacylhydrazines[7] and *N*-acyl-*N'*-enylhydrazines.[8] The 3-aza-4-oxa[3,3] sigmatropic shifts of *N,O*-divinylhydroxylamines, which appear to be exothermic,[9] should be widely applicable for synthesis, but have been little used because of the instability of the requisite *N,O*-divinylhydroxylamine systems. In this paper, we describe anionic 3-aza-4-oxa[3,3] rearrangements of *N*-aryl-*O*-acylhydroxylamines, *N,O*-diacylhydroxylamines and *N*-acylhydroxylamine-*O*-carbamates to generate products with new C–C or C–N bonds. Some of the present results have been summarized in previous papers.[10,11,12] A new [3,5] rearrangement of *N,O*-diacylhydroxylamines competing with the [3,3] rearrangement is also described.

Rearrangements of *N*-Phenyl-*O*-acylhydroxylamines

The thermal rearrangement of *N*-aryl-*N*-acyl-*O*-acetoacetylhydroxylamines, which are enolizable under neutral conditions, to *O*-(*N*-acylamino)aryl ketones has been reported by Coates and Said.[13] The acid-catalyzed rearrangement of *O*-aryl-*N*-acetoacetylhydroxylamines to benzofurans, which has been reported by us,[14] also utilizes a spontaneously enolizable component for the [3,3] rearrangement. However, it is desirable to develop base-catalyzed enolization and rearrangement of non-activated acyl groups for the synthetic application of 3-aza-4-oxa[3,3] rearrangements.

Treatment of *N*-phenyl-*N*-*tert*-butyl-*O*-acylhydroxylamines **1** with an equivalent amount of potassium bis(trimethylsilyl)amide (KHMDS) in toluene at −78 °C for 1 hour, followed by esterification with diazomethane gave the corresponding methyl 2-(*N*-*tert*-butylamino)phenylacetate **2** as the major product in 38–76% yield (Table 1). The rates of the rearrangements were lower in a polar solvent. When **1a** was treated with KHMDS in THF at −78 °C for 1 hour, it was recovered quantitatively. Treatment of **1a** with LDA in THF at −78 °C for 1 hour gave only a 5% yield of **2a** and 92% recovery of **1a**. Elevation of the temperature to −20 °C in the latter case resulted in rearrangement of **1a** to give **2a** in 54% yield. The formation of **2** can be explained in terms of a 3-aza-4-oxa[3,3] sigmatropic shift of enolate **4** and prototropic aromatization. *para*-Substituted products, methyl 2-(*N*-*tert*-butylamino)phenylacetate **3c,d**, were isolated along with the major products in the case of rearrangement of **1c** and **1d**. Although an external dienolated carboxylic acid did not participate in the rearrangement, the formation of appreciable amounts of **3** suggests that the N–O bond in the transition state is significantly polarized in the form, $N^{\delta+}$–$O^{\delta-}$ **5** or that an intermolecular ionic pathway is involved in part.

The following variations upon this rearrangement serve to illustrate further its synthetic utility. *N*-Phenyl-*N*-acet-

Scheme 1

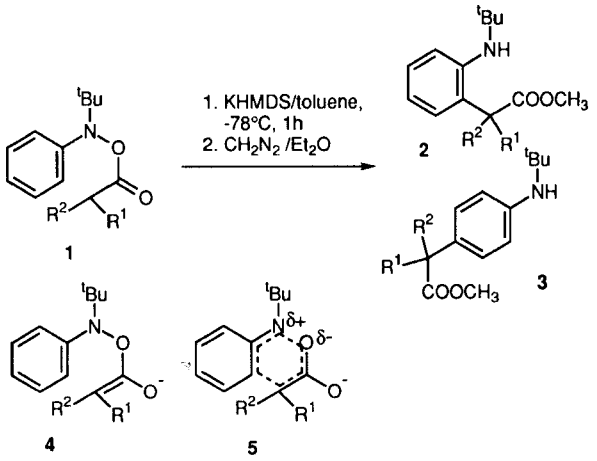


Table 1. Rearrangement of *N*-Phenyl-*N*-*t*-butyl-*O*-acylhydroxylamines **1**.

Reactant	R^1	R^2	Yield (%)	
			2	**3**
1a	H	H	62	0
1b	CH_3	H	66	0
1c	$CH(CH_3)_2$	H	75	2
1d	C_6H_5	H	56	16
1e	CH_3	CH_3	38	0

yl-*O*-acylhydroxylamines **6** were rearranged by treatment with 2.5 equivalents of KHMDS in toluene, followed by esterification with diazomethane, to give methyl 2-(*N*-acetylamino)phenylacetate **7** (Table 2). In these rearrangements, the succinic acid derivatives **8a** and **8d** were isolated in addition to the major products **7**. The C–C bond formation between the α-position of the ester enolate and the α-position of the amide enolate by 3-aza-4-oxa[3,3] rearrangement indicates that the rearrangement is applicable to non-aromatic systems (*vide infra*). On the other hand, the aliphatic C–C bond formation could be prevented by substitution of an isobutyryl group on the nitrogen atom of the rearrangement precursor, probably because of its bulkiness. *N*-Phenyl-*N*-isobutyryl-*O*-acylhydroxylamines **10** were smoothly rearranged by treatment with 2.5 equivalents of LDA in THF at −78 °C for 1.5 hours, followed by esterification with diazomethane, to give the *ortho*-rearranged products **11** in fairly good yield except for the case of the *O*-acetyl derivative **10a** (Table 3). The formation of *N*-phenyl-*N*-acyl-*O*-methylhydroxylamines (**9** and **13** from **7** and **10**, respectively) can be interpreted in terms of inverse cleavage of the ester carbonyl–oxygen bond, because of the activated ester nature of **7** and **10**.

Rearrangement of *N,O*-Diacylhydroxylamines

The low-yield formation of succinic acid derivatives (**8a** and **8d**) in the rearrangement of **6a** and **6d** with KHMDS indicates the possibility of extending of the aromatic [3,3] rearrangement of *N*-phenyl-*N,O*-diacylhydroxylamines to aliphatic systems. When **6a** and **6d** were treated with 2.5 equivalents of LDA in THF at −78 °C for 1.5 hours, followed by esterification with diazomethane, the yields

Scheme 2

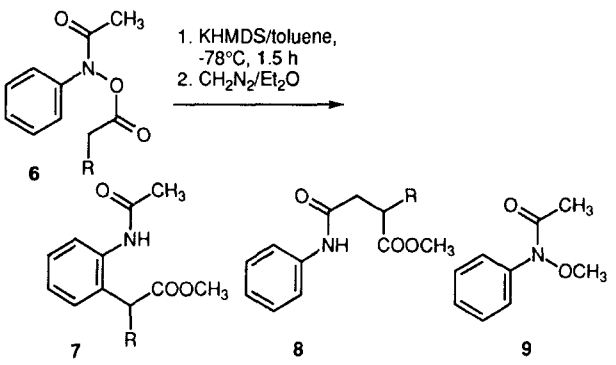


Table 2. Rearrangement of *N*-phenyl-*N*-acetyl-*O*-acylhydroxylamines **6**.

Reactant	R	Yield (%)		
		7	**8**	**9**
6a	H	14	16	22
6b	CH_3	51	0	16
6c	$CH(CH_3)_2$	26	0	11
6d	C_6H_5	63	13	20

of **8a** and **8d** were increased to 31% and 39%, respectively. However, treatment of *N,O*-diacetyl-*N*-methylhydroxylamine **(14a)**, in which the *N*-phenyl group of **6a** is replaced by an *N*-methyl group, with KHMDS or LDA in various solvents did not give the expected product. The [3,3] sigmatropic shift generally requires a chair form for the cyclic six-centered transition state, such as **18**. However, as described above, *N,O*-diacylhydroxylamines are activated esters, and the carbonyl carbon–oxygen

Biographical Sketch

Yasuyuki Endo was born in Kamakura, Kanagawa, Japan, in 1954. He received his Ph. D. from the University of Tokyo in 1983 under the guidance of Prof. K. Shudo. He joined the faculty at the University of Tokyo in 1979, where he is currently associate professor of organic and medicinal chemistry. From 1988 to 1989, he did postdoctoral work with Prof. Leo. A. Paquette at the Ohio State University. His current interests include the mechanism of new reactions and structure-activity studies of tumor-promoting substances and active compound binding to nuclear receptors.

Scheme 3

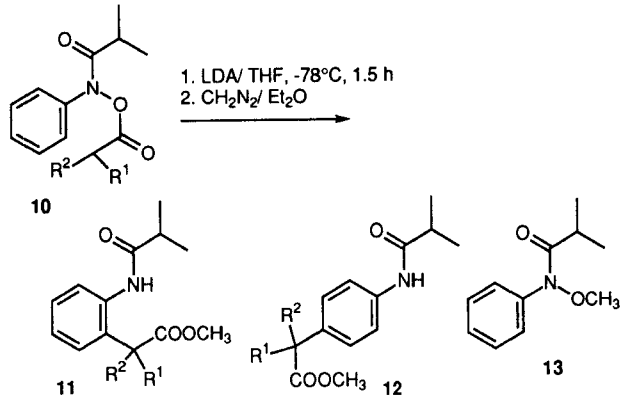
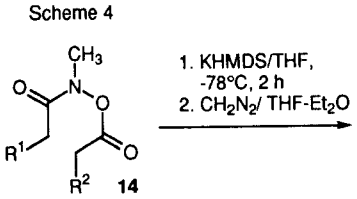


Table 3. Rearrangement of *N*-Phenyl-*N*-isobutyryl-*O*-acylhydroxylamines **10**.

Reactant	R^1	R^2	Yield (%) 11	12	13
10a	H	H	14	0	61
10b	CH_3	H	69	4	13
10c	$CH(CH_3)_2$	H	54	1	10
10d	C_6H_5	H	64	21	0
10e	CH_3	CH_3	88	0	0

bonds cleave easily. Thus, the difference between **8a** and **14a** can be interpreted in terms of the possibility of forming a favorable transition state for [3,3] rearrangement. When the dienolates of *N,O*-diacylhydroxylamines **19** are stable enough to form the cyclic transition state, or have favorable steric factors for the cyclic transition state, the [3,3] rearrangement seems to proceed effectively. From the former viewpoint, substitution of a phenyl group at the α-position of the enolates seems to be favorable for the rearrangement. As expected, *N*-acetyl-*O*-phenylacetyl-*N*-methylhydroxylamine **(14c)** smoothly rearranged upon treatment with 2.5 equivalents of KHMDS in THF at −78 °C for 2 hours, followed by esterification with diazomethane, to give the desired product **15c** in a yield of 47 %. The *N*-acyl-*O*-phenylacetylhydroxylamine derivatives (**14d–g**, R^2 = Ph) rearranged to the corresponding products in 37–67 % yields (Table 4). In these reactions, α-hydroxyacetic acid derivatives **17** were isolated along with the major products. The structure of **17**, which corresponds to rearrangement of the oxygen atom of the amide to the carbon atom of the ester enolates, can be explained in terms of 1,4-dioxa-3-aza[3,3] rearrangement of the monoenolates **20**. From the viewpoint of the steric factor for formation of the cyclic transition state **18**, the difference in the reaction between **6a** and **14a** indicates that a more favorable conformation for the rearrangement can be expected with a sterically larger substituent on the nitrogen. Thus, a bulkier substituent is more effective for the C–C bond-forming reaction. Treatment of diacetyl-*N*-isopropylhydroxylamine with base followed by esterification gave the desired products in low yields, comparable to that of *N*-phenyl-substituted **8a**. A significant improvement was achieved with the *N*-*tert*-butyl substituent. *N,O*-Diacetyl-*N*-*tert*-butylhydroxylamine **(21a)** rearranged to the succinic acid derivative **22** in 68 % yield, although the reactant does not have an α-stabilizing group. The *N,O*-diacyl-*N*-*tert*-butylhydroxylamines **21** rearranged to give the corresponding products in 49–75 % yields (Table 5).

Scheme 4



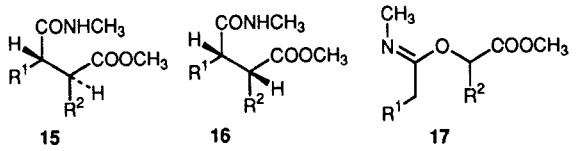
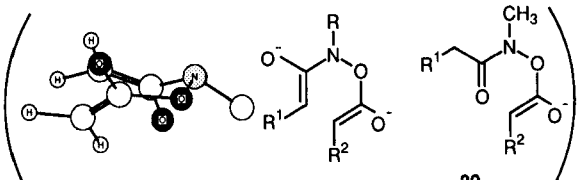


Table 4. Rearrangement of *N,O*-Diacyl-*N*-methylhydroxylamines **14**.

Reactant	R^1	R^2	Yield (%) 15 + 16 (*threo*:*erythro*)	17
14a	H	H	0	0
14b	C_6H_5	H	0	0
14c	H	C_6H_5	47	10
14d	CH_3	C_6H_5	43 (2:1)	15
14e	Cl	C_6H_5	44 (5:4)	15
14f	OCH_3	C_6H_5	37 (2:1)	0
14g	C_6H_5	C_6H_5	67 (5:2)	31



Scheme 5

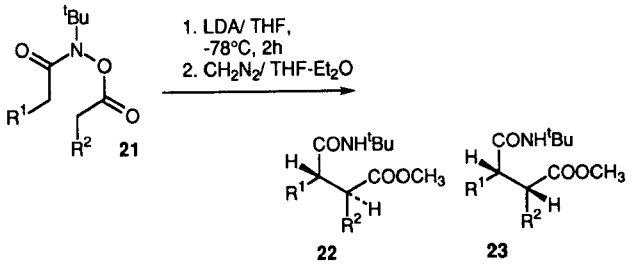


Table 5. Rearrangement of *N,O*-Diacyl-*N*-*tert*-butylhydroxylamines **21**.

Reactant	R^1	R^2	Yield (%) 22 + 23 (*dl*:*meso*)
21a	H	H	68
21b	C_6H_5	H	59
21c	C_6H_5	C_6H_5	75 (6:4)
21d	H	C_6H_5	74
21e	CH_3	CH_3	49(7:3)

In the case of the rearrangement of *O*-phenylacetyl-*N*-methylsulfenylacetyl-*N*-methylhydroxylamine **(24a)**, an unexpected [3,5] rearranged product was observed during the investigation of the rearrangement. 2-(2-methoxycarbonylmethyl)phenyl-2-methylsulfenylacetic acid methylamide **(27a)**, was isolated in a 10% yield along with the [3,3] rearranged products (**25a** and **26a**). The [3,5] rearrangement requires a sulfur functional group on the amide enolate component. Where a phenylsulfenyl or 1,3-dithiadine group is substituted on the enolate in place of the methylsulfenyl group, the [3,5] rearranged products were formed in 5 and 2% yields, respectively. No [3,5] rearranged product was obtained in the case of other carbon, halogen or oxygen functional groups on the enolates, as far as we examined. Although the effect of the sulfur atom in the rearrangement is not clear, a possible factor is the stabilizing effects on both the adjacent anion and the adjacent cation, since a substituent having an efficient stabilizing effect only on the anion (a phenyl group) is not effective for the [3,5] rearrangement. This [3,5] rearrangement plausibly proceeds via an intramolecular concerted pathway involving a polarized transition state of the form $N^{\delta+}$–$O^{\delta-}$. From the above consideration, increasing the electron density at the reaction site on the phenyl ring seems to be advantageous for the [3,5] rearrangement. Reaction of *O*-(3,5-dimethoxy)-phenylacetyl-*N*-methylsulfenylacetyl-*N*-methylhydroxylamine **(24b)** under the same conditions as **24a** gave a 21% yield of the [3,5] rearranged product **27b** along with a 34% yield of [3,3] rearranged product (**25b** and **26b**) (Table 6).

Non-aromatic [3,5] rearrangement was observed with *O*-(4-phenylbut-3-enoyl)-*N*-methylsulfenylacetyl-*N*-methylhydroxylamine **(28)**. Treatment of **28** under the same conditions as **24a** gave a 49% yield of [3,3] rearranged products (**29** and **30**) and a 20% yield of *erythro*-selective [3,5] rearranged products (**31** and **32**) (Table 7). The stereoselectivity of the [3,5] rearranged products indicates that the rearrangement process is not completely dissociative. A simple interpretation of the [3,5] rearrangement would involve a thermally allowed *supra-antara* oriented transition state. [3,5] Sigmatropic shifts have occasionally been proposed as a step in a complex rearrangement.[15] In one of the simple [3,5] sigmatropic shifts of 7-vinylnorcaradiene **(33)**, the vinyl group is well positioned to function as the *antara* component in a thermally allowed $\pi^{4s} + \sigma^{2s} + \pi^{2a}$, 8-electron process.[16] However, application of the transition state of **33** to the present [3,5] rearrangement would imply a transition state consisting of the *E*-enolate of the ester component and the *Z*-enolate of the amide component, which is sterically unlikely. In the present *erythro*-selective [3,5] rearrangement, the only possible transition state involves the *Z*-enolate of the ester component and the *E*-enolate of amide component (such as **34**). It seems that the present [3,5] rearrangement can be regarded as the more normal reaction, in which the electrostatic factor predominates over the symmetry factor.

Scheme 6

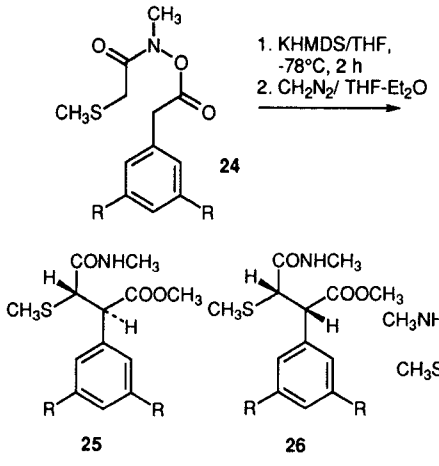


Table 6. Rearrangement of **24**.

Reactant	R	Yield (%) 25 + 26 (threo:erythro)	27
24a	H	37 (2:1)	10
24b	CH_3O	34 (2:1)	21

Scheme 7

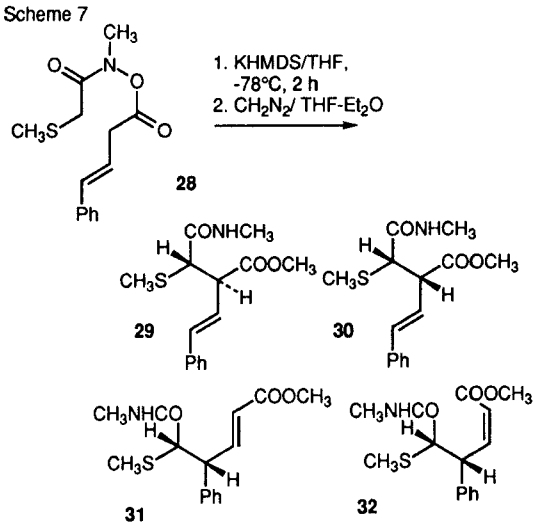


Table 7. Rearrangement of **28**.

Reactant	Yield (%) 29 + 30 (threo:erythro)	31 + 32 (E:Z)
28	49 (11:9)	20 (7:3)

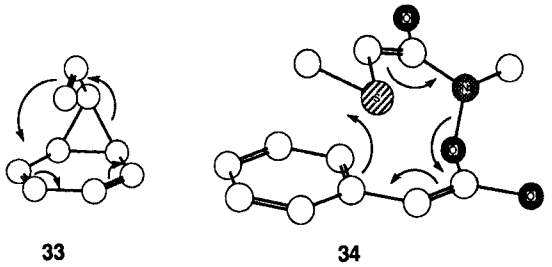


Figure 1

Rearrangement of *N*-Acylhydroxylamine-*O*-carbamates

We have previously reported the acid-catalyzed [3,3] rearrangement of *N*-alkyl-*N'*-phenoxyureas to 2-alkylaminophenols.[17] The first step of the aromatic rearrangement includes isomerization of the urea moiety to isourea. Isocarbamate anions may also be useful as nitrogen sources in C–N bond-forming [3,3] rearrangement systems. Treatment of *N*-phenylacetyl-*N*-methylhydroxylamine-*O*-carbamate **(35)**, readily available by reaction of *N*-phenylacetyl-*N*-methylhydroxylamine with isocyanate in diethyl ether, with 2.5 equivalents of LDA in THF at −78 °C for 2 hours gave *N*-substituted phenylglycine methylamides **36** in 34–50% yields. To examine the generality of the C–N bond-forming [3,3] rearrangement for introduction of an amino group at the α-position of a carboxylic acid, the following investigation was performed. *N*-Boc-*N*-methylhydroxylamine-*O*-benzylcarbamate **(38)**, prepared from *N*-Boc-*N*-methylhydroxylamine **(37)** and benzyl isocyanate in 95% yield, is a stable crystalline solid. Deprotection of the Boc group with trifluoroacetic acid at 0 °C, afforded *N*-methylhydroxylamine-*O*-benzylcarbamate as the trifluoroacetate salt **39**. The hydroxylamine-*O*-carbamate **39** was easily *N*-acylated with an acyl chloride or mixed anhydride in THF to give various kinds of *N*-acyl-*N*-methylhydroxylamine-*O*-carbamates **35** in 85–95% yields. Treatment of **35** with 2.5 equivalents of LDA or KHMDS in THF at −78 °C gave *N*-benzylamino acid methylamides **36** in 38–76% yields (Table 8). Among the numerous methods of α-amino acid synthesis,[18] α-amination of carboxylic acid derivatives can be classified as nucleophilic amination (the displacement of a leaving group at the α-position to a carboxylic acid) and electrophilic amination[19] (reaction of an electrophilic aminating reagent with the ester enolate). The present rearrangement is mechanistically a new class of α-amination of unactivated carboxylic acids, i.e., concerted amination. This reaction should be widely applicable for synthetic purposes.

Scheme 8

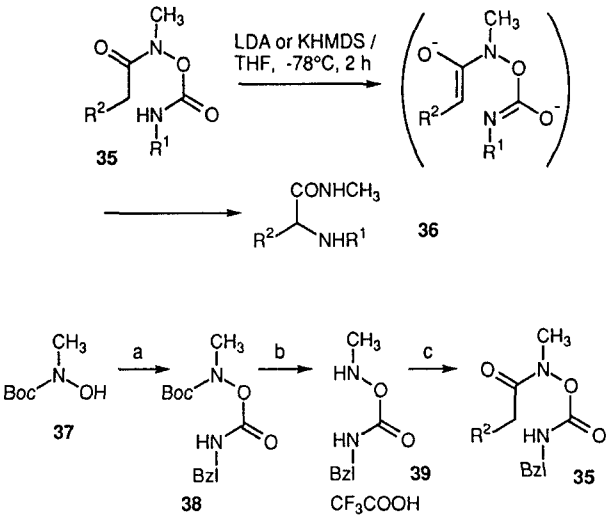


Table 8. Rearrangement of *N*-Acyl-*N*-methylhydroxylamine-*O*-carbamates **35**.

Reactant	R^1	R^2	Condition[a]	Yield (%) of **36**
35a	CH_3	C_6H_5	A	50
35b	$CH_2C_6H_5$	C_6H_5	A	40
35c	$CH(CH_3)_2$	C_6H_5	A	34
35d	C_6H_5	C_6H_5	A	49
35e	$CH_2C_6H_5$	H	A,B	0
35f	$CH_2C_6H_5$	CH_3	B	74
35g	$CH_2C_6H_5$	$CH(CH_3)_2$	A	69
35h	$CH_2C_6H_5$	$C(CH_3)_3$	A	66
35i	$CH_2C_6H_5$	$CH_2C_6H_5$	B	76

[a] Condition A: 2.5 eq of LDA was used as base, Condition B: 2.5 eq of KHMDS was used as Base.

Conclusion

The utility of [3,3] rearrangements of hydroxylamine derivatives is exemplified by the rearrangements of *N*-phenyl-*O*-acylhydroxylamines, *N,O*-diacylhydroxylamines and *N*-acylhydroxylamine-*O*-carbamates. The base-catalyzed formation of ester enolates, amide enolates and isocarbamate anions is useful for the construction of the [3,3] rearrangement systems. The ease of cleavage of the N–O bonds is an important factor, and the experimental results suggest that a polarized transition state in the form $N^{\delta+}$–$O^{\delta-}$ and oxygen anion of the enolates accelerate the new [3,3] sigmatropic shifts. The [3,5] rearrangements of *N,O*-diacylhydroxylamines with a sulfur substituent are considered to have an ionic character. These findings should have general utility for the development of synthetic methods in organic chemistry.

The ^{1}H NMR spectra were recorded on a JEOL JMN-FX-400 spectrometer using TMS as an internal standard. Melting points were measured with a Yanagimoto micro hot stage, without correction. Chromatographic separations were made using Merck Kieselgel 60 (230–400 mesh).

***N*-Phenyl-*N*-*tert*-butyl-*O*-acylhydroxylamines (1a–1e); General Procedure:**

A solution of acyl chloride (1.8 mmol) in benzene (2 mL) was added dropwise to a stirred solution of *N*-phenyl-*N*-*tert*-butylhydroxylamine[20] (1.5 mmol) and diisopropylethylamine (0.6 mL) in benzene (5 mL) at r.t. The mixture was stirred for 2 h, the solvent was removed under reduced pressure, and the product was purified by silica gel column chromatography using n-hexane/CH_2Cl_2 as the eluent to give **1** in 93–97% yields. Spectral data of the products are summarized in Table 9.

Table 9. Characteristic Data of Compounds **1a-1e**[a]

Compound	mp(°C)	^{1}H-NMR($CDCl_3$,400MHz) δ, *J* (Hz)
1a	34-36	1.19 (s,9H), 2.11 (s,3H), 7.14-7.34 (m,5H)
1b	Syrup	1.17 (t,3H,*J*=7.7), 1.18 (s,9H), 2.38 (q, 2H,*J*=7.7), 7.16 (m,1H), 7.25-7.32 (m,4H)
1c	Syrup	0.94 (d,6H,*J*=6.6), 1.18 (s,9H), 2.13 (m,1H), 2.22 (d,2H,*J*=7.0), 7.15-7.19 (m,1H), 7.25-7.31 (m,4H)
1d	50.5-52.0	1.09 (s,9H), 3.67 (s,2H), 7.14-7.34 (m,10H)
1e	Syrup	1.19 (s,9H), 1.20 (d,6H,*J*=7.3), 2.62(m,1H), 7.15-7.31 (m,5H)

[a] Satisfactory HRMS obtained: ±0.0020

Rearrangement of 1; General Procedure:
A solution of **1** (0.5 mmol) in dry toluene (5 mL) was stirred and cooled at −78 °C, then a 0.5 M solution of KHMDS in toluene (1.1 mL, 1.1 mmol) was added dropwise at −78 °C. Stirring was continued for 1.5 h, then the reaction was quenched by the addition of aq sat. NH_4Cl (5 mL). The solution was diluted with brine (5 mL), neutralized with 2 N HCl and aq sat. $NaHCO_3$, and extracted with Et_2O (3 × 50 mL). The organic layer was dried ($MgSO_4$), filtered and concentrated. The resulting residue was dissolved in Et_2O (5 mL) and a solution of excess diazomethane in Et_2O was added. After standing for 1 h, the solution was concentrated and the residue was chromatographed on silica gel using *n*-hexane/CH_2Cl_2 to give the rearranged products **2** and **3**. Spectral data of the products are listed in Table 10.

Table 10. Characteristic Data of Compounds **2a-2e**, **3c** and **3d**[a]

Compound	mp(°C)	^{1}H-NMR($CDCl_3$,400MHz) δ, *J* (Hz)
2a	48-50	1.39 (s,9H), 3.52 (s,2H), 3.67 (s,3H), 6.69 (t,1H,*J* = 7.8), 6.96 (d,1H,*J* =7.8), 7.09 (d,1H,*J* =7.8), 7.14 (t,1H,*J*= 7.8)
2b	Syrup	1.38 (s,9H), 1.51 (t,3H,*J* =7.7), 3.66 (s,3H), 3.77 (q, 2H,*J* =7.7), 6.75 (t,1H,*J* =8.1), 6.97 (d,1H,*J* = 8.1), 7.13 (d,1H,*J* =8.1), 7.16 (t,1H,*J*= 8.1)
2c	Syrup	0.74 (d,3H,*J* =7.0), 1.05 (d,3H,*J* =7.0), 1.38 (s,9H), 2.57 (m,1H), 3.20 (d,1H,*J* =11.0), 3.64 (s,3H), 4.41 (bs,1H), 6.72 (t,1H,*J* =8.0), 6.96 (d,1H,*J* =8.0), 7.10 (d,1H,*J* =8.0), 7.16 (t,1H,*J*= 8.0)
2d	52-54	1.21 (s,9H), 3.76 (s,3H), 4.98 (bs,1H), 6.72 (t,1H,*J* =7.8), 6.94 (d,1H,*J* =7.8), 7.07 (d,1H,*J* =7.8), 7.17 (dt,1H,*J*= 1.8, 8.0), 7.24-7.34 (m,5H)
2e	Syrup	1.36 (s,9H), 1.56 (d,6H,*J* =7.3), 3.65 (s,3H), 6.72 (t,1H,*J* =7.0), 6.91 (d,1H,*J* =8.1), 7.13 (d,1H,*J* = 8.1), 7.6 (t,1H,*J*= 7.0)
3c	Syrup	0.70 (d,3H,*J*= 7.0), 0.99 (d,3H,*J*= 7.0), 1.38 (s,9H), 2.26 (m,1H), 3.00 (d,1H,*J*= 10.6), 3.64 (s,3H), 6.71 (bd,2H,*J*= 8.5),6.78 (bs,1H), 7.09 (d,2H,*J*= 8.5)
3d	Syrup	1.32 (s,9H), 3.73 (s,3H), 4.92 (s,1H), 6.75 (bd,2H, *J*= 8.4), 7.09 (d,2H,*J*= 8.4), 7.24-7.34 (m,5H)

[a]Satisfactory HRMS obtained: ±0.0014

***N*-Acetyl-*N*-phenyl-*O*-acylhydroxylamines (6a–6d); General Procedure:**
Acyl chloride (3.3 mmol) was added to a stirred solution of *N*-acetyl-*N*-phenylhydroxylamine (3 mmol) and diisopropylethylamine (0.57 mL) in CH_2Cl_2 (10 mL) at 0 °C. The mixture was stirred for 5 min at 0 °C and for 0.5 h at r.t., then the solvent was removed under reduced pressure, and the product was purified by silica gel column chromatography using *n*-hexane/EtOAc as the eluent to give **6** in higher than 98% yield. Spectral data of the products are given in Table 11.

Table 11. Characteristic Data of Compounds **6a-6d**[a]

Compound	mp(°C)	^{1}H-NMR($CDCl_3$,400MHz) δ, *J* (Hz)
6a	43-45	2.07 (s,3H), 2.20 (s,3H), 7.29-7.48 (m,5H)
6b	Syrup	1.22 (t,3H,*J* =7.3), 2.05 (s,3H), 2.49 (q, 2H,*J* =7.3), 7.30-7.48 (m,5H)
6c	Syrup	0.97 (d,6H,*J* =6.6), 2.07 (s,3H), 2.16 (m,1H), 2.33 (d,2H,*J* =7.0), 7.30-7.48 (m,5H)
6d	48-50	2.01 (s,3H), 3.78 (s,2H), 7.25-7.40 (m,10H)

[a]Satisfactory HRMS obtained: ±0.0012

Rearrangement of 6; General Procedure:
A solution of **6** (0.5 mmol) in dry toluene (5 mL) was stirred and cooled at −78 °C, then a 0.5 M solution of KHMDS in toluene (2.5 mL, 2.5 mmol) was added dropwise at −78 °C. The mixture was stirred for 1.5 h, then the reaction was quenched by the addition of aq sat. NH_4Cl (5 mL). The solution was diluted with brine (5 mL), acidified with 2 N HCl to pH 2 and extracted with Et_2O (3 × 50 mL). The organic layer was dried ($MgSO_4$), filtered and concentrated to 3 ~ 5 mL. The resulting residue was diluted with Et_2O (5 mL) and a solution of excess diazomethane in Et_2O was added. After standing for 1 h, the solution was concentrated and the residue was chromatographed on silica gel using *n*-hexane/EtOAc to give the rearranged products **7, 8** and the degradation product **9**. Spectral data of the products are listed in Table 12.

Table 12. Characteristic Data of Compounds **7a-7d**, **8a** and **8d**[a]

Compound	mp(°C)	^{1}H-NMR($CDCl_3$,400MHz) δ, *J* (Hz)
7a	91-92	2.22 (s,3H), 3.64 (s,2H), 3.73 (s,3H), 7.11 (t,1H,*J* = 8.0), 7.20 (d,1H,*J* =8.0), 7.31 (t,1H,*J* =8.0), 7.83 (d,1H,*J*= 8.0), 8.71 (bs,1H)
7b	70-71	1.56 (t,3H,*J* =7.3), 2.23 (s,3H), 3.70 (s,3H), 3.90 (q, 2H,*J* =7.3), 7.16 (t,1H,*J* =8.1),7.26-7.32 (m,2H), 7.80 (d,1H,*J*= 8.1), 8.51 (bs,1H)
7c	Syrup	0.70 (d,3H,*J* =6.6), 1.05 (d,3H,*J* =6.6), 2.23 (s,3H), 2.57 (m,1H), 3.26 (d,1H,*J* =11.3), 3.71 (s,3H), 7.09 (t,1H,*J* =7.7), 7.17-7.22 (m,2H), 7.92 (d,1H,*J* =7.7), 9.08 (bs,1H)
7d	128-129	1.80 (s,3H), 3.83 (s,3H), 5.13 (s,1H), 7.12-7.38 (m,8H), 7.76 (d,1H,*J*= 8.0), 8.20 (bs,1H)
8a	Syrup	2.68 (m,2H), 2.76 (m,2H), 3.72 (s,3H), 7.10 (t,1H,*J* =7.7), 7.34 (t,2H,*J* =7.7), 7.50 (d,1H,*J* =7.7), 7.50 (bs,1H)
8d	151-153	2.68 (dd,1H,*J* =5.1,15.4), 3.21 (dd,1H,*J* =9.9, 15.4), 3.68 (s,3H), 4.24 (dd,1H, 5.1,9.9), 7.09-7.49 (m,10H)

[a]Satisfactory elemental analyses obtained: C,H,N±0.22 or satisfactory HRMS obtained: ±0.0009

***N*-Isobutyryl-*N*-phenyl-*O*-acylhydroxylamines (10a–10e); General Procedure:**
These compounds were obtained in more than 95% yields by means of the procedure described in the case of **6**. Spectral data of the products are compiled in Table 13.

Table 13. Characteristic Data of Compounds **10a-10e**[a]

Compound	mp(°C)	^{1}H-NMR($CDCl_3$,400MHz) δ, *J* (Hz)
10a	Syrup	1.13 (d,6H,*J* =6.6), 2.11 (s,3H), 2.55 (bs,1H), 7.43-7.49 (m,5H)
10b	Syrup	1.14 (d,6H,*J* =6.6), 1.21 (t,3H,*J* =7.7), 2.48 (q,2H,*J* =7.7), 2.56 (bs,1H), 7.43-7.49 (m,5H)
10c	Syrup	0.98 (d,6H,*J* =6.6), 1.14 (d,6H,*J* =6.6), 2.16 (m,1H), 2.31 (d,2H,*J* =7.0), 2.56 (bs,1H), 7.42-7.49 (m,5H)
10d	69-70	1.10 (d,6H,*J* =6.6), 2.50 (sept,1H,*J* =6.6), 3.77 (s,2H), 7.22-7.52 (m,10H)
10e	62-63	1.14 (d,6H,*J* =6.6), 1.24 (d,6H,*J* =7.0), 2.57 (bs,1H), 2.70 (sept,1H,*J* =7.0), 7.41-7.48 (m,5H)

[a]Satisfactory HRMS obtained: ±0.0014

Rearrangement of 10; General Procedure:
A solution of freshly distilled diisopropylamine (0.35 mL, 2.5 mmol) in THF (4 mL) was treated with 1.55 M BuLi in hexanes (1.61 mL, 2.5 mmol) at −20 °C under Ar. After stirring for 15 min at 0 °C, the LDA solution was cooled to −78 °C, and a solution of **10**

(1 mmol) in THF (4 mL) was added at −78 °C with stirring. The mixture was stirred for 1 h, and the reaction was quenched by the addition of aq sat. NH_4Cl (5 mL). The mixture was diluted with brine (5 mL), acidified with 2 N HCl and extracted with Et_2O (3 × 50 mL). The organic layer was dried ($MgSO_4$), filtered and concentrated to 3 ~ 5 mL. The residue was diluted with Et_2O (5 mL) and excess diazomethane in Et_2O was added. After standing for 1 h, the solution was concentrated and the residue was chromatographed on silica gel using *n*-hexane/EtOAc to give the rearranged products **11, 12** and degradation product **13**. Spectral data of the products are compiled in Table 14.

Table 14. Characteristic Data of Compounds **11a-11e, 12b** and **12d**[a]

Compound	mp(°C)	^{1}H-NMR($CDCl_3$,400MHz) δ, *J* (Hz)
11a	111-112	1.30 (d,6H,*J*=6.6), 2.61 (sept,1H,*J*=6.6), 3.62 (s, 2H), 3.73 (s,3H), 7.10 (t,1H,*J*=7.7), 7.20 (d,1H, *J*= 7.7), 7.29 (t,1H,*J*=7.7), 7.88 (d,1H,*J*=7.7), 8.71 (bs,1H)
11b	87-88	1.31 (d,6H,*J*=6.6) 1.56 (d,3H,*J*=7.3), 2.62 (sept, 1H,*J*=6.6), 3.71 (s,3H), 3.88 (q,1H,*J*=7.3), 7.14 (t,1H,*J*=7.7), 7.28 (d,1H,*J*=7.7), 7.29 (t,1H,*J*=7.7), 7.85 (d,1H,*J*=7.7), 8.56 (bs,1H)
11c	107-109	0.70 (d,3H,*J*=6.6), 1.05 (d,3H,*J*=6.6), 1.30 (d,3H,*J* =7.0), 1.31 (d,3H,*J*=7.0), 2..62 (*m*,2H), 3.25 (*d*,1H, *J*=11.4), 3.71 (s,3H), 3.88(q,1H,*J*=7.0), 7.08 (t,1H, *J*=8.1), 7.17 (d,1H,*J*=8.1), 7.28 (t,1H,*J*=8.1), 7.99 (d,1H,8.1), 9.03 (bs,1H)
11d	Syrup	0.87(d,3H,*J*=6.6), 0.99 (d,3H,*J*=6.6), 2.18 (sept, 1H,*J*=6.6), 3.84 (s,3H), 5.13 (s,1H), 7.10 (d,2H, *J*= 8.0), 7.16 (t,1H,*J*=8.0), 7.27-7.32 (m,4H), 7.37 (t,1H,*J*=8.0), 7.93 (d,1H,*J*=8.0), 8.36 (bs,1H)
11e	86-87	1.26 (d,6H,*J*=7.0), 1.59 (s,6H), 2.52 (sept,1H,*J*= 7.0), 3.68 (s,3H), 7.20 (t,1H,*J*=7.8), 7.30 (dt,1H,*J*= 1.5,7.8), 7.35 (bs,1H), 7.39 (dd,1H,*J*=1.5,7.8), 7.70 (d,1H,*J*=7.8)
12b	Syrup	1.23 (d,6H,*J*=7.0), 1.48 (d,3H,*J*=7.3), 2.51 (sept, 1H,*J*=7.0) 3.65 (s,3H), 3.71 (q,1H,*J*=7.3) 7.15 (bs,1H), 7.25 (d,2H,*J*=8.0), 7.49 (d,2H,*J*=8.0)
12d	84-86	1.24 (d,6H,*J*=7.0), 2.49 (sept,1H,*J*=7.0), 3.74 (s,3H), 5.00 (s,1H), 7.12 (bs,1H), 7.24-7.34(m,7H), 7.48 (d,2H,*J*=8.1)

[a]Satisfactory elemental analyses obtained: C,H,N±0.28 or satisfactory HRMS obtained: ±0.0014

N,O-Diacyl-N-methylhydroxylamines (14a–14g); Typical Procedure for 14c:

N-Methylhydroxylamine hydrochloride (835 mg, 10 mmol) was dissolved in 50 % aq THF (15 mL), and K_2CO_3 (1.79 g, 13 mmol) was added at 0 °C with stirring. Then a solution of acetyl chloride (942 mg, 12 mmol) in THF (5 mL) was added at r.t. with stirring. Stirring was continued for 1 h, and the mixture was poured into ice-water (50 mL). The whole mixture was extracted with CH_2Cl_2 (3 × 70 mL), then the aqueous layer was saturated with NaCl and extracted with CH_2Cl_2 (2 × 50 mL). The combined organic layer was washed with brine, dried ($MgSO_4$) and concentrated. The crude residue was chromatographed on silica gel using *n*-hexane/EtOAc to give *N*-acetyl-*N*-methylhydroxylamine (737 mg, 82.8 %): ^{1}H NMR ($CDCl_3$) 3.24 (bs, 3 H), 3.36 (bs, 3 H). To a solution of the hydroxamic acid (712 mg, 8 mmol) in CH_2Cl_2 (20 mL) was added diisopropylethylamine (1.84 mL), then a solution of phenylacetyl chloride (1.48 g, 9.6 mmol) in CH_2Cl_2 (5 mL) at 0 °C with stirring. After stirring for 2 h at 0 °C, the mixture was poured into ice-water (100 mL), and extracted with CH_2Cl_2 (3 × 50 mL). The organic layer was washed with water, 10 % aq citric acid, and brine, dried ($MgSO_4$) and concentrated. The residue was chromatographed on silica gel using *n*-hexane/EtOAc followed by molecular distillation at 50 °C to give **14c** (1.02 g, 61.6 %). Spectral data of the products are given in Table 15.

N,O-Diacyl-N-methylhydroxylamines (24a,b, 28); Typical Procedure for 24a:

Ethyl chloroformate (0.50 mL) was added dropwise to a solution of methylsulfenylacetic acid (545 mg, 5.14 mmol) and *N*-methylmorpholine (0.6 mL) in THF (15 mL) at −30 °C with stirring. Stirring was continued for 5 min, then a solution of *N*-methylhydroxylamine hydrochloride (418 mg, 5 mmol) and K_2CO_3 (352 mg, 2.55 mmol) in water was added at −30 °C. The mixture was further stirred for 2 h at −20 ~ −30 °C, then for 1.5 h at r.t., poured into ice-water (50 mL) and neutralized with dilute HCl. The solution was saturated with NaCl and extracted with EtOAc (4 × 100 mL). Drying ($MgSO_4$) and concentration afforded a residue, which was purified by silica gel column chromatography to give *N*-methylsulfenylacetyl-*N*-methylhydroxylamine (637 mg, 94.1 %). A solution of the hydroxamic acid (637 mg, 2.7 mmol) in CH_2Cl_2 (20 mL) was treated with diisopropylethylamine (1.1 mL), then a solution of phenylacetyl chloride (867 mg, 5.7 mmol) in CH_2Cl_2 (5 mL) was added at 0 °C with stirring. Stirring was continued for 2 h at 0 °C, then the mixture was poured into ice-water (100 mL), and extracted with CH_2Cl_2 (3 × 100 mL). The organic layer was washed with water, 10 % aq citric acid, and brine, dried ($MgSO_4$) and concentrated. The residue was chromatographed on silica gel using *n*-hexane/EtOAc to give **24a** (636 mg, 53.2 %). Spectral data of the products are given in Table 15.

Table 15. Characteristic Data of Compounds **14a-14g, 24a,b** and **28**[a]

Compound	mp(°C)	^{1}H-NMR($CDCl_3$,400MHz) δ, *J* (Hz)
14a	Syrup	2.02 (bs,3H), 2.21 (s,3H), 3.28 (s,3H)
14b	Syrup	2.14 (s,3H), 3.30 (s,3H), 3.64 (s,3H), 7.22-7.32 (*m*,5H)
14c	54-55	3.27 (s,3H), 3.49 (s,2H0, 3.71 (s,2H), 7.12-7.38 (m,5H)
14d	Syrup	1.85 (bs,3H), 3.25 (s,3H), 3.75 (s,2H), 7.29-7.39 (m,5H)
14e	Syrup	1.03 (bt,3H), 2.10 (bq,2H), 3.26 (s,3H), 3.75 (s,2H), 7.21-7.39 (m,5H)
14f	Syrup	3.32 (s,3H), 3.78 (s,2H), 3.84 (bs,2H), 7.11-7.40 (m,5H)
14g	Syrup	3.29 (s,3H), 3.31 (s,3H), 3.74 (s,2H), 3.84 (bs,2H), 7.31-7.39 (m,5H)
24a	Syrup	2.12 (s,3H), 3.04 (bs,2H), 3.32 (s,3H), 3.76 (s,2H), 7.32-7.39 (m,5H)
24b	Syrup	2.13 (s,3H), 3.06 (bs,2H), 3.32 (s,3H), 3.69 (s,2H), 3.79 (s,6H), 6.41 (t,1H,*J*=2.2), 6.46 (d,2H,*J*=2.2)
28	Syrup	2.17 (s,3H), 3.22 (bs,2H), 3.37 (s,3H), 3.39 (dd,1H,*J*=1.3,9.0), 3.40 (dd,1H,1.3,7.0), 6.27 (dt,1H, 7.0,15.8), 6.60 (d,1H,*J*=15.8), 7.28-7.40 (m,5H)

[a]Satisfactory HRMS obtained: ±0.0032

Rearrangement of 14; General Procedure:

A solution of **14** (1.0 mmol) in dry THF (7 mL) was stirred and cooled at −78 °C, then a 0.5 M solution of KHMDS in toluene (5.0 mL, 2.5 mmol) was added dropwise at −78 °C. After stirring for 2 h, the reaction was quenched by the addition of aq sat. NH_4Cl (5 mL). The solution was diluted with brine (5 mL), acidified with 2 N HCl to pH 3 and extracted with Et_2O (3 × 50 mL). The organic layer was washed with brine (50 mL), dried ($MgSO_4$), filtered and concentrated. The resulting residue was dissolved in THF (5 mL) and a solution of excess diazomethane in Et_2O was added. After standing for 1 h, the solution was concentrated and chromatographed on silica gel using *n*-hexane/EtOAc to give the rearranged C–C products **15** and **16** and the C–O product **17**. Spectral data of the products are compiled in Table 16.

Table 16. Characteristic Data of Compounds **15c-15g, 16c-16g, 17c-17f**[a]

Compound	mp(°C)	^{1}H-NMR($CDCl_3$,400MHz) δ, J (Hz)
15c[b]	103-104	2.49 (dd,1H,J=4.8,14.7), 2.78 (d,3H,J=5.1), 3.01 (dd,1H,J=9.9,14.7), 3.67 (dd,1H,J=4.8,5.1), 5.48 (bs,1H), 7.25-7.52 (m,5H)
17c[c]	Syrup	2.17 (s,3H), 2.82 (s,3H), 3.78 (s,3H), 6.48 (s,1H), 7.22-7.24(m,2H), 7.35-7.40 (m,3H)
15d	Syrup	1.27 (d,3H,J=7.0), 2.47 (d,3H,J=5.1), 2.79-2.86 (m,1H), 3.68 (s,3H), 3.82 (d,1H,J=11.0), 5.10 (bs,1H), 7.18-7.42 (m,5H)
16d	135-136	0.91 (d,3H,J=7.0), 2.84 (d,3H,J=5.1), 2.89 (dq,1H,J=7.0,11.0), 3.61 (s,3H), 3.85 (d,1H,J=11.0), 5.64 (bs,1H), 7.27-7.52 (m,5H)
17d[c]	Syrup	1.19 (t,3H,J=7.3), 2.41 (dq,1H,J=7.3,14.6), 2.80 (s,3H), 3.78 (s,3H), 6.49 (s,1H), 7.21-7.52 (m,5H)
15e	138-139	2.73 (d,3H,J=5.1), 3.73 (s,3H), 4.48 (d,1H,J=11.1), 4.66 (d,1H,J=11.1), 7.29-7.53 (m,5H)
16e	178-181	2.81 (d,3H,J=5.1), 3.71 (s,3H), 4.38 (d,1H,J=8.1), 4.80 (d,1H,J=8.1), 7.29-7.37 (m,5H)
17e[c]	Syrup	2.88 (s,3H), 3.80 (s,3H), 4.14 (d,1H,J=12.8), 4.20 (d,1H,J=12.8), 6.40 (s,1H), 7.20-7.39 (m,5H)
15f	Syrup	2.62 (d,3H,J=5.1), 3.43 (s,3H), 3.73 (s,3H), 4.17 (d,1H,J=4.2), 4.42 (d,1H,J=4.2), 6.20 (bs,1H), 7.23-7.34 (m,5H)
16f	Syrup	2.77 (d,3H,J=5.1), 3.33 (s,3H), 3.69 (s,3H), 4.05 (d,1H,J=6.6), 4.08 (d,1H,J=6.6), 6.39 (bs,1H), 7.23-7.34 (m,5H)
15g	207-209	2.77 (d,3H,J=5.1), 3.70 (s,3H), 4.04 (d,1H,J=11.4), 4.32 (d,1H,J=11.4), 5.40 (bs,1H), 6.99-7.13 (m,10H)
16g	200-201	2.50 (d,3H,J=5.1), 3.39 (s,3H), 3.95 (d,1H,J=11.7), 4.50 (d,1H,J=11.7), 5.24 (bs,1H), 7.25-7.52 (m,10H)
17g[c]	Syrup	2.79 (s,3H), 3.78 (s,3H), 3.81 (s,2H), 6.49 (s,1H), 7.20-7.38 (m,10H)

[a]Satisfactory elemental analyses obtained: C,H,N±0.36 or satisfactory HRMS obtained: ±0.0012

[b]Product is theoretically the sole isomer, which is represented by **15**.

[c]The C-O products are not analytically pure.

N,O-Diacyl-*N*-*tert*-butylhydroxylamines (21a–21e); Typical Procedure for 21c and 21b:

Phenylacetyl chloride (4.41 g, 28.4 mmol) was added dropwise to a solution of *N*-*tert*-butylhydroxylamine (1.05 g, 11.8 mmol) and diisopropylethylamine (4.5 mL, 28.3 mmol) in THF (10 mL) at 0 °C. 4-Dimethylaminopyridine (217 mg) was added and the mixture was heated at 60 °C for 10 h. The solvent was evaporated under reduced pressure and the residue was dissolved in CH_2Cl_2 (300 mL). The organic layer was washed with aq sat. $NaHCO_3$ (80 mL), 10% aq citric acid (80 mL), and brine (80 mL), dried ($MgSO_4$), filtered and concentrated. The crude product was chromatographed on silica gel using *n*-hexane/CH_2Cl_2 (1:1) to give **21c** (2.24 g, 58%), which was converted into **21b** by the following procedure. A solution of **21c** (837 mg, 2.57 mmol) in MeOH (5 mL) was treated with 2 N KOH (2.5 mL, 5.0 mmol) at r.t. for 1 h. After concentration under reduced pressure, the residue obtained was diluted with 2 N HCl (10 mL) and extracted with CH_2Cl_2 (3 × 30 mL). The organic layer was dried ($MgSO_4$) and concentrated. Purification by silica gel column chromatography using *n*-hexane/EtOAc (3:1) gave *N*-phenylacetyl-*N*-*tert*-butylhydroxylamine (331 mg, 62%). The hydroxamic acid was dissolved in CH_2Cl_2 (20 mL), and diisopropylethylamine (0.46 mL, 2.6 mmol) was added at 0 °C with stirring. To this solution was added a solution of acetyl chloride (189 mg, 2.4 mmol) in CH_2Cl_2 (3 mL) at 0 °C. After stirring for 3 h, the whole mixture was poured into ice-water (20 mL). After separation, the aqueous layer was extracted with CH_2Cl_2 (3 × 100 mL). The combined organic layer was washed with aq sat. $NaHCO_3$ (80 mL), 10% aq citric acid (80 mL), and brine (80 mL), dried ($MgSO_4$), filtered and concentrated. The crude product was chromatographed on silica gel using *n*-hexane/EtOAc (6:1) to give **21b** (371 mg, 93%). Spectral data of the products are listed in Table 17.

Table 17. Characteristic Data of Compounds **21a-21e**[a]

Compound	mp(°C)	^{1}H-NMR($CDCl_3$,400MHz) δ, J (Hz)
21a	Syrup	1.42 (s,9H), 1.94 (s,3H), 2.20 (s,3H)
21b	Syrup	1.42 (s,9H), 2.17 (s,3H), 3.46 (d,1H,J=15.8), 3.54 (d,1H,J=15.8), 7.17 -7.33 (m,5H)
21c	128-129	1.36 (s,9H), 3.33 (d,1H,J=15.6), 3.37 (d,1H,J=15.6), 3.72 (s,2H), 7.07-7.09 (m,2H), 7.21-7.40 (m,8H)
21d	Syrup	1.39 (s,9H), 1.78 (s,3H), 3.74 (s,2H), 7.26-7.38 (m,5H)
21e	Syrup	1.05 (t,3H,J=7.3), 1.25 (t,3H,J=7.3), 1.42 (s,9H), 2.01-2.30 (m,2H), 2.47 (q,2H,J=7.3)

[a]Satisfactory elemental analyses obtained: C,H,N±0.24 or satisfactory HRMS obtained: ±0.0011

Rearrangement of 21; General Procedure:

A solution of freshly distilled diisopropylamine (0.35 mL, 2.5 mmol) in THF (3 mL) was treated with 1.55 M BuLi in hexanes (1.61 mL, 2.5 mmol) at −20 °C under Ar. After stirring for 15 min at 0 °C, the LDA solution was cooled to −78 °C, and a solution of **21** (1 mmol) in THF (4 mL) was added at −78 °C with stirring. Stirring was continued for 1 h, and the reaction was quenched by the addition of aq sat. NH_4Cl (5 mL). The mixture was diluted with brine (30 mL), acidified with 2 N HCl and extracted with Et_2O (3 × 80 mL). The organic layer was washed with brine (100 mL), dried ($MgSO_4$), filtered and concentrated. The residue was dissolved in THF (5 mL), and excess diazomethane in Et_2O was added. After standing for 1 h, the solution was concentrated and the residue was chromatographed on silica gel using *n*-hexane/EtOAc to give the rearranged C–C products **22** and **23**. Spectral data of the products are given in Table 18.

Table 18. Characteristic Data of Compounds **22a-e, 23a-e**[a]

Compound	mp(°C)	^{1}H-NMR($CDCl_3$,400MHz) δ, J (Hz)
22a[b]	75-76	1.34 (s,9H), 2.39 (t,2H,J=7.0), 2.64 (t,2H,J=7.0), 3.69 (s,3H), 5.45 (bs,1H)
22b[b]	108-109	1.27 (s,9H), 2.57 (dd,1H,J=5,7,16.9), 3.23 (dd,1H,J=9.2,16.9), 3.65 (s,3H), 3.79 (dd,1H,J=5.7,9.2), 5.23 (bs,1H), 7.27-7.35 (m,5H)
22c	154-155	1.27 (s,9H), 3.67 (s,3H), 3.94 (d,1H,J=11.4), 4.23 (d,1H,J=11.4), 5.28 (bs,1H), 7.00-7.11 (m,10H)
23c	180-181	0.97 (s,9H), 3.39 (s,3H), 3.85 (d,1H,J=11.4), 4.39 (d,1H,J=11.4), 5.10 (bs,1H), 7.26-7.52 (m,10H)
22d[b]	101-102	1.27 (s,9H), 2.42 (dd,1H,J=5,5,14.7), 2.90 (dd,1H,J=9.7,14.7), 3.67 (s,3H), 4.14 (dd,1H,J=5.7,9.2), 5.25 (bs,1H), 7.27-7.32 (m,5H)
22e	67-68	1.12 (d,3H,J=7.0), 1.16 (d,3H,J==7.0), 1.32 (s,9H), 2.34 -2.42 (m,1H), 2.69 -2.77 (m,1H), 3.67 (s,3H), 5.51 (bs,1H)
23e	82-83	1.11 (d,3H,J=7.0), 1.16 (d,3H,J==7.0), 1.36 (s,9H), 2.33 -2.41 (m,1H), 2.64 -2.76 (m,1H), 3.69 (s,3H), 5.67 (bs,1H)

[a]Satisfactory elemental analyses obtained: C,H,N±0.32.

[b]Product is theoretically the sole isomer, which are presented by **22**.

Rearrangement of 24 and 28:

The reaction of **24** and **28** was carried out by the same procedure as used for the rearrangement of **14** with KHMDS as the base. The stereochemistry of the products was deduced from the ^{1}H NMR spectra. The large coupling constant between the two hydrogens on the two asymmetric carbons indicates that the dihedral angle between these hydrogens is close to 180°. The signal (δ = 1.92) of the methyl group on the sulfur atom of the *threo* isomer **25a** is shifted to higher field by the aromatic current anisotropy. The signal

of the methyl group on the nitrogen atom of the *erythro* isomer **26a** appears at $\delta = 2.13$. These characteristics were utilized in the stereochemical determination of **31** and **32**. The two isomers are *E*–*Z* isomers of a double bond, since they were convertible by exposure to light. The chemical shifts of the methyl groups correspond to that of the *erythro* isomer of **25**. Spectral data of the products are given in Table 19.

Table 19. Characteristic Data of Compounds **25-32**[a]

Compound	mp(°C)	^{1}H-NMR($CDCl_3$,400MHz) δ, *J* (Hz)
25a	168-170	1.92 (s,3H), 2.86 (d,3H,*J*=5.1), 3.67 (s,3H), 3.86 (d,1H,*J*=10.6), 4.15 (d,1H,*J*=10.6), 6.25 (bs,1H), 7.30-7.37 (m,5H)
26a	157-158	2.13 (s,3H), 2.67 (d,3H,*J*=4.8), 3.64 (d,1H,*J*=9.9), 3.71 (s,3H), 4.30 (d,1H,*J*=9.9), 5.95 (bs,1H), 7.24-7.40 (m,5H)
27a	157-160	2.12 ((s,3H), 2.83 (d,1H,*J*=5.0), 3.72 (s,3H), 3.78 (d,1H,*J*=14.0), 3.84 (d,1H,*J*=14.0), 4.78 (s,1H), 7.21-7.37 (m,4H)
25b	163-164	1.95 (s,3H), 2.87 (d,3H,*J*=4.8), 3.67 (s,3H), 3.78 (s,6H), 3.82 (d,1H,*J*=11.0), 4.06 (d,1H,*J*=11.0), 6.24 (bs,1H), 6.40 (t,1H,*J*=2.2), 6.45 (d,2H,*J*=2.2)
26b	162-164	2.14 (s,3H), 2.70 (d,3H,*J*=4.8), 3.61 (d,1H,*J*=9.9), 3.71 (s,3H), 3.77 (s,6H), 4.23 (d,1H,*J*=9.9), 5.97 (bs,1H), 6.36 (t,1H,*J*=2.2), 6.53 (d,1H,*J*=2.2)
27b	Syrup	2.13 ((s,3H), 2.81 (d,1H,*J*=4.8), 3.70 (s,3H), 3.71 (d,1H,*J*=16.1), 3.78 (s,3H), 3.79 (s,3H), 3.81 (d,1H,*J*=16.1), 4.80 (s,1H), 6.40 (s,1H), 6.73 (s,1H)
29	161-163	2.05 (s,3H), 2.84 (d,3H,*J*=4.8), 3.74 (s,3H), 3.77 (d,1H,*J*=8.8), 3.84 (d,1H,*J*=8.8), 6.15 (dd,1H, *J*= 8.8,15.8), 6.57 (d,1H,*J*=15.8), 6.65 (bs,1H), 7.19-7.40 (m,5H)
30	116-118	2.18 (s,3H), 2.82 (d,3H,*J*=4.8), 3.50 (d,1H,*J*=8.4), 3.75 (s,3H), 3.85 (d,1H,*J*=8.4), 6.24 (dd,1H, *J*= 8.4,15.8), 6.27 (bs,1H), 6.59 (d,1H,*J*=15.8), 7.22-7.38 (m,5H)
31	Syrup	2.07 (s,3H), 2.69 (d,3H,*J*=4.4), 3.49 (d,1H,*J*=8.4), 3.71 (s,3H), 4.10 (t,1H,*J*=8.4), 5.88 (d,1H,*J*= 15.8), 6.27 (bs,1H), 7.21-7.35 (m,6H)
32	Syrup	2.10 (s,3H), 2.68 (d,3H,*J*=4.8), 3.55 (d,1H,*J*=8.8), 3.72 (s,3H), 5.25 (t,1H,*J*=9.9), 5.88 (d,1H,*J*= 11.5), 6.23 (bs,1H), 6.57 (t,1H, *J*=11.5), 7.21-7.35 (m,5H)

[a]Satisfactory elemental analyses obtained: C,H,N±0.31 or satisfactory HRMS obtained: ±0.0020

N-Acyl-N-methylhydroxylamine-O-carbamates 35; General Procedure:

Procedure A: A solution of isocyanate (7.5 mmol) in dry Et_2O (5 mL) was added to a solution of *N*-methyl-*N*-phenylacetylhydroxylamine (495 mg, 3.0 mmol) in dry Et_2O (8 mL) at r.t. with stirring. Stirring was continued for 3.5 h, then the solution was concentrated. The crude residue was chromatographed on silica gel using *n*-hexane/EtOAc to give **35a–35d** in 63–93% yields.

Procedure B: A solution of benzyl isocyanate (998 mg, 7.5 mmol) in dry Et_2O (1.5 mL) was added to a solution of *N*-Boc-*N*-methylhydroxylamine (**37**, 737 mg, 5.0 mmol) in dry Et_2O (6 mL) at r.t. with stirring. Stirring was continued for 3 h, then the solvent was removed and the residue was chromatographed on silica gel (*n*-hexane/EtOAc 3:1) to give 1.33 g of **38** (95%). Mp 76–77 °C, ^{1}H NMR ($CDCl_3$): $\delta = 1.47$ (s, 9H), 3.24 (s, 3H), 4.43 (d, 2H, $J = 5.9$ Hz), 5.38 (bs, 1H), 7.28–7.37 (m, 5H). A solution of **38** (280 mg, 1.0 mmol) in CH_2Cl_2 (3 mL) was treated with trifluoroacetic acid (3 mL) at 0 °C. After stirring for 30 min at 0 °C, the solution was concentrated under reduced pressure to give the salt **39**. To a solution of the crude **39** and diisopropylethylamine (258 mg, 2.0 mmol) in CH_2Cl_2 (10 mL) was added a solution of acyl chloride or mixed anhydride (1.1 mmol) at 0 °C with stirring. Stirring was continued for 1 h at r.t., then the mixture was poured into water (20 mL) and extracted with CH_2Cl_2 (3 × 20 mL). The organic layer was washed with 10% aq citric acid and 5% aq $NaHCO_3$, dried ($MgSO_4$), filtered and concentrated. The crude residue was chromatographed on silica gel (*n*-hexane/EtOAc) to give **35e–i**. Spectral data of the products are compiled in Table 20.

Table 20. Characteristic Data of Compounds **35a-35i**[a]

Compound	mp(°C)	^{1}H-NMR($CDCl_3$,400MHz) δ, *J* (Hz)
35a	Syrup	2.85 (d,3H,*J*=5.1), 3.30 (s,3H), 3.66 (s,2H), 5.01 (bs,1H), 7.23-7.33 (m,5H)
35b	85-86	3.32 (s,3H), 3.67 (s,2H), 4.40 (d,2H,*J*=5.9), 5.29 (bs,1H), 7.21-7.39 (m,10H)
35c	59-59.5	1.20 (d,6H,*J*=6.6), 3.29 (s,3H), 3.65 (s,2H), 3.84 (m,1H), 4.78 (bs,1H), 7.23-7.33 (m,5H)
35d	135-136	3.38 (s,3H), 3.72 (s,2H), 6.82 (bs,1H), 7.15-7.37 (m,10H)
35e	75-77	2.06 (s,3H), 3.31 (s,3H), 4.45 (d,2H,*J*=5.9), 5.36 (bs,1H), 7.29-7.40 (m,5H)
35f	53-55	1.13 (t,3H,*J*=7.3), 2.32 (q,2H,*J*=7.3), 3.31 (s,3H), 4.45 (d,2H,*J*=5.9), 5.30 (bs,1H), 7.30-7.40 (m,5H)
35g	31-32	0.95 (d,6H,*J*=6.0), 2.13 (m,3H), 3.31 (s,3H), 4.45 (d,1H,*J*=6.0), 5.32 (bs,1H), 7.30-7.40 (m,5H)
35h	50-52	1.04 (s,9H), 2.20 (s,2H), 3.31 (s,3H), 4.45 (d,2H,*J*=5.9), 5.37 (bs,1H), 7.30-7.39 (m,5H)
35i	66-67	2.61 (t,2H,*J*=7.7), 2.95 (t,2H,*J*=7.7), 3.30 (s,3H), 4.42 (d,2H,*J*=6.2), 5.33 (s,1H), 7.17-7.36 (m,5H)

[a]Satisfactory elemental analyses obtained: C,H,N±0.28 or satisfactory HRMS obtained: ±0.0012

Rearrangement of 35; General Procedure:

A solution of freshly distilled diisopropylamine (0.35 mL, 2.5 mmol) in THF (4 mL) was treated with 1.55 M BuLi in hexanes (1.61 mL, 2.5 mmol) at −20 °C under Ar. After stirring for 15 min at 0 °C, the LDA solution was cooled to −78 °C and a solution of **35** (1 mmol) in THF (4 mL) was added at −78 °C with stirring. Stirring was continued for 2 h, then the reaction was quenched by the addition of aq sat. NH_4Cl (5 mL). The mixture was extracted with CH_2Cl_2 (3 × 30 mL). The organic layer was extracted with 5% HCl (2 × 20 mL). The aqueous layer was basified with powdered K_2CO_3 and extracted with CH_2Cl_2 (3 × 30 mL). The organic layer was dried ($MgSO_4$), filtered and concentrated. The residue was chromatographed on aluminum oxide using *n*-hexane/EtOAc to give the rearranged product **36**. Spectral data of the products are given in Table 21.

Table 21. Characteristic Data of Compounds **36a-36d,36f-36l**[a]

Compound	mp(°C)	^{1}H-NMR($CDCl_3$,400MHz) δ, *J* (Hz)
36a	87-88	2.83 (d,3H,*J*=5.1), 4.09 (s,1H), 7.08 (bs,1H), 7.27-7.39 (m,5H)
36b	75-76	2.81 (d,3H,*J*=4.8), 3.83 (d,2H,*J*=5.5), 4.46 (bs,1H), 7.14 (bs,1H), 7.28-7.44 (m,10H)
36c	46-47	1.09 (d,6H,*J*=6.2), 2.82 (m,1H), 2.85 (d,3H,*J*= 4.8), 4.27 (s,1H), 7.27-7.37 (m,5H), 7.41 (bs,1H)
36d	113-114	2.84 (d,1H,*J*=4.8), 4.54 (bs,1H), 4.74 (s,1H), 6.51 (d,2H,*J*=8.8), 6.69 (bs,1H), 6.81 (t,1H,*J*= 7.3), 7.20 (dd,2H,*J*=8.8,7.3), 7.27-7.45 (m,5H)
36f	Syrup	1.39 (d,3H,*J*=6.6), 2.83 (m,3H), 3.31 (s,2H), 7.24-7.36 (m,5H), 7.45 (bs,1H)
36g	72-74	0.88 (d,3H,*J*=7.0), 0.95 (d,3H,*J*=7.0), 2.13 (m,1H), 2.83 (d,3H,*J*=4.8), 3.00 (d,1H,*J*=4.4), 3.65 (d,1H,*J*=13.2), 3.77 (d,1H,*J*=13.2), 7.20 (bs,1H), 7.27-7.37 (m,5H)
36h	58-60	0.99 (s,9H), 2.84 (d,3H,*J*=4.8), 2.85 (s,1H), 3.60 (bd,1H,*J*=13.2), 3.82 (bd,1H,*J*=13.2), 6.89 (bs,1H), 7.28-7.37 (m,5H)
36l	62-63	2.79 (dd,1H,*J*=9.2,13.9), 2.81 (d,3H,*J*=5.1), 3.23 (dd,1H,*J*=4.2,13.9), 3.45 (s,1H), 3.59 (d,1H,*J*=13.6), 3.72 (d,1H,*J*=13.6), 7.09-7.32 (m,10H)

[a]Satisfactory elemental analyses obtained: C,H,N±0.35 or satisfactory HRMS obtained: ±0.0011

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