Stereoselective Allylation of 2-Formyl Amides or 3-Oxo Amides

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(Received August 19, 1994)

Stereoselective allylation of 2-formyl amides or 3-oxo amides has been studied. Treatment of 2-formyl-*N*,*N*-dimethylpropanamide (**1a**) with allylzinc bromide gave 3-hydroxy-2,*N*,*N*-trimethyl-5-pentenamide as a stereoisomeric mixture (**2a**:**3a**=63:37). Meantime, the reaction of **1a** with allyltrimethylsilane in the presence of Lewis acid such as $EtAlCl_2$ or $BF_3{\cdot}OEt_2$ afforded *threo*-adduct **2a** exclusively. Whereas treatment of 2-benzoyl-*N*,*N*-dimethylpropanamide ($PhCOCH(Me)CONMe_2$) with allylzinc bromide provided *erythro*-3-hydroxy-2-methyl-3-phenyl-5-hexenamide with high stereoselectivity, allylation with allylsilane in the presence of a catalytic amount of *n*-Bu_4NF afforded stereoisomeric *threo* hydroxy amide exclusively.

The reaction of allylic organometallic reagents with carbonyl compounds is one of the most basic carbon–carbon bond forming methodologies in organic synthesis and has attracted much attention of many organic chemists.[1] Recently, we have reported an effective procedure for the stereoselective reduction of 2-methyl-3-oxo amides[2] and stereoselective alkylation of 2-formyl-2-methyl amides or 2-methyl-3-oxo amides with organoaluminium or organomanganese reagents.[3] We describe here further exploitation of this approach and the development of stereoselective allylation of 2-formyl amides or 3-oxo amides.[4]

(1) Allylation with Allylzinc Reagents. We have reported that (1) treatment of 2-alkyl-2-formyl amides with $RAlCl_2$ or $PhAlCl_2$ provided *threo*-2-alkyl-3-hydroxy amides under high stereocontrol[3a,5] and (2) treatment of 2-methyl-3-oxo amides with trialkylaluminium or alkylmanganese halide afforded the corresponding *erythro* (or *threo*) 3-hydroxy-2-methyl amides with high stereoselectivity.[3b] Here we describe an extension of the method for the stereoselective addition of allylic organometallic reagents to these amides. Among many allylic organometallic reagents, allylmagnesium and allylzinc reagents were chosen because of their facile accessibility. Allylation of **1a** with allylmagnesium chloride gave allylated product in only 27% yield (**2a**:**3a**=54:46). In contrast, treatment of **1a** with allylzinc bromide, prepared from allyl bromide and zinc dust, provided the same homoallylic alcohol in 95% yield. Moreover, whereas the reaction of **1b** with allylmagnesium chloride afforded a mixture of **2b** and **3b** (**2b**:**3b**=80:20), the reaction with allylzinc bromide provided one stereoisomer **2b** with high stereoselectivity (>99%). In these cases, the zinc reagent proved to be superior to the corresponding magnesium reagent in terms of yield and stereoselectivity. Based on these facts, we focused our attention to allylzinc reagents.

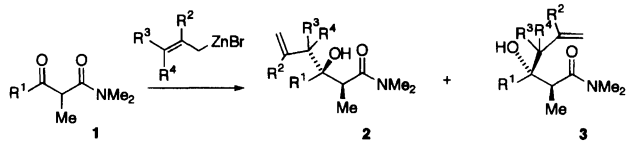
The representative results with allylic zinc reagents are shown in Table 1. *N*-Phenyl amides (**1d**, **1e**) as well as *N*,*N*-dimethyl amides (**1a**, **1b**, and **1c**) reacted easily with zinc reagents, although excess zinc reagents were needed to complete the allylation. An addition of allylzinc bromide to formyl amide **1a** afforded a mixture of **2a** and **3a** (63:37). The poor selectivity might be attributed to high reactivity of formyl group compared of keto group. The addition of allyl group to formyl carbonyl could proceed without activation of carbonyl group by metal chelation. In contrast to the addition of allylzinc bromide to 2-formyl amide, allylation of 2-methyl-3-oxo amides **1b**, **1c** with allylzinc bromide proceeded with high stereoselectivity. For instance, treatment of **1b** with allylzinc bromide at 25 °C under argon atmosphere gave allylated product, *erythro*-3-hydroxy-2-methyl-3-phenyl-5-hexenamide (**2c**) selectively (**2c**:**3c**=>99:1) in 91% yield. However, the reaction of *N*-phenyl amide **1e** with allylic zinc reagents gave the adducts with moderate stereoselectivity.

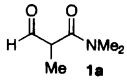
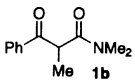
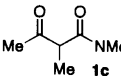
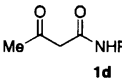
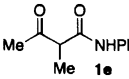
The stereochemistry of the adduct **2c** was determined as follows. Hydrogenation of **2c** under PtO_2 catalyst gave 3-hydroxy-2-methyl-3-phenylhexanamide (**9**) which was identical with a sample derived from the reaction of **1b** with *n*-PrMnCl (Scheme 1).[3b]

The selective formation of the product **2** can be attributed to the selective attack of allyl group from the opposite side of the 2-methyl group of **1b**, **1c**, or **1e** in a six-membered metal chelation (Scheme 2).[6]

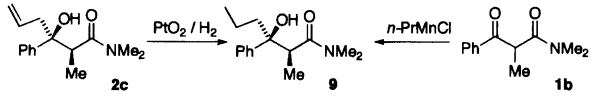
Not only allylzinc bromide but also 2-methyl-2-propenylzinc bromide or 2-butenylzinc bromide added to **1a**—**1e** easily to give the corresponding hydroxy amides in good to excellent yields under high stereocontrol.

Table 1. Allylation of Formyl Amide and 3-Oxo Amides with Allylmagnesium Chloride or Allylzinc Bromide[a)]

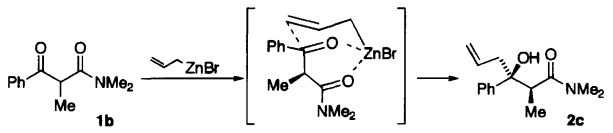


Entry	Keto amide	Allylic metal/(mmol)		Yield/%		Ratio of **2** : **3**		
1	 **1a**	CH_2=$CHCH_2$ZnBr	(2.0)	95	63	(**2a**)	: 37	(**3a**)
2		CH_2=$C(CH_3)CH_2$ZnBr	(2.0)	80	50	(**2b**)	: 50	(**3b**)
3		CH_2=$CHCH_2$MgCl	(1.1)[b)]	90	80	(**2c**)	: 20	(**3c**)
4	 **1b**	CH_2=$CHCH_2$ZnBr	(2.0)	91	>99	(**2c**)	: 1	(**3c**)
5		CH_2=$C(CH_3)CH_2$ZnBr	(2.0)	96	>99	(**2d**)	: 1	(**3d**)
6		CH_3CH=$CHCH_2$ZnBr	(4.0)[c)]	99	>99	(**2e**)	: 1	(**3e**)
7		$(CH_3)_2C$=$CHCH_2$ZnBr	(3.0)[d)]	94[e)]	>99	(**2f**)	: 1	(**3f**)
					>99	(**2f′**)	: 1	(**3f′**)
8	 **1c**	CH_2=$CHCH_2$ZnBr	(2.0)	92	98	(**2g**)	: 2	(**3g**)
9		CH_2=$C(CH_3)CH_2$ZnBr	(2.0)	93	97	(**2h**)	: 3	(**3h**)
10		CH_3CH=$CHCH_2$ZnBr	(2.0)[c)]	92	96	(**2i**)	: 4	(**3i**)
11		CH_2=$CHCH_2$MgCl	(5.0)[b)]	42			—	
12	 **1d**	CH_2=$CHCH_2$ZnBr	(5.0)	91			—	
13		CH_2=$C(CH_3)CH_2$ZnBr	(5.0)	84			—	
14		CH_3CH=$CHCH_2$ZnBr	(5.0)[c)]	93[f)]			—	
15		$(CH_3)_2C$=$CHCH_2$ZnBr	(5.0)[d)]	75			—	
16	 **1e**	CH_2=$CHCH_2$ZnBr	(2.0)	99	89	(**2j**)	: 11	(**3j**)
17		CH_2=$C(CH_3)CH_2$ZnBr	(2.0)	93	86	(**2k**)	: 14	(**3k**)

a) Reactions were performed at 25 °C unless otherwise noted. b) Reaction was performed at 0 °C. c) Prepared from a mixture of 1-bromo-2-butene and 3-bromo-1-butene (purchased from Aldrich Chemical Co). d) Chlorotrimethylsilane was used for the activation of zinc dust. e) 1 : 1 regioisomeric mixture of $PhC(OH)(CMe_2CH$=$CH_2)CHMeCONMe_2$ (**2f** : **3f** = > 99 : 1) and $PhC(OH)(CH_2CH$=$CMe_2)$-$CHMeCONMe_2$ (**2f′** : **3f′** = > 99 : 1) See text. f) Mixture of stereoisomers. Isomeric ratio=67/33.



Scheme 1.

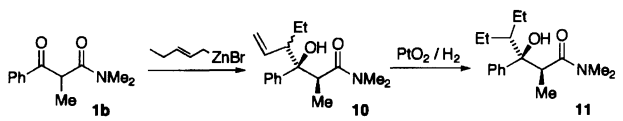


Scheme 2.

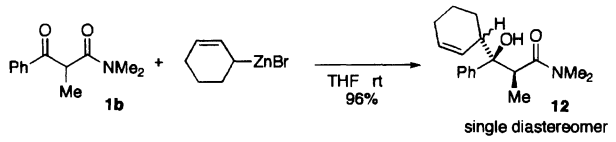
The allylic zinc reagent such as 2-butenylzinc bromide reacted regioselectively at the secondary carbon. Small amount (<4%) of regioisomer, which was generated by the reaction of allylic zinc at the primary carbon, was detected in the reaction mixture. Exceptionally, the reaction of 3-methyl-2-butenylzinc bromide with **1b** proceeded to afford the corresponding hydroxy amide as a mixture of an equimolar amount of regioisomers (Entry 7).

In the reaction of 2-butenylzinc bromide with **1b** or **1c**, the corresponding allylated product **2e** or **2i** was obtained as a 1 : 1 diastereomeric mixture of ($3R^*$, $4R^*$) and ($3R^*$, $4S^*$) (Entries 6 and 10). The stereochemistry was confirmed by the following experiments. The addition of 2-pentenylzinc bromide to **1b** gave an adduct **10** as a stereoisomeric mixture. Hydrogenation of **10** afforded *erythro*-4-ethyl-3-hydroxy-*N*,*N*, 2-trimethyl-3-phenylhexanamide (**11**) as a single product (Scheme 3). The formation of a diastereomeric mixture could be attributed to the stereochemistry of 2-butenylzinc bromide or 2-pentenylzinc bromide which consists of (*E*) and (*Z*)-isomers.[7)] The assumption was supported by the result that the reaction of **1b** with 2-cyclohexen-1-ylzinc bromide provided single diastereomer **12** (Scheme 4).

2-Propynylzinc bromide[8)] reacted with **1d** at 25 °C to give a mixture of propargylated product (MeC-



Scheme 3.

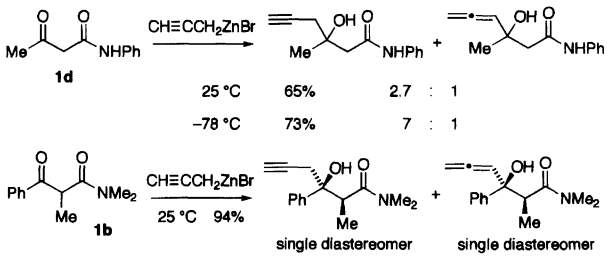


Scheme 4.

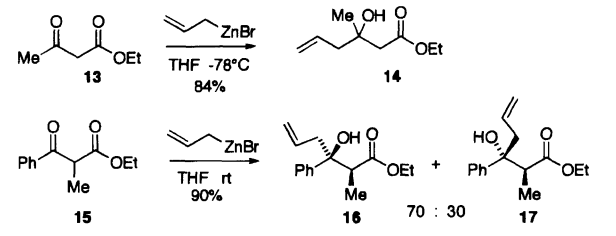
$(CH_2C{\equiv}CH)(OH)CH_2CONHPh$) and allenylated product ($MeC(CH{=}C{=}CH_2)(OH)CH_2CONHPh$) in a 2.7 : 1 ratio in 65% combined yield. The distribution of the products depended on the reaction temperature. Reaction at −78 °C provided a mixture of propargylated adduct and allenylated adduct in a 7 : 1 ratio. In contrast, the ratio (1 : 1) of propargylated product to allenylated product in the reaction of **1b** with propynylzinc bromide was not affected by the reaction temperature (Scheme 5). Hydrogenation of both products gave the same *erythro*-3-hydroxy-*N*,*N*,2-trimethyl-3-phenylhexanamide **9** which was identical with a sample derived from **2c** in Scheme 1.

An addition of allylzinc bromide to 3-oxo ester instead of 3-oxo amide was examined. Exposure of ethyl acetoacetate (**13**) to allylzinc reagent at −78 °C afforded ethyl 3-hydroxy-3-methyl-5-hexenoate (**14**) in 84% yield. Treatment of $PhC(O)CH(CH_3)COOEt$ (**15**) with allylzinc bromide afforded 3-hydroxy ester as a stereoisomeric mixture (*erythro* : *threo* = 7 : 3) in 90% yield (Scheme 6). The low stereoselectivity of 3-oxo ester compared to 3-oxo amide might be explained by the fact that the coordination of ester to zinc reagents is weaker than that of amide.[2b]

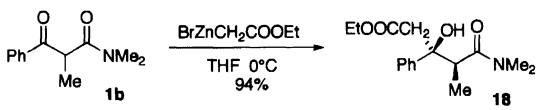
Reformatsky reaction also proceeded stereoselectively as shown below. Treatment of **1b** (1.0 mmol) with the reagent generated from ethyl bromoacetate (2.0 mmol) and zinc dust (2.0 mg atom) gave the corresponding adduct in good yield (Scheme 7). Stereochemistry of **18** was determined as follows (Scheme 8). Reduction of **18** with *i*-Bu_2AlH gave the *erythro*-3,5-dihydroxyl-*N*,*N*,2-



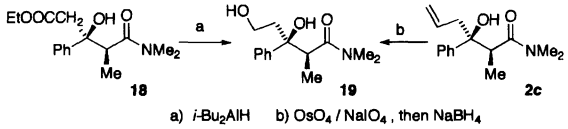
Scheme 5.



Scheme 6.



Scheme 7.



Scheme 8.

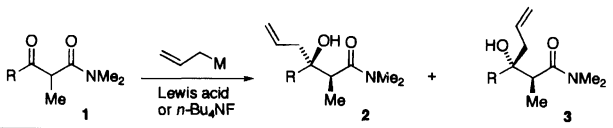
trimethyl-3-phenylpentanamide **19** which was identical with a sample derived from the adduct **2c** by oxidative cleavage of C=C bond (OsO_4, $NaIO_4$) and successive reduction ($NaBH_4$).

(2) Stereoselective Allylation with Allyltrimethylsilane. Allysilanes have been used extensively as an allyl anion equivalent and the addition of allyltrimethylsilane to carbonyl compounds is induced either by Lewis acid[9] or fluoride ions.[10] First, allylation of formyl amides and 3-oxo-amides with allyltrimethylsilane in the presence of various Lewis acids has been examined. Treatment of formyl amide **1a** with allyltrimethylsilane in the presence of $TiCl_4$ or $SnCl_4$ gave allylated product as a mixture of stereoisomers **2a** and **3a** in **2a** : **3a** = 80 : 20 or 85 : 15 ratio. The use of $EtAlCl_2$ resulted in a selective formation of **2a**. However, the yield was poor (22%) and ethylated product $EtCH(OH)–CHMeCONMe_2$ was obtained as a main product (41% yield). Diethyl ether-boron trifluoride (1/1) provided **2a** in good yield with high stereoselectivity. In the case of 3-oxo amides **1b** and **1c**, Lewis acid-induced allylation afforded homoallylic alcohols **2c**, **2g** stereoselectively irrespective of the nature of the catalysts (Table 2).

The stereochemical results with Lewis acid mediated allylation may be rationalized as follows: (1) coordination of formyl amide or 3-oxo amide to Lewis acid such as $TiCl_4$ to give a six-membered metal chelation, and (2) stereoselective attack of allylsilane from the opposite side of 2-methyl group of **1a**, **1b**, or **1c**.

In contrast to Lewis acid mediated allylation, tetrabutylammonium fluoride induced allylation of **1b** or **1c** gave isomeric adduct **3b** or **3c** selectively. In the case of formyl amide **1a**, the reaction did not proceed and the starting material was recovered. The selective formation of **3b** or **3c** with allylsilane–*n*-Bu_4NF system can be explained by Felkin–Anh model. We have reported *threo* selective reduction of 3-oxo esters and 3-oxo amides with *n*-Bu_4NBH_4.[2b] The *threo* selectivity may be attributed to the hydride attack on *β*-carbonyl group from the opposite side of the bulky CO_2R or $CONMe_2$ group. In the allylsilane–*n*-Bu_4NF system, allylic anion, more bulky nucleophile than hydride, attacks *β*-carbonyl group in high stereoselectivity.

Table 2. Allylation of Formyl Amide and 3-Oxo Amides with Allylsilane or Allylstannane[a)]



Entry	Substrate	M	Lewis acid or n-Bu_4NF	Yield (%)	Ratio of **2** : **3**				
1	**1a**	Me_3Si	$TiCl_4$	100	80	(**2a**)	:	20	(**3a**)
2	(R=H)	Me_2PhSi	$TiCl_4$	93	79	(**2a**)	:	21	(**3a**)
3		Me_3Si	$SnCl_4$	78	85	(**2a**)	:	15	(**3a**)
4		Me_3Si	$EtAlCl_2$	22	>99	(**2a**)	:	<1	(**3a**)
5		Me_3Si	$BF_3{\cdot}OEt_2$	68	>99	(**2a**)	:	<1	(**3a**)
6		n-Bu_3Sn	$BF_3{\cdot}OEt_2$	60	40	(**2a**)	:	60	(**3a**)
7	**1b**	Me_3Si	$TiCl_4$	76	>99	(**2c**)	:	<1	(**3c**)
8	(R=Ph)	Me_3Si	$MeAlCl_2$	80	96	(**2c**)	:	4	(**3c**)
9		Me_3Si	$BF_3{\cdot}OEt_2$	57	>99	(**2c**)	:	<1	(**3c**)
10		Me_3Si	n-Bu_4NF[b)]	84	>1	(**2c**)	:	>99	(**3c**)
11	**1c**	Me_3Si	$TiCl_4$	65	>99	(**2g**)	:	<1	(**3g**)
12	(R=Me)	Me_3Si	$MeAlCl_2$	76	>99	(**2g**)	:	<1	(**3g**)
13		Me_3Si	n-Bu_4NF[b)]	61	17	(**2g**)	:	83	(**3g**)

a) Reactions were performed −78 °C to rt unless otherwise noted. b) Reaction was performed at 0 °C.

Experimental

Distillation of the products was performed by the use of Kugelrohr (Büchi), and boiling points are indicated by air-bath temperature without correction. Melting point was obtained on a Yanako MP-50929 melting point apparatus and are uncorrected. ^{1}H NMR and ^{13}C NMR spectra were taken on a Varian GEMINI 300 spectrometer, $CDCl_3$ was used as solvent, and chemical shifts being given in δ with tetramethylsilane as an internal standard. IR spectra were determined on a JASCO IR-810 spectrometer. The analyses were carried out at the Elemental Analysis Center of Kyoto University.

Preparation of 3-Oxo Amides and 3-Oxo Esters. These compounds were prepared according to the reported procedure.[2b)]

Preparation of Zinc Reagent. Allylic zinc or propargylic zinc reagents were prepared from allylic bromides or 3-bromo-1-propyne and zinc dust in THF at room temperature. Zinc dust was washed by 1 M (1 M=1 mol dm^{-3}) HCl according to the usual procedure.[11)] The addition of the catalytic amount of chlorotrimethylsilane was effective for the further activation of the surface of zinc dust.[12)] For example, the reaction of 1-bromo-3-methyl-2-butene with zinc dust proceeded sluggishly to give zinc reagent in low yield without pre-treatment of zinc dust with chlorotrimethylsilane.

General Procedure for Allylation of 3-Oxo Amides. Allyl bromide (0.24 g, 2.0 mmol) was added to a suspension of zinc dust (0.13 g, 2.0 mg atom) in THF (5 ml) at 25 °C. Exothermic reaction took place and the reaction mixture turned pale gray. After being stirred for 30 min, a THF (3 ml) solution of 3-oxo amide **1b** (0.21 g, 1.0 mmol) was added to the resulting allylzinc bromide at 25 °C. The mixture was stirred for another 30 min and poured into 1 M HCl and extracted with ethyl acetate (20 ml×3). The combined organic extracts were dried over Na_2SO_4 and concentrated in vacuo. The residual oil was purified by silica-gel column chromatography to give allylated product, *erythro*-3-hydroxy-*N*,*N*,2-trimethyl-3-phenyl-5-hexenamide (**2c**, 0.22 g) in 91% yield: Mp 104.0—104.5 °C; IR ($CHCl_3$) 3344, 3008, 1617, 1497, 1451, 1418, 1401 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ=0.89 (d, J=7.1 Hz, 3H), 2.58 (d, J=7.1 Hz, 2H), 3.04 (s, 3H), 3.07 (q, J=7.1 Hz, 1H), 3.15 (s, 3H), 4.88—5.05 (m, 2H), 5.46—5.67 (m,1H), 5.80 (bs, 1H), 6.95—7.28 (m, 5H); ^{13}C NMR ($CDCl_3$) δ=12.53, 35.56, 37.62, 42.45, 46.76, 77.26, 117.2, 125.5, 126.4, 128.0, 134.1, 143.6, 177.7. Found: C, 72.64; H, 8.75%. Calcd for $C_{15}H_{21}NO_2$: C, 72.85; H, 8.56%. The isomeric ratios of stereoisomers were determined by the examination of methyl signals at C-2 in ^{1}H NMR spectra of crude products. The separation of stereoisomers was performed by silica-gel column chromatography. The data for the compounds, which could not be separated by silica-gel column chromatography, are shown as a isomeric mixture.

General Procedure for the Reaction of 3-Oxo Amides with Allyltrimethylsilane Catalyzed by n-Bu_4NF. n-Bu_4NF (1.0 M THF solution purchased from Aldrich chemical Co., 0.05 ml, 0.05 mmol) was added to a THF (5 ml) suspension of molecular sieves 4A (63 mg) at room temperature under argon atmosphere and was stirred for 10 min. To the resulting mixture was added a THF (3 ml) solution of 3-oxo amide **1b** (108 mg, 0.53 mmol) and allyltrimethylsilane (114 mg, 1.0 mmol) at 0 °C. After being stirred for 1.5 h, the resulting mixture was poured into saturated NH_4Cl and extracted with ethyl acetate (20 ml×2). The combined organic layer was dried over Na_2SO_4 and concentrated in vacuo. Purification by silica-gel column chro-

matography gave **3c** (109 mg, 84% yield, **2c**/**3c**=1/>99).

***threo*-3-Hydroxy-*N*,*N*,2-trimethyl-3-phenyl-5-hexenamide (3c):** Mp 98.0—99.0 °C; IR ($CHCl_3$) 3336, 3006, 1616, 1493, 1416, 1399, 1160 cm^{-1}; ^1H NMR ($CDCl_3$) δ=1.36 (d, J=7.0 Hz, 3H), 2.47 (dd, J=13.8, 7.3 Hz, 1H), 2.66 (s, 3H), 2.68 (dd, J=13.8, 6.7 Hz, 1H), 2.88 (s, 3H), 3.26 (q, J=7.0 Hz, 1H), 4.91—5.03 (m, 2H), 5.51 (dddd, J=17.2, 10.1, 7.3, 6.7 Hz, 1H), 6.20 (bs, 1H), 7.15—7.40 (m, 5H); ^{13}C NMR ($CDCl_3$) δ=11.88, 35.11, 37.26, 41.96, 43.82, 117.6, 125.3, 126.5, 127.8, 133.4, 146.4, 176.9. Found: C, 72.95; H, 8.76%. Calcd for $C_{15}H_{21}NO_2$: C, 72.85; H, 8.56%.

3-Hydroxy-*N*,*N*,2-trimethyl-5-hexenamide (Mixture of 2a and 3a): Bp 67—68 °C (6 Torr, 1 Torr= 133.322 Pa); IR (neat) 3396, 2930, 1620, 1459, 1419, 1401, 1160, 1032 cm^{-1}; ^1H NMR ($CDCl_3$) δ=1.16 (d, J=7.1 Hz, 3H for **3a**), 1.24 (d, J=7.1 Hz, 3H for **2a**), 2.10—2.43 (m, 2H for **2a** and **3a**), 2.67—2.82 (m, 2H for **2a** and **3a**), 2.96 (s, 3H for **3a**), 2.97 (s, 3H for **2a**), 3.05 (s, 3H for **2a** and **3a**), 3.65—3.76 (m, 1H for **2a**), 3.96 (td, J=6.8, 2.4 Hz, 1H for **3a**), 4.34 (d, J=5.3 Hz, for **2a**), 4.55 (bs, 1H for **3a**), 5.03—5.18 (m, 2H for **2a** and **3a**), 5.75—5.94 (m, 1H for **2a** and **3a**); ^{13}C NMR ($CDCl_3$) δ=9.487, 15.01, 35.30, 37.30, 37.67, 38.13, 38.76, 40.37, 70.69, 73.92, 117.0, 117.3, 134.8, 135.2, 176.6, 177.5. Found: C, 62.83; H, 9.98%. Calcd for $C_9H_{17}NO_2$: C, 65.13; H, 10.01%.

3-Hydroxy-*N*,*N*,2,5-tetramethyl-5-hexenamide (2b or 3b: Faster Moving Isomer on Silica Gel Eluted with Ethyl Acetate/Hexane=1/1): Bp 73—74 °C (6 Torr); IR (neat) 3408, 2964, 2932, 1623, 1506, 1456, 1418, 1400, 1258, 1154, 1054, 888 cm^{-1}; ^1H NMR ($CDCl_3$) δ=1.17 (d, J=7.1 Hz, 3H), 1.77 (s, 3H), 2.14 (dd, J=13.8, 6.6 Hz, 1H), 2.28 (dd, J=13.8, 7.7 Hz, 1H), 2.70 (qd, J=7.1, 3.4 Hz, 1H), 2.96 (s, 3H), 3.05 (s, 3H), 4.06—4.11 (m, 1H), 4.32 (bs, 1H), 4.80 (m, 1H), 4.84 (m, 1H); ^{13}C NMR ($CDCl_3$) δ= 9.691, 22.41, 35.32, 37.33, 37.89, 41.97, 68.94, 112.9, 142.5, 177.5. Found: C, 65.03; H, 10.52%. Calcd for $C_{10}H_{19}NO_2$: C, 64.83; H, 10.34%.

3-Hydroxy-*N*,*N*,2,5-tetramethyl-5-hexenamide (2b or 3b: Slower Moving Isomer on Silica Gel): Bp 77—78 °C (5 Torr); IR (neat) 3382, 2930, 1619, 1508, 1498, 1458, 1419, 1401, 1376, 1155, 1059, 1035, 887 cm^{-1}; ^1H NMR ($CDCl_3$) δ=1.25 (d, J=7.2 Hz, 3H), 1.76 (s, 3H), 2.19—2.34 (m, 2H), 2.75 (qd, J=7.2, 4.6 Hz, 1H), 2.97 (s, 3H), 3.04 (s, 3H), 3.81 (td, J=6.8, 4.6 Hz, 1H), 4.20 (bs, 1H), 4.72 (m, 1H), 4.83 (m, 1H); ^{13}C NMR ($CDCl_3$) δ=15.05, 22.34, 35.26, 37.30, 38.65, 44.47, 72.51, 112.7, 143.0, 176.7. Found: C, 67.88; H, 10.58%. Calcd for $C_{10}H_{19}NO_2$: C, 64.83; H, 10.34%.

***erythro*-3-Hydroxy-*N*,*N*,2,5-tetramethyl-3-phenyl-5-hexenamide (2d):** Mp 117.0—117.5 °C; IR (Nujol) 3338, 2922, 2852, 1615, 1450, 1417, 1402, 1376, 885, 707 cm^{-1}; ^1H NMR ($CDCl_3$) δ=0.87 (d, J=7.0 Hz, 3H), 1.46 (d, J=1.4 Hz, 3H), 2.52 (dd, J=13.4, 0.8 Hz, 1H), 2.58 (d, J=13.4 Hz, 1H), 3.04 (s, 3H), 3.06 (q, J=7.0 Hz, 1H), 3.15 (s, 3H), 4.44 (m, 1H), 4.61 (m, 1H), 5.90 (bs, 1H), 7.18—7.45 (m, 5H); ^{13}C NMR ($CDCl_3$) δ=12.48, 24.12, 35.56, 37.65, 43.53, 49.68, 77.74, 114.3, 125.7, 126.3, 127.7, 142.4, 143.6, 177.8. Found: C, 73.60; H, 9.00%. Calcd for $C_{16}H_{23}NO_2$: C, 73.53; H, 8.87%.

***erythro*-3-Hydroxy-*N*,*N*,2,4-tetramethyl-3-phenyl-5-hexenamide (2e, 1 to 1 Mixture of Stereoisomers at C-4):** Mp 63.5—65.0 °C; IR (Nujol) 3312, 2954, 2924, 2852, 1608, 1498, 1455, 1419, 1403, 1375, 981, 918, 770, 709 cm^{-1}; ^1H NMR ($CDCl_3$) δ=0.75 (d, J=6.7 Hz, 1.5H), 0.76 (d, J=6.8 Hz, 1.5H), 0.80 (d, J=7.1 Hz, 1.5H), 0.92 (d, J=7.2 Hz, 1.5H), 2.49—2.58 (m, 0.5H), 2.63—2.73 (m, 0.5H), 2.93 (s, 1.5H), 3.04 (s, 1.5H), 3.07 (q, J=7.1 Hz, 0.5H), 3.10 (s, 1.5H), 3.11 (s, 1.5H), 3.34 (q, J=7.2 Hz, 0.5H), 4.84—5.06 (m, 2H), 5.63 (ddd, J=17.1, 10.0, 10.0 Hz, 0.5H), 5.63 (m, 0.5H), 7.20—7.80 (m, 5H), OH proton was not detected; ^{13}C NMR ($CDCl_3$) δ=12.76, 14.35, 15.40, 16.51, 35.44, 37.36, 37.43, 39.38, 40.32, 48.86, 50.55, 79.69, 79.84, 112.8, 115.0, 124.5—128.2 (many peaks), 141.0, 141.6, 141.9, 144.1, 178.0, 178.3. Found: C, 73.51; H, 9.02%. Calcd for $C_{16}H_{23}NO_2$: C, 73.53; H, 8.87%.

***erythro*-3-Hydroxy-*N*,*N*,2,4,4-pentamethyl-3-phenyl-5-hexenamide (2f, γ Adduct):** Bp 72—73 °C; (0.6 Torr); IR (neat) 3252, 3076, 3056, 2966, 2930, 2874, 1616, 1495, 1463, 1416, 1400, 1375, 1154, 773, 710 cm^{-1}; ^1H NMR ($CDCl_3$) δ=0.85 (d, J=6.9 Hz, 3H), 0.88 (s, 3H), 0.89 (s, 3H), 2.94 (s, 3H), 3.18 (s, 3H), 3.39 (q, J=6.9 Hz, 1H), 4.92 (dd, J=17.5, 1.5 Hz, 1H), 4.97 (dd, J=10.8, 1.5 Hz, 1H), 6.11 (dd, J=17.5, 10.8 Hz, 1H), 7.06 (bs, 1H), 7.18—7.42 (m, 4H), 7.80 (bs, 1H); ^{13}C NMR ($CDCl_3$) δ=15.96, 23.27, 24.15, 35.62, 35.71, 37.56, 45.93, 81.98, 111.0, 126.1, 127.6 (broad), 128.4 (broad), 143.0, 146.5, 178.8. Found: C, 73.91; H, 9.40%. Calcd for $C_{17}H_{25}NO_2$: C, 74.14; H, 9.15%.

***erythro*-3-Hydroxy-*N*,*N*,2,6-tetramethyl-3-phenyl-5-heptenamide (2f', α Adduct):** Mp 82.5—83.0 °C; IR (Nujol) 3278, 2920, 2852, 1609, 1458, 1376, 1161, 889, 699 cm^{-1}; ^1H NMR ($CDCl_3$) δ=0.90 (d, J=7.0 Hz, 3H), 1.46 (s, 3H), 1.58 (d, J=1.1 Hz, 3H), 2.51 (d, J=7.0 Hz, 2H), 3.03 (s, 3H), 3.10 (q, J=7.0 Hz, 1H), 3.14 (s, 3H), 4.88—4.95 (m, 1H), 5.97 (bs, 1H), 7.19—7.45 (m, 5H); ^{13}C NMR ($CDCl_3$) δ=12.62, 17.96, 25.91, 35.60, 37.59, 40.89, 41.99, 77.68, 119.4, 125.5, 126.2, 127.8, 133.6, 144.1, 177.8. Found: C, 73.91; H, 9.25%. Calcd for $C_{17}H_{25}NO_2$: C, 74.14; H, 9.15%.

***erythro*-3-Hydroxy-*N*,*N*,2-trimethyl-3-phenyl-5-hexynamide and *erythro*-3-Hydroxy-*N*,*N*,2-trimethyl-3-phenyl-4,5-hexadienamide:** Mp 101.0—105.0 °C; IR (Nujol) 3288, 2922, 2852, 1618, 1461, 1420, 1377, 1319, 1166, 704 cm^{-1}; ^1H NMR ($CDCl_3$) δ=0.89 (d, J=7.1 Hz, 3H for allenylated product), 0.95 (d, J=7.1 Hz, 3H for propargylated product), 2.05 (t, J=2.7 Hz, 1H for propargylated product), 2.66 (dd, J=16.9, 2.7 Hz, 1H for propargylated product), 2.80 (dd, J=16.9, 2.8 Hz, 1H for propargylated product), 3.00 (s, 3H for allenylated product), 3.04 (s, 3H for propargylated product), 3.09 (s, 3H for allenylated product), 3.12 (q, J=7.1 Hz, 1H for allenylated product), 3.20 (s, 3H for propargylated product), 3.48 (q, J=7.1 Hz, 1H for propargylated product), 4.79 (dd, J=10.4, 6.8 Hz, 1H for allenylated product), 4.98 (dd, J=10.4, 6.8 Hz, 1H for allenylated product), 5.49 (t, J=6.8 Hz, 1H for allenylated product), 6.37 (bs, 1H for propargylated product), 6.91 (bs, 1H for allenylated product), 7.22—7.67 (m, 5H for both products); ^{13}C NMR ($CDCl_3$) δ=12.21, 12.54, 33.44, 35.46, 35.65, 37.28, 37.65, 40.28, 42.05, 70.85, 76.24, 81.50, 100.4, 125.2, 125.7, 126.9, 127.9, 143.6, 143.8, 177.4, 177.9, 205.7. Found: C, 73.53; H, 7.74%. Calcd for $C_{15}H_{19}NO_2$: C, 73.44; H, 7.81%.

***threo*-3-Hydroxy-*N*,*N*,2,3-tetramethyl-5-hexenamide (2g):** Bp 71—72 °C (10 Torr); IR (neat) 3358,

2974, 2932, 1619, 1452, 1420, 1401, 1315, 1175, 1128, 923 cm^{-1}; ^1H NMR ($CDCl_3$) δ=1.15 (s, 3H), 1.19 (d, J=7.1 Hz, 3H), 2.21—2.36 (m, 2H), 2.62 (q, J=7.1 Hz, 1H), 2.97 (s, 3H), 3.03 (s, 3H), 4.94—5.08 (m, 2H), 5.30 (bs, 1H), 5.81 (dddd, J=16.9, 10.1, 8.9, 6.1 Hz, 1H); ^{13}C NMR ($CDCl_3$) δ=11.92, 23.76, 35.29, 37.35, 40.43, 47.45, 73.11, 117.3, 134.9, 177.9. Found: C, 64.59; H, 10.54%. Calcd for $C_{10}H_{19}NO_2$: C, 64.83; H, 10.34%.

***erythro*-3-Hydroxy-*N*,*N*,2,3-tetramethyl-5-hexenamide (3g):** Bp 71—72 °C (10 Torr); IR (neat) 3370, 2972, 2932, 1721, 1622, 1499, 1465, 1417, 1398, 1373, 1317, 1256, 1140, 1081, 1058, 1000, 925 cm^{-1}; ^1H NMR ($CDCl_3$) δ=1.18 (s, 3H), 1.18 (d, J=7.0 Hz, 3H), 2.21—2.36 (m, 2H), 2.67 (q, J=7.0 Hz, 1H), 2.98 (s, 3H), 3.06 (s, 3H), 5.09—5.18 (m, 2H), 5.22 (bs, 1H), 5.73—5.86 (m, 1H); ^{13}C NMR ($CDCl_3$) δ=11.58, 26.43, 35.31, 37.58, 40.41, 43.50, 72.29, 118.1, 133.7, 177.7. Found: C, 64.81; H, 10.39%. Calcd for $C_{10}H_{19}NO_2$: C, 64.83; H, 10.34%.

***threo*-3-Hydroxy-*N*,*N*,2,3,5-pentamethyl-5-hexenamide (2h):** Bp 81—82 °C (20 Torr); IR (neat) 3362, 2974, 2936, 1619, 1500, 1452, 1419, 1400, 1314, 1126 cm^{-1}; ^1H NMR ($CDCl_3$) δ=1.16 (s, 3H), 1.20 (d, J=7.1 Hz, 3H), 1.83 (s, 3H), 2.20 (d, J=13.2 Hz, 1H), 2.28 (d, J=13.2 Hz, 1H), 2.63 (q, J=7.1 Hz, 1H), 2.97 (s, 3H), 3.05 (s, 3H), 4.62 (s, 1H), 4.85 (s, 1H), 5.27 (bs, 1H); ^{13}C NMR ($CDCl_3$) δ=12.08, 24.06, 24.33, 35.28, 37.38, 41.50, 50.33, 73.49, 114.2, 143.4, 178.0. Found: C, 66.00; H, 10.82%. Calcd for $C_{10}H_{21}NO_2$: C, 66.29; H, 10.62%.

***threo*-3-Hydroxy-*N*,*N*,2,3,4-pentamethyl-5-hexenamide (2i, 1 to 1 Mixture of Stereoisomers A and B at C-4):** Bp 76—77 °C (7 Torr); IR (neat) 3356, 2972, 2932, 1618, 1449, 1419, 1400, 1138, 917 cm^{-1}; ^1H NMR ($CDCl_3$) δ=0.93 (d, J=7.0 Hz, 3H for A), 1.01 (s, 3H for B), 1.02 (s, 3H for A), 1.07 (d, J=6.8 Hz, 3H for B), 1.18 (d, J=7.2 Hz, 3H for B), 1.20 (d, J=7.1 Hz, 3H for A), 2.34—2.45 (m, 2H for both isomers), 2.68 (q, J=7.2 Hz, 1H for B), 2.80 (q, J=7.1 Hz, 1H for A), 2.90, 2.98, 3.08, (three bs, 6H for both isomers), 4.20 (bs, 1H for both isomers), 4.88 (dd, J=17.0, 2.3 Hz, 1H for B), 4.97 (dd, J=10.2, 2.3 Hz, 1H for B), 4.95—5.08 (m, 2H for A), 5.63 (ddd, J=17.0, 10.2, 10.2 Hz, 1H for B), 6.11 (ddd, J=17.3, 10.5, 6.4 Hz, 1H for A); ^{13}C NMR ($CDCl_3$) δ=11.91, 12.02, 12.46, 14.51, 15.16, 17.95, 19.78, 23.72, 35.20, 35.35, 37.18, 37.30, 39.32, 40.25, 45.95, 48.09, 75.11, 75.29, 114.0, 114.8, 140.8, 141.8, 177.9, 178.2. Found: C, 66.13; H, 10.63%. Calcd for $C_{11}H_{21}NO_2$: C, 66.29; H, 10.62%.

3-Hydroxy-3-methyl-*N*-phenyl-5-hexenamide: Bp 85—86 °C (0.8 Torr); IR (neat) 3306, 3298, 2970, 1663, 1648, 1641, 1601, 1549, 1536, 1500, 1445, 754, 691 cm^{-1}; ^1H NMR ($CDCl_3$) δ=1.33 (s, 3H), 2.36 (d, J=7.5 Hz, 2H), 2.47 (d, J=15.0 Hz, 1H), 2.58 (d, J=15.0 Hz, 1H), 3.53 (bs, 1H), 5.11—5.24 (m, 2H), 5.89 (ddt, J=17.0, 10.3, 7.5 Hz, 1H), 7.09—7.16 (m, 1H), 7.30—7.37 (m, 2H), 7.48—7.54 (m, 2H), 8.02 (bs, 1H); ^{13}C NMR ($CDCl_3$) δ=26.83, 46.80, 47.37, 71.45, 119.4, 120.1, 124.4, 129.0, 133.3, 137.5, 170.2. Found: C, 71.12; H, 7.91%. Calcd for $C_{13}H_{17}NO_2$: C, 71.21; H, 7.81%.

3-Hydroxy-3,5-dimethyl-*N*-phenyl-5-hexenamide: Mp 57.0—57.5 °C; IR (Nujol) 3508, 3324, 2920, 2852, 1642, 1602, 1552, 1535, 1460, 1376, 1356, 1301, 1161, 1110, 958, 906, 772, 692 cm^{-1}; ^1H NMR ($CDCl_3$) δ=1.34 (s, 3H), 1.88 (s, 3H), 2.29 (d, J=13.7 Hz, 1H), 2.35 (d, J=13.7 Hz, 1H), 2.47 (d, J=15.0 Hz, 1H), 2.62 (d, J=15.0 Hz, 1H), 2.91 (bs, 1H), 4.78 (m, 1H), 4.98 (m, 1H), 7.09—7.14 (m, 1H), 7.30—7.36 (m, 2H), 7.49—7.52 (m, 2H), 8.17 (bs, 1H); ^{13}C NMR ($CDCl_3$) δ=24.84, 27.40, 48.06, 49.83, 71.65, 115.6, 120.0, 124.4, 129.0, 137.6, 142.1, 170.3. Found: C, 72.14; H, 8.33%. Calcd for $C_{14}H_{19}NO_2$: C, 72.07; H, 8.21%.

3-Hydroxy-3,4-dimethyl-*N*-phenyl-5-hexenamide (Mixture of Stereoisomers at C-4, Isomer Ratio 67/33): Bp 91—92 °C (0.9 Torr); IR (neat) 3298, 2970, 2924, 1656, 1648, 1600, 1544, 1499, 1445, 753, 690 cm^{-1}; ^1H NMR ($CDCl_3$) δ=1.09 (d, J=6.8 Hz, 3H), 1.25 (s, 3H), 2.31—2.66 (m, 3H), 3.11 (bs, 1H for minor isomer), 3.69 (bs, 1H for major isomer), 5.09—5.21 (m, 2H), 5.73 —5.90 (m, 1H), 7.08—7.16 (m, 1H), 7.29—7.34 (m, 2H), 7.48—7.54 (m, 2H), 7.94 (bs, 1H for minor isomer), 8.31 (bs, 1H for major isomer); ^{13}C NMR ($CDCl_3$) δ=14.41, 15.55, 23.14, 23.78, 45.84, 46.26, 48.04, 73.36, 73.42, 116.7, 117.4, 119.7, 120.0, 120.1, 124.2, 124.5, 129.0, 137.5, 137.7, 139.3, 140.1, 170.2, 170.7. Found: C, 71.98; H, 8.17%. Calcd for $C_{14}H_{19}NO_2$: C, 72.07; H, 8.21%.

3-Hydroxy-3,4,4-trimethyl-*N*-phenyl-5-hexenamide: Bp 90—91 °C (0.75 Torr); IR (neat) 3294, 2974, 1656, 1600, 1542, 1499, 1444, 1415, 1375, 1324, 752, 691 cm^{-1}; ^1H NMR ($CDCl_3$) δ=1.09 (s, 3H), 1.10 (s, 3H), 1.30 (d, J=0.7 Hz, 3H), 2.38 (d, J=14.6 Hz, 1H), 2.65 (bs, 1H), 2.70 (dd, J=14.6, 0.7 Hz, 1H), 5.10 (dd, J=17.5, 1.4 Hz, 1H), 5.15 (dd, J=10.9, 1.4 Hz, 1H), 6.05 (dd, J=17.5, 10.9 Hz, 1H), 7.07—7.14 (m, 1H), 7.28—7.36 (m, 2H), 7.48—7.54 (m, 2H), 8.28 (bs, 1H); ^{13}C NMR ($CDCl_3$) δ=21.68, 22.03, 43.83, 44.26, 75.25, 114.3, 120.0, 124.3, 129.0, 137.7, 144.3, 171.0. Found: C, 72.58; H, 8.66%. Calcd for $C_{15}H_{21}NO_2$: C, 72.84; H, 8.56%.

3-Hydroxy-3-methyl-*N*-phenyl-5-hexynamide and 3-Hydroxy-3-methyl-*N*-phenyl-4,5-hexadienamide: Bp 89—90 °C (0.8 Torr); IR (neat) 3294, 1956, 1655, 1599, 1542, 1499, 1444, 754, 690 cm^{-1}; ^1H NMR ($CDCl_3$) δ=1.43 (s, 3H for propargylated product), 1.45 (s, 3H for allenylated product), 2.14 (t, J=2.7 Hz, 1H for propargylated product), 2.51 (d, J=2.7 Hz, 2H for propargylated product), 2.58 (d, J=14.9 Hz, 1H for propargylated product), 2.66 (s, 2H for allenylated product), 2.76 (d, J=14.9 Hz, 1H for propargylated product), 4.91 (d, J=6.7 Hz, 2H for allenylated product), 5.40 (dd, J=6.7, 6.7 Hz, 1H for allenylated product), 7.10—7.17 (m, 1H for both products), 7.30—7.38 (m, 2H for both products), 7.47—7.54 (m, 2H for both products), 7.91 (bs, 1H for propargylated product), 7.99 (bs, 1H for allenylated product); ^{13}C NMR ($CDCl_3$) δ=26.65, 29.68, 32.45, 46.36, 47.92, 70.29, 71.18, 71.10, 71.69, 78.98, 80.43, 98.36, 120.2, 124.5, 124.7, 129.0, 137.3, 137.4, 169.9, 170.0, 205.5. Found: C, 71.62; H, 7.09%. Calcd for $C_{13}H_{15}NO_2$: C, 71.87; H, 6.96%.

***erythro*- 3- Hydroxy- 2, 3- dimethyl- *N*- phenyl- 5-hexenamide (2j, Mixture of *erythro* and *threo* Isomers, *erythro*/*threo*=89/11):** The separation of two stereoisomers **2j** and **3j** (or **2k** and **3k**) by silica-gel column chromatography resulted in failure and the physical data are given as a mixture. The stereochemistry of the products was estimated by the comparison of ^1H NMR data of **2j** and **3j** (or **2k** and **3k**) with those of the corresponding *N*,*N*-dimethylamides **2g** and **3g** (or **2h** and **3h**). Bp 84—85 °C (0.7 Torr); IR (neat) 3296, 2974, 1655, 1618, 1600, 1546, 1500, 1443, 1307, 1247, 919, 754, 691 cm^{-1}; ^1H NMR ($CDCl_3$)

δ=1.22 (s, 3H), 1.31 (d, J=7.1 Hz, 3H for *erythro* isomer), 1.32 (d, J=7.1 Hz, 3H for *threo* isomer), 2.30—2.46 (m, 3H), 3.37 (bs, 1H for *erythro* isomer), 3.29 (bs, 1H for *threo* isomer), 5.09—5.22 (m, 2H), 5.84—5.95 (m, 1H), 7.09—7.16 (m, 1H), 7.30—7.37 (m, 2H), 7.49—7.54 (m, 2H), 7.94 (bs, 1H); ^{13}C NMR ($CDCl_3$) δ=12.53, 12.70, 23.57, 26.36, 43.36, 46.45, 48.88, 49.28, 72.80, 73.19, 119.2, 120.0, 124.4, 129.0, 133.7, 133.0, 137.6, 174.4. Found: C, 71.81; H, 8.25%. Calcd for $C_{14}H_{19}NO_2$: C, 72.07; H, 8.21%.

***erythro*-3-Hydroxy-2,3,5-trimethyl-*N*-phenyl-5-hexenamide (2k, Mixture of *erythro* and *threo* Isomers, *erythro*/*threo*=86/14):** Bp 74—75 °C (0.6 Torr); IR (neat) 3294, 2974, 2936, 1662, 1600, 1546, 1500, 1444, 1378, 1306, 1247, 896, 754, 691, 421 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ=1.22 (s, 3H), 1.33 (d, J=7.1 Hz, 3H), 1.87 (s, 3H), 2.10—2.49 (m, 3H), 3.11 (s, 1H for *threo* isomer), 3.28 (s, 1H for *erythro* isomer), 4.77 (m, 1H), 4.92 (m, 1H), 7.08—7.15 (m, 1H), 7.30—7.37 (m, 2H), 7.49—7.55 (m, 2H), 8.06 (bs, 1H for *erythro* isomer), 8.10 (bs, 1H for *threo* isomer); ^{13}C NMR ($CDCl_3$) δ=12.69, 12.98, 23.76, 24.88, 26.56, 45.83, 48.98, 50.11, 50.77, 73.08, 73.41, 115.6, 120.1, 124.3, 128.9, 137.7, 142.0, 142.3, 174.3, 174.6. Found: C, 72.76; H, 8.51%. Calcd for $C_{15}H_{21}NO_2$: C, 72.84; H, 8.56%.

***erythro*-3-Hydroxy-*N*,*N*,2-trimethyl-3-phenylhexanamide (9):** Mp 137.0—137.5 °C; IR (Nujol) 3276, 2924, 2852, 1622, 1490, 1458, 1419, 1401, 1377, 709, 635 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ=0.72—0.82 (m, 4H), 0.85 (d, J=7.1 Hz, 3H), 1.32—1.49 (m, 1H), 1.63—1.80 (m, 2H), 3.00 (q, J=7.0 Hz, 1H), 3.05 (s, 3H), 3.16 (s, 3H), 5.68 (bs, 1H), 7.19—7.45 (m, 5H); ^{13}C NMR ($CDCl_3$) δ=12.47, 14.43, 16.83, 35.57, 37.71, 43.75, 44.00, 77.22, 125.5, 126.2, 127.9, 144.0, 178.0. Found: C, 72.27; H, 9.56%. Calcd for $C_{15}H_{23}NO_2$: C, 72.25; H, 9.30%.

4-Ethyl-3-hydroxy-*N*,*N*,2-trimethyl-3-phenyl-5-hexenamide (10, Mixture of Stereoisomers A and B, A : B=82 : 18): Mp 69.0—72.0 °C; IR (Nujol) 3380, 3276, 2952, 2942, 2852, 1609, 1457, 1420, 1376, 926, 706 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ=0.25 (ddq, J_{ab}=13.0, J_{ac}=10.4, J_{aCH_3}=7.4 Hz, 1H for Ha (CH_3–CHaHb–CHc) of A), 0.62 (t, J=7.4 Hz, 3H for B), 0.67 (t, J=7.4 Hz, 3H for A), 0.75 (d, J=7.1 Hz, 3H for B), 0.91 (d, J=7.2 Hz, 3H for A), 1.00—1.31 (m, 2H for B), 1.87 (ddq, J_{ab}=13.0, J_{bc}=2.6, J_{bCH_3}=7.4 Hz, 1H for Hb (CH_3–CHaHb–CHc) of A), 2.15 (ddd, J=10.0, 10.0, 3.0 Hz, 1H for B), 2.33 (ddd, J=10.4, 10.4, 2.6 Hz, 1H for Hc (CH_3–CHaHb–CHc) of A), 2.92 (s, 3H for B), 2.99 (q, J=7.0 Hz, 1H for B), 3.03 (s, 3H for A), 3.08 (s, 3H for B), 3.10 (s, 3H for A), 3.32 (q, J=7.1 Hz, 1H for A), 4.95 (dd, J=17.3, 2.5 Hz, 1H for A), 4.96—5.06 (m, 2H for B), 5.16 (dd, J=10.4, 2.5 Hz, 1H for A), 5.53 (ddd, J=17.3, 10.4, 10.4 Hz, 1H for A), 5.65 (ddd, J=17.3, 10.0, 10.0 Hz, 1H for B), 6.95—7.88 (m, 5H for both isomers), OH proton was not observed; ^{13}C NMR ($CDCl_3$) δ=12.11, 12.60, 14.10, 14.44, 21.57, 21.84, 22.62, 31.55, 35.41, 37.33, 39.97, 40.59, 57.16, 59.16, 79.59, 80.30, 114.9, 117.0, 124—129 (broad peaks), 140.0, 141.6, 144.8, 178.0, 178.5. Found: C, 74.18; H, 8.96%. Calcd for $C_{17}H_{25}NO_2$: C, 74.14; H, 9.15%.

***erythro*-4-Ethyl-3-hydroxy-*N*,*N*,2-trimethyl-3-phenylhexanamide (11):** Bp 83—84 °C (1 Torr); IR (Nujol) 3328, 2958, 2930, 2872, 1619, 1498, 1452, 1417, 1401, 704, 628 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ=0.75—0.96 (m, 9H), 1.00—1.17 (m, 1H), 1.49—1.67 (m, 4H), 3.04 (s, 3H), 3.20 (s, 3H), 3.48 (q, J=7.0 Hz, 1H), 5.85 (s, 1H), 7.18—7.49 (m, 5H); ^{13}C NMR ($CDCl_3$) δ=13.11, 14.01, 14.13, 23.39, 24.57, 35.49, 37.41, 39.47, 52.07, 80.49, 126.2, 127.4, 142.7, 178.0. Found: C, 73.51; H, 9.74%. Calcd for $C_{17}H_{27}NO_2$: C, 73.61; H, 9.81%.

3-(2-Cyclohexen-1-yl)-3-hydroxy-*N*,*N*,2-trimethyl-3-phenyl-propanamide (12): Mp 128.0—129.0 °C; IR (Nujol) 3344, 3028, 2926, 2852, 1609, 1454, 1421, 1396, 1375, 1165, 1120, 769, 728, 710 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ=0.97 (d, J=7.0 Hz, 3H), 1.23—1.51 (m, 2H), 1.57—1.87 (m, 4H), 2.60—2.70 (m, 1H), 3.04 (s, 3H), 3.22 (s, 3H), 3.44 (q, J=7.0 Hz, 1H), 5.45—5.53 (m, 1H), 5.83—5.90 (m, 1H), 6.12 (bs, 1H), 7.18—7.45 (m, 5H); ^{13}C NMR ($CDCl_3$) δ=13.07, 22.49, 24.79, 25.43, 35.62, 37.48, 38.32, 46.27, 79.49, 126.2, 126.3, 127.1, 127.3, 128.1, 141.7, 177.8. Found: C, 75.00; H, 8.74%. Calcd for $C_{18}H_{25}NO_2$: C, 75.22; H, 8.77%.

Ethyl 3-Hydroxy-3-methyl-5-hexenoate (14): Bp 64—65 °C (40 Torr); IR (neat) 3444, 2976, 2930, 1720, 1376, 1334, 1195, 1137, 1031, 917 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ=1.25 (s, 3H), 1.29 (t, J=7.2 Hz, 3H), 2.30 (d, J=7.3 Hz, 2H), 2.42 (d, J=15.8 Hz, 1H), 2.52 (d, J=15.8 Hz, 1H), 3.64 (bs, 1H), 4.18 (q, J=7.2 Hz, 2H), 5.06—5.15 (m, 2H), 5.86 (ddt, J=16.9, 10.3, 7.3 Hz, 1H); ^{13}C NMR ($CDCl_3$) δ=14.17, 26.82, 44.28, 46.48, 60.66, 70.70, 118.6, 133.7, 173.0. Found: C, 62.58; H, 9.45%. Calcd for $C_9H_{16}O_3$: C, 62.77; H, 9.36%.

***erythro*-Ethyl 3-Hydroxy-2-methyl-3-phenyl-5-hexenoate (16):** Bp 68—69 °C (2.0 Torr); IR (neat) 3498, 2978, 1708, 1449, 1395, 1376, 1338, 1190, 701 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ=0.96 (d, J=7.2 Hz, 3H), 1.31 (t, J=7.2 Hz, 3H), 2.52 (ddt, J=14.1, 7.4, 1.1 Hz, 1H), 2.71 (ddt, J=14.1, 6.5, 1.1 Hz, 1H), 2.88 (q, J=7.2 Hz, 1H), 3.96 (bs, 1H), 4.23 (qd, J=7.2, 1.1 Hz, 2H), 4.92—5.00 (m, 2H), 5.46—5.60 (m, 1H), 7.20—7.41 (m, 5H); ^{13}C NMR ($CDCl_3$) δ=12.72, 14.14, 46.41, 48.23, 60.91, 76.48, 118.0, 125.5, 126.6, 127.9, 133.3, 142.7, 177.2. Found: C, 72.36; H, 8.14%. Calcd for $C_{15}H_{20}O_3$: C, 72.55; H, 8.12%. The stereochemistry of **16** (or **17**) was assigned as follows. Reduction of **16** (or **17**) with *i*-Bu_2AlH followed by hydrogenation (H_2, PtO_2) gave Ph(*n*-Pr)OH–CHMe–CH_2OH which was determined as *erythro* diol (or *threo* from **17**) by the comparison of the ^{1}H NMR spectrum with that of *erythro* PhC(Et)OH–CHMe–CH_2OH derived from *erythro* PhC(Et)OH–CHMe–COOMe.[3]

***threo*-Ethyl 3-Hydroxy-2-methyl-3-phenyl-5-hexenoate (17):** Bp 67—68 °C (2.0 Torr); IR (neat) 3486, 2978, 1712, 1459, 1447, 1373, 1338, 1183, 1023, 699 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ=0.96 (t, J=7.1 Hz, 3H), 1.37 (d, J=7.2 Hz, 3H), 2.51 (dd, J=13.9, 7.4 Hz, 1H), 2.60 (dd, J=13.9, 6.8 Hz, 1H), 3.08 (q, J=7.2 Hz, 1H), 3.82—3.97 (m, 2H), 4.03 (bs, 1H), 4.95—5.03 (m, 2H), 5.48 (dddd, J=17.1, 9.8, 7.4, 6.8 Hz, 1H), 7.18—7.43 (m, 5H); ^{13}C NMR ($CDCl_3$) δ=11.97, 13.76, 43.49, 46.93, 60.46, 76.21, 118.2, 125.5, 126.8, 127.9, 132.9, 145.2, 176.7. Found: C, 72.63; H, 8.24%. Calcd for $C_{15}H_{20}O_3$: C, 72.55; H, 8.12%.

4-Ethoxycarbonyl-3-hydroxy-*N*,*N*,2-trimethyl-3-phenylbutanamide (18): Mp 57.5—58.0 °C; IR ($CHCl_3$) 3308, 3014, 1713, 1618, 1451, 1419, 1401, 1210 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ=1.02 (d, J=7.0 Hz, 3H), 1.04 (t, J=7.1 Hz, 3H), 2.79 (d, J=14.5 Hz, 1H), 2.97 (s, 3H), 3.03 (s, 3H), 3.05 (d, J=14.5 Hz, 1H), 3.47 (q, J=7.0 Hz, 1H), 3.95 (q, J=7.1 Hz, 2H), 6.20 (bs, 1H), 7.25—7.55 (m, 5H); ^{13}C NMR ($CDCl_3$) δ=12.51, 13.91, 35.55, 37.41, 41.72, 43.31, 60.25,

75.95, 125.1, 126.9, 128.0, 143.6, 171.4, 176.8. Found: C, 65.27; H, 8.00%. Calcd for $C_{16}H_{23}NO_4$: C, 65.51; H, 7.90%.

3,5-Dihydroxy-*N*,*N*,2-trimethyl-3-phenylpentanamide (19). A hexane solution of *i*-Bu_2AlH (1.0 M solution, 1.5 ml, 1.5 mmol) was added to a solution of **18** (137 mg, 0.47 mmol) in ether (5 ml) at 0 °C. After being stirred for 1 h at 25 °C, the resulting mixture was poured into 1 M HCl and extracted with ether (10 ml×3). The combined organic layer was dried over Na_2SO_4 and concentrated in vacuo. Purification by silica-gel column chromatography gave dihydroxy amide **19** (91 mg) in 77% yield: Bp 118—120 °C (0.5 Torr); IR (neat) 3348, 2932, 1615, 1497, 1452, 1419, 1401, 1319, 1254, 1223, 1165, 1125, 1068, 1031, 908, 730, 703 cm^{-1}; ^1H NMR ($CDCl_3$) δ=0.84 (d, J=7.0 Hz, 3H), 1.90 (dd, J=14.0, 4.0 Hz, 1H), 2.19 (dt, J=13.9, 7.3 Hz, 1H), 2.30—3.40 (bs, 1H, OH), 3.03 (q, J=7.0 Hz, 1H), 3.05 (s, 3H), 3.15 (s, 3H), 3.45 (dd, J=7.3, 4.0 Hz, 1H), 6.30—6.80 (bs, 1H, OH), 7.22—7.30 (m, 1H), 7.32—7.48 (m, 4H); ^{13}C NMR ($CDCl_3$) δ=11.01, 34.58, 36.65, 41.21, 42.40, 58.85, 77.84, 124.41, 125.75, 127.23, 141.64, 176.56. Found: C, 66.74; H, 8.50%. Calcd for $C_{14}H_{21}NO_3$: C, 66.90; H, 8.42%. To a solution of **2c** (236 mg, 0.96 mmol) in THF–H_2O (3 ml–3 ml) was added OsO_4 (CH_2Cl_2 solution, 0.1 mmol) and $NaIO_4$ (0.8 g, 3.7 mmol) at 25 °C. The mixture was stirred overnight, then poured into aqueous $Na_2S_2O_3$ and extracted with ethyl acetate (10 ml×3). The combined organic layer was concentrated to give a crude product which was diluted with methanol and treated with $NaBH_4$ (20 mg). Extractive workup followed by silica-gel column purification provided **19** (112 mg) in 47% overall yield.

General Procedure for the Reaction of Formyl Amides with Allyltrimethylsilane in the Presence of Lewis Acid. The reaction of **1a** with allyltrimethylsilane in the presence of BF_3·OEt_2 was representative. BF_3·OEt_2 (0.14 ml, 1.1 mmol) was added dropwise to a CH_2Cl_2 (3 ml) solution of formyl amide **1a** (70 mg, 0.5 mmol) and allyltrimethylsilane (114 mg, 1.0 mmol) at −78 °C under argon atmosphere. The reaction mixture was stirred at −78 °C for 2 h and at room temperature for 30 min. The resulting mixture was poured into 1 M HCl and extracted with $CHCl_3$–EtOH (3 : 1) (20 ml×3). The combined organic layer was dried over Na_2SO_4 and concentrated in vacuo. Purification by silica-gel column chromatography gave **2a** (64 mg, 68% yield, **2a**/**3a**=>99/1). The stereochemistry of the adduct **2a** was determined as follows. Hydrogenation of **2a** in ethyl acetate under PtO_2 catalyst at 25 °C gave 3-hydroxy-2-methylhexanamide quantitatively which was identical with a sample derived from stereoselective reduction of 3-oxo amide.[2b]

***erythro*-3-Hydroxy-*N*,*N*,2-trimethylhexanamide:** Bp 80—82 °C (0.3 Torr); IR (neat) 3396, 2954, 2932, 2870, 1624, 1508, 1459, 1419, 1400, 1163, 1117, 1095, 1078, 1020 cm^{-1}; ^1H NMR ($CDCl_3$) δ=0.94 (t, J=7.2 Hz, 3H), 1.15 (d, J=7.1 Hz, 3H), 1.20—1.65 (m, 4H), 2.64 (qd, J=7.1, 2.1 Hz, 1H), 2.96 (s, 3H), 3.06 (s, 3H), 3.86—3.94 (m, 1H), 4.60 (bs, 1H); ^{13}C NMR ($CDCl_3$) δ=9.48, 14.05, 19.19, 35.30, 35.85, 37.30, 38.64, 70.79, 177.85. Found: C, 62.41; H, 11.28%. Calcd for $C_9H_{19}NO_2$: C, 62.39; H, 11.05.

***threo*-3-Hydroxy-*N*,*N*,2-trimethylhexanamide:** Bp 78—80 °C (0.3 Torr); IR (neat) 3406, 2954, 2932, 2870, 1624, 1499, 1491, 1459, 1416, 1162, 1121 cm^{-1}; ^1H NMR ($CDCl_3$) δ=0.93 (t, J=7.0 Hz, 3H), 1.22 (d, J=7.2 Hz, 3H), 1.30—1.63 (m, 2H), 2.72 (qd, J=7.2, 5.0 Hz, 1H), 2.97 (s, 3H), 3.07 (s, 3H), 3.55—3.67 (m, 1H), 4.10 (d, J=7.6 Hz, 1H); ^{13}C NMR ($CDCl_3$) δ=14.00, 15.01, 19.11, 35.19, 37.27, 37.62, 40.05, 73.92, 176.7. Found: C, 62.15; H, 11.26%. Calcd for $C_9H_{19}NO_2$: C, 62.39; H, 11.05%.

One of us (M. T) is grateful for Research Fellowships of the Japan Society for the Promotion of Science for Japanese Junior Scientists.

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