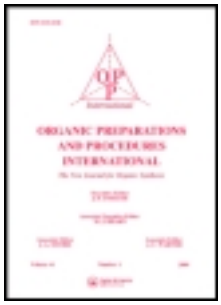

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# REACTION OF *N*-[(TRIMETHYLSILYL)METHYL]CARBODIIMIDES WITH BIFUNCTIONAL NUCLEOPHILES

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We previously reported the first synthesis of thermally stable (trimethylsilyl)methyl azide[1] and developed a convenient one-pot route for (trimethylsilyl)methyl-substituted isocyanate, isothiocyanate, carbodiimides, and ketenimine using the iminophosphorane generated from the azide.[2] These heterocumulenes bearing a (trimethylsilyl)methyl (hereinafter abbreviated as silylmethyl) group adjacent to the cumulene moiety are useful reagents in heterocyclic synthesis. The generation and cycloaddition of synthetic equivalents of nonstabilized nitrile ylides starting from silylmethyl isothiocyanate[3-5] and carbodiimides[3,6] provide routes to various heterocyclic systems which are otherwise relatively inaccessible. It has also been demonstrated that imino-2-azaallyl anions generated from the desilylation of silylmethylcarbodiimides react with aldehydes to give regioisomeric imino-1,3-oxazolidines.[7] Carbodiimides are attractive starting materials since a large number of heterocyclic compounds are formed by cycloaddition or by reaction with bifunctional compounds.[8] Our continued interest in silylmethyl-substituted heterocumulenes was thus directed to the preparation of silylmethyl-substituted heterocyclic compounds by the reaction of silylmethylcarbodiimides with bifunctional compounds. The present paper describes the addition of 1-aryl-3-silylmethylcarbodiimides (**1**) to bifunctional nucleophiles such as 1,2-ethanediol or 2-aminoethanol and the cyclization of the resulting adducts.

The reaction of carbodiimides **1** with 1,2-ethanediol (**2**) was investigated first. Although single iminooxazolidine derivatives are formed by the copper(I) or copper(II) chloride-catalyzed reaction of diol **2** with symmetrically disubstituted carbodiimides such as 1,3-diisopropyl- and 1,3-dicyclohexylcarbodiimide (DCC),[9,10] to the best of our knowledge little has been investigated on the reaction of diol **2** with unsymmetrically substituted carbodiimides.

The unsymmetrically substituted carbodiimides **1** as well as DCC[11] were essentially inert toward alcohols, but reaction with ethanol occurred smoothly in the presence of copper(I) iodide (CuI)

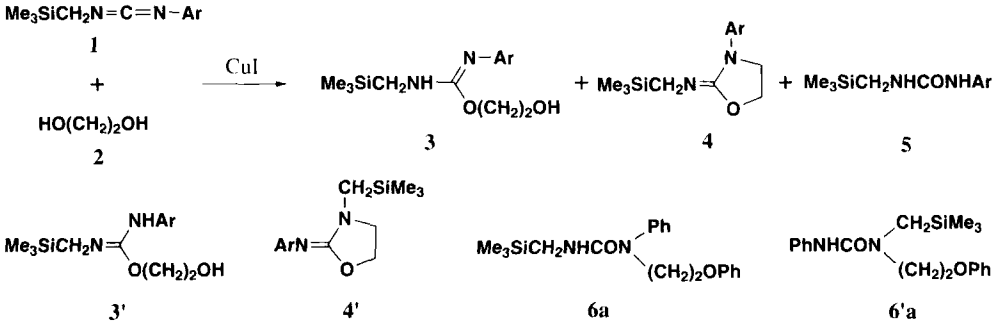
to give the corresponding isourea in a quantitative yield.[12] The reaction of 1-phenyl-3-silylmethyl- (**la**), and 1-(*p*-tolyl)-3-silylmethylcarbodiimide (**lb**) with diol **2** in the presence of CuI was investigated under various conditions (*Table 1*). The reaction of **1** with excess **2** (10 equiv.) gave the isourea **3** exclusively, while the reaction of **1** with one equiv. of **2** in benzene afforded a mixture of **3**, the iminooxazolidine **4** and 1-aryl-3-(silylmethyl)urea (**5**). On the other hand, the reaction with 0.5 equivlent of **2** at 20° in *N,N*-dimethylformamide (DMF) or acetonitrile gave a mixture of **4** and **5** in good yield.

**TABLE 1**. Reaction of Carbodiimides **1** with 1,2-Ethanediol (**2**)[a]

| Entry | **1** | Molar ratio[b] | Solvent[c] | Temp./°C | Time/h | Products (Yield/%) |
|---|---|---|---|---|---|---|
| 1 | **la** | 1/10/0.5 | B | 40 | 5 | **3a** (87) |
| 2 | **la** | 1/10/0.5 | AN | 20 | 2.5 | **3a** (92) |
| 3 | **la** | 1/5/0.5 | B | 40 | 6 | **3a** (60), **4a** (17), **5a** (17)[d] |
| 4 | **la** | 1/1/0.5 | B | 40 | 4 | **3a** (50), **4a** (17), **5a** (17)[d] |
| 5 | **la** | 1/1/0.5 | B | reflux | 1 | **3a** (19), **4a** (32), **5a** (38)[d] |
| 6 | **la** | 1/0.5/0.5 | B | reflux | 2 | **4a** (78), **5a** (74)[e] |
| 7 | **la** | 1/0.5/0.5 | DMF | 20 | 2 | **4a** (77), **5a** (80)[e] |
| 8 | **la** | 1/0.5/0.5 | AN | 20 | 2.5 | **4a** (92), **5a** (90)[e] |
| 9 | **lb** | 1/10/0.5 | B | 40 | 5 | **3b** (89) |
| 10 | **lb** | 1/1/0.5 | B | 40 | 2 | **3b** (62), **4b** (13), **5b** (15)[d] |

a) All the reactions were carried out in the presence of CuI in dry solvent under argon. b) Molar ratio of **1/2**/CuI. c) B: benzene, DMF: *N,N*-dimethylformamide, AN: acetonitrile. d) Yields were determined by $^1$H NMR. e) Yields based on **2**.

Although two tautomers, 3-aryl-2-(β-hydroxyethyl)-1-(silylmethyl)isourea (**3**) and 1-aryl-2-(β-hydroxyethyl)-3-(silylmethyl) isomer (**3'**), are possible for the initial adduct, its $^1$H NMR data displayed the silylmethyl protons as a doublet, thus indicating the adduct to be **3** and not **3'**. 3-Aryl-2-(silylmethyl)imino- (**4**) or 2-arylimino-3-(silylmethyl)oxazolidine (**4'**) is also possible for the iminooxazolidine derived from the initial isourea **3** with dehydration. On the basis of spectral data, however, it was difficult to conclude which of the two structures **4** or **4'** is more reasonable for the iminooxazolidine. As it is known that iminooxazolidine reacts with phenol through a nucleophilic substitution to produce the corresponding urea compound upon ring opening,[13] it may be expected that 1-aryl-1-(β-phenoxyethyl)-3-(silylmethyl)- (**6**) or 3-aryl-1-(β-phenoxyethyl)-1-(silylmethyl)urea (**6'**) is formed from **4** or **4'**, respectively. In fact, the iminooxazolidine derived from **3a** reacted with phenol at 80° for 20 h to afford 1-(β-phenoxyethyl)-1-phenyl-3-(silylmethyl)urea (**6a**), but not 1-(β-phenoxyethyl)-3-phenyl-1-(silylmethyl)urea (**6'a**) (*Scheme 1*). Thus, it can be concluded that the iminooxazolidine is silylmethyliminooxazolidine **4**.




a ) Ar = Ph ; b ) Ar = *p*-tolyl

**Scheme 1**

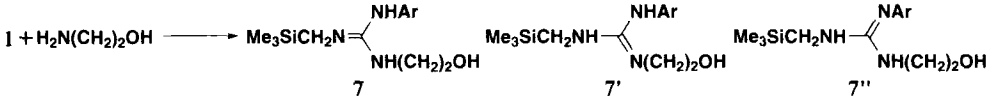
As shown in Table 1, the iminooxazolidine **4** is always accompanied by an equimolar amount of urea **5**, indicating that half of the carbodiimide **1** is consumed for the formation of urea **5**. Thus the cyclization reaction of isourea **3** using DCC instead of **1** was investigated. It was found that the combination of CuI with DCC was essential for the cyclization, the corresponding iminooxazolidine **4**[14] and 1,3-dicyclohexylurea (DCU) being obtained in good yields, especially in DMF (*Table 2*).

**TABLE 2**. Cyclization of **3** to **4** by Combination of DCC and CuI[a]

| Entry | **3** | Solvent | Time/h | Product (Yield/%)[b] | |
|---|---|---|---|---|---|
| 1 | **3a** | $CH_3CN$ | 5 | **4a** (75) | DCU (78) |
| 2 | **3a** | DMF | 3 | **4a** (90) | DCU (92) |
| 3 | **3b** | $CH_3CN$ | 3 | **4b** (77) | DCU (80) |
| 4 | **3b** | DMF | 3 | **4b** (90) | DCU (93) |

a) All the reactions (molar ratio of **3**/DCC/CuI=1/1/0.5) were carried out at 20° under argon. b) DCU: 1,3-dicyclohexylurea.

The reaction of carbodiimides **1** with 2-aminoethanol was investigated next; **1** reacted easily with excess 2-aminoethanol in the absence of catalyst to give the corresponding 1-aryl-3-(β-hydroxyethyl)-2-(silylmethyl)guanidine (**7**) in excellent yield. The other two isomers, 1-aryl-2-(β-hydroxyethyl)-3-(silylmethyl)- (**7'**), and 2-aryl-1-(β-hydroxyethyl)-3-(silylmethyl)guanidine (**7''**) were excluded on the basis of $^1H$ NMR spectra in which silylmethyl protons appeared as a singlet.




a ) Ar = Ph ; b ) Ar = *p*-tolyl

**Scheme 2**

Since guanidine **7** might be expected to undergo cyclization in the same manner as the isourea **3** to give an imidazolidine compound, the reaction of **7** with an equivalent **1** was investigated. The reaction of **7a** with **1a** in refluxing acetonitrile for 2 h afforded three products **8a**, **9a**, and 1,3-diphenyl-2-(silylmethyl)guanidine (**10a**) in 44%, 7% and 39% yields respectively (*Scheme 3*). Compound **10a** was identical with an authentic sample prepared from **1a** with aniline.

The structure of **8a** whose molecular formula corresponded to a 1:1 adduct **A** (Ar = Ph) of **7a** to **1a** with loss of aniline, was established to be 2-(silylmethyl)-1-{3-[2-(silylmethyl)iminooxazolydinyl]}-3-phenylguanidine on the basis of spectral data and X-ray crystallographic analysis. The ORTEP drawing of **8a** is shown in Figure 1.[15]

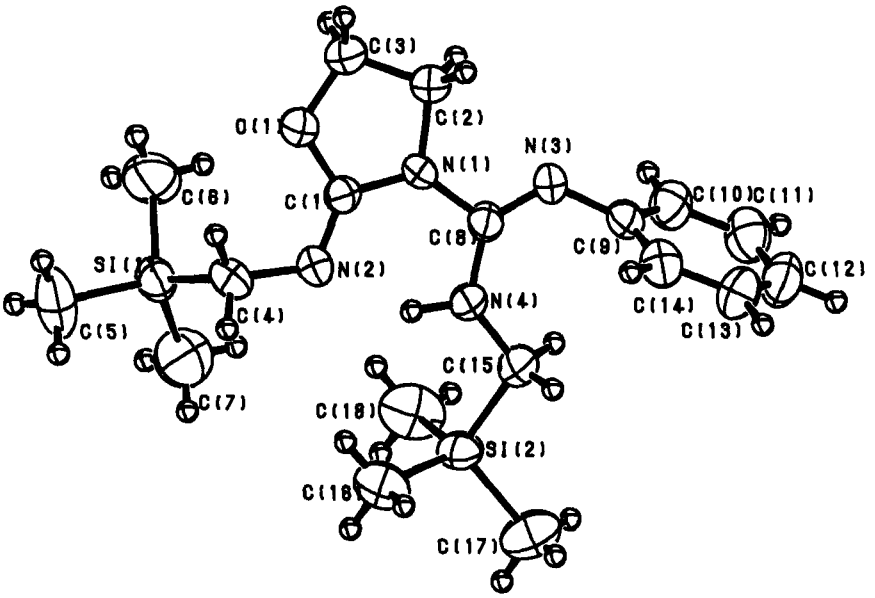
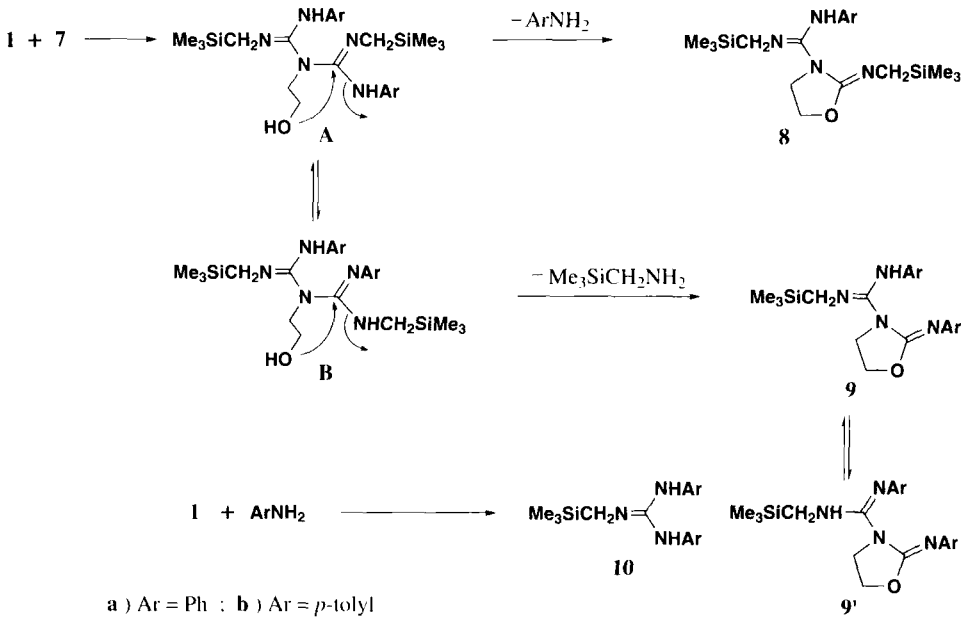


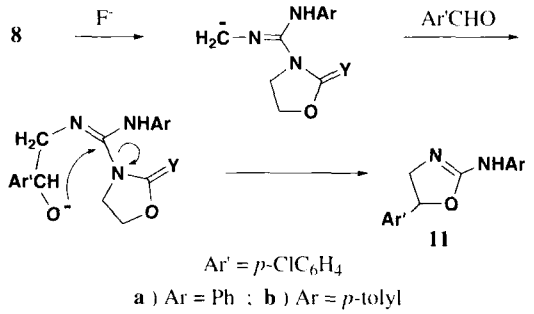

**Fig. 1** ORTEP Drawing of **8a**

On the other hand, the minor guanidine product which corresponded to the 1:1 adduct **B** (Ar = Ph) of **7a** to **1a** by loss of (silylmethyl)amine, and was deduced to be a tautomeric mixture of 2-(silylmethyl)-1-aryl-3-{3-[2-(arylimino)oxazolydinyl]}- (**9a**) and 3-(silylmethyl)-2-aryl-1-{3-[2-(arylimino)oxazolydinyl]}guanidine (**9'a**) on the basis of spectral data. The reaction of **7b** with **1b** under similar conditions gave the corresponding guanidines **8b** and **9b** in 36% and 6% yields respectively (*Scheme 3*).[16]

We had previously reported that 2-azaallyl anion generated from the desilylation of *N*-(silylmethyl)thioimidates reacted with aromatic aldehydes to give 2,5-disubstituted 2-oxazolines[4] and were thus interested in the behavior of 2-azaallyl anion generated from desilylation of **8**. It was found that the desilylation of **8** with tetrabutylammonium fluoride (TBAF) in the presence of excess *p*-chlorobenzaldehyde gave the corresponding 2-arylamino-5-*p*-chlorophenyl-2-oxazoline (**11**) in 57% yield (*Scheme 4*).




**Scheme 3**




**Scheme 4**

## EXPERIMENTAL SECTION

Melting points were determined on a Yanagimoto micro-apparatus and are uncorrected. IR spectra were measured as KBr pellets unless otherwise noted. $^{1}H$ and $^{13}C$ NMR spectra were measured in $CDCl_3$ unless otherwise mentioned, and recorded at 270 and 67.5 MHz, respectively. Chemical shifts are expressed in parts per million downfield from $Me_4Si$. $^{13}C$ NMR resonance assignments were aided by the use of the DEPT technique to determine number of attached hydrogens. Mass spectra (EI mode) were measured at 70 eV of ionization energy and mass spectra (FAB mode) by using Xe accelerated to 8 keV as the atom beam and *m*-nitrobenzyl alcohol as a matrix, respectively. Column chromatography was carried out on silica gel BW-200 or NH-DM1020 (Fuji Silysia Chem. Ltd.).

**1-Aryl-3-(silylmethyl)carbodiimides (1).**- 1-(Silylmethyl)-3-phenylcarbodiimide (**1a**) was prepared according to the previously reported method.[2] 1-(Silylmethyl)-3-(*p*-tolyl)carbodiimide (**1b**) was prepared as follows. A solution of iminophosphorane, which was prepared from silylmethyl azide[1] (1.29 g, 10 mmol) and triphenylphosphine (2.62 g, 10 mmol) in dry benzene (10 mL), was refluxed with *p*-tolyl isothiocyanate (1.49 g, 10 mmol) for 1 h. The solvent was evaporated in *vacuo,* and the residue was extracted with hexane (50 mL). The extract was concentrated *in vacuo,* and bulb-to-bulb distillation of the residue gave 1.91 g (87%) of carbodiimide **1b**. Both the carbodiimides **1a** and **1b** are quite stable for several months upon storage in a refrigerator.

**1b**: colorless oil, bp 88-91°/1.0 mmHg. IR (neat): 2142, 1251, 855 $cm^{-1}$; $^1H$ NMR: δ 0.14 (s, 9H, $SiCH_3$), 2.30 (s, 3H, $CH_3$), 2.86 (s, 2H, $SiCH_2$), 6.92-7.13 (m, 4H, Ar-H); $^{13}C$ NMR: δ -2.93 ($SiCH_3$), 20.86 ($CH_3$), 36.65 ($SiCH_2$), 123.09, 129.86, 133.78, 134.93 (Ar-C), 138.56 (N=C=N); EIMS: *m/z* 218 ($M^+$, 57).

*Anal.* Calcd for $C_{12}H_{18}N_2Si$: C, 66.00; H, 8.31; N, 12.83. Found: C, 65.98; H, 8.32; N, 12.93

**Reaction of Carbodiimides (1) with 1,2-Ethanediol (2).**- A typical procedure is given with an example for the reaction of **1a** with **2** (entry 1 in Table 1). A solution of **1a** (204 mg, 1.0 mmol) and **2** (620 mg, 10 mmol) in dry benzene (3 mL) was stirred with CuI (95 mg, 0.5 mmol) at 40° for 5 h under argon. After the reaction mixture was filtered to remove the copper catalyst, benzene (7 mL) was added to the filtrate. The organic layer was washed with water (10 mL x 3), dried over anhydrous magnesium sulfate, and then concentrated *in vacuo* to leave 231 mg (87%) of isourea **3a**.

**2-(β-Hydroxyethyl)-3-phenyl-1-(silylmethyl)isourea (3a)**: pale yellow oil; IR (neat): 3432, 3320, 1651, 1251, 859 $cm^{-1}$; $^1H$ NMR: δ 0.04 (s, 9H, $SiCH_3$), 2.54 (d, 2H, J = 4.8 Hz, $SiCH_2$), 3.70-3.90 (m, 2H, β-hydroxy-$CH_2$), 4.30-4.55 (m, 2H, $OCH_2$), 5.70 (br s, 1H, NH), 6.65-7.40 (m, 6H, Ar-H and OH); EIMS: *m/z* 248 ($M^+$ - $H_2O$, 1); FABMS: *m/z* 267 ($M^+$ + 1, 26), 249 (100).

**2-(β-Hydroxyethyl)-1-(silylmethyl)-3-(*p*-tolyl)isourea (3b).**- colorless oil; IR (neat): 3424, 3318, 1649, 1253, 859 $cm^{-1}$; $^1H$ NMR: δ 0.00 (s, 9H, $SiCH_3$), 2.27 (s, 3H, $CH_3$), 2.65 (d, 2H, J = 5.2 Hz, $SiCH_2$), 3.72-3.98 (m, 3H, $CH_2OH$), 4.30-4.55 (m, 2H, $OCH_2$), 5.75 (br s, 1H, NH), 6.70-7.30 (m, 4H, Ar-H); EIMS: *m/z* 262 ($M^+$ - $H_2O$, 1); FABMS: *m/z* 281 ($M^+$ + 1, 22), 263 (100).

As the isoureas **3a** and **3b** were somewhat unstable and decomposed on purification by chromatography (silica gel), they were used for the cyclization reaction without purification.

The reaction with one equivalent of **2** (62 mg, 1.0 mmol) with **1b** (218 mg, 1.0 mmol) in the presence CuI (95 mg, 0.5 mmol) in dry benzene (14 mL) gave 244 mg of a mixture of **3b**, **4b** and **5b** (5:1:1 by $^1H$ NMR estimation[7]) [entry 10 in Table 1]. Because of lability of **3b**, chromatographic separation of this mixture was unsuccessful.

**Direct Preparation of 3-Aryl-2-(silylmethyl)iminooxazolidines (4). Typical Procedure.**- A solution of **1a** (204 mg, 1.0 mmol) and **2** (31 mg, 0.5 mmol) in dry benzene (3 mL) was refluxed with CuI (95 mg, 0.5 mmol) for 2 h under argon. The reaction mixture was filtered to remove the copper catalyst, and the filtrate was extracted with benzene (10 mL). The extract was washed with water (10 mL x 2), dried over anhydrous magnesium sulfate and then concentrated *in vacuo.* The residue was chromatographed on silica gel (NH-DM1020) with a mixture of hexane-benzene (2:1) and benzene-ethyl

acetate (9:1) to give iminooxazolidine **4a** (95 mg, 78%) and urea **5a** (82 mg, 74%), respectively.

**3-Phenyl-2-(silylmethyl)iminooxazolidine (4a)**: colorless needles, mp 106-107°. IR: 1694, 1247, 859 $cm^{-1}$; $^1H$ NMR: δ 0.06 (s, 9H, $SiCH_3$), 2.92 (s, 2H, $SiCH_2$), 3.75-3.98 (m, 2H, 4-$CH_2$), 4.20-4.45 (m, 2H, 5-$CH_2$), 6.85-7.75 (m, SH, Ar-H); $^{13}C$ NMR: δ -2.41 ($SiCH_3$), 38.20 (4-C), 46.32 (5-C), 62.86 ($SiCH_2$), 117.61, 121.56, 125.65, 140,76 (Ar-C), 148.10 (2-C); EIMS: *m/z* 248 ($M^+$, 91), 247 (100).

*Anal.* Calcd for $C_{13}H_{20}N_2OSi$: C, 62.86; H, 8.12; N, 11.28. Found: C, 62.86; H, 8.17; N, 11.27

**2-(Silylmethyl)imino-3-(*p*-tolyl)oxazolidine (4b)**: colorless needles, mp 123-123.5°. IR: 1692, 1245, 862 $cm^{-1}$; $^1H$ NMR: δ 0.06 (s, 9H, $SiCH_3$), 2.29 (s, 3H, $CH_3$), 2.90 (s, 2H, $SiCH_2$), 3.85 (dd, 2H, J= 6.3, 7.6 Hz, 4-$CH_2$), 4.31 (dd, 2H, J= 6.3, 7.6 Hz, 5-$CH_2$), 7.12, 7.52 (each d, 2H, J= 8.4 Hz, Ar-H); $^{13}C$ NMR: δ -2.43 ($SiCH_3$), 20.65 ($CH_3$), 38.13 (4-C), 46.49 (5-C), 62.89 ($SiCH_2$), 117.82, 129.16, 131.05, 138.31 (Ar-C), 148.41 (2-C); EIMS: *m/z* 262 ($M^+$, 60).

*Anal.* Calcd for $C_{14}H_{22}N_2OSi$: C, 64.08; H, 8.45; N, 10.67. Found: C, 64.02; H, 8.44; N, 10.66

**3-Phenyl-1-(silylmethyl)urea (5a)**: colorless needles (hexane), mp 103-104°. IR: 3310, 1644, 1247, 859 $cm^{-1}$; $^1H$ NMR: δ 0.03 (s, 9H, $SiCH_3$), 2.68 (d, 2H, J= 5.3 Hz, $SiCH_2$), 5.43 (br s, 1H, NH), 6.80-7.40 (m, 5H, Ar-H), 7.61 (br s, 1H, NH); $^{13}C$ NMR: δ -2.79 ($SiCH_3$), 30.03 ($SiCH_2$), 120.03, 122.86, 129.01, 139.27 (Ar-C), 157.45 (C=O).

*Anal.* Calcd. for $C_{11}H_{18}N_2OSi$: C, 59.42; H, 8.16; N, 12.59. Found: C, 59.61; H, 8.01; N, 12.64

**1-(Silylmethyl)-3-(*p*-tolyl)urea (5b)**: colorless needles (hexane), mp 108.5-109.5°. IR: 3330, 1638, 1253, 859 $cm^{-1}$; $^1H$ NMR: δ 0.01 (s, 9H, $SiCH_3$), 2.24 (s, 3H, $CH_3$), 2.66 (d, 2H, J= 5.5 Hz, $SiCH_2$), 5.66, 7.82 (each br s, 1H, NH), 6.99, 7.16 (each d, 2H, J= 8.0 Hz, Ar-H); $^{13}C$ NMR: δ -2.80 ($SiCH_3$), 20.70 ($CH_3$), 29.88 ($SiCH_2$), 120.14, 129.40, 132.09, 136.75 (Ar-C), 157.84 (CO).

*Anal.* Calcd for $C_{12}H_{20}N_2OSi$: C, 60.97; H, 8.53; N, 11.85. Found: C, 61.08; H, 8.64; N, 11.68

**Typical Procedure for the Cyclization of 3 with DCC and CuI**.- A solution of isourea **3b** (280 mg, 1.0 mmol) and DCC (206 mg, 1.0 mmol) in dry DMF (3 mL) was stirred with CuI (95 mg, 0.5 mmol) for 3 h under argon. The reaction mixture was filtered to remove the copper catalyst, and the filtrate was concentrated *in vacuo*. The residue was washed with benzene (10 mL) to leave DCU (208 mg, 93%), mp 232-233°, as an insoluble material. The benzene washings were washed with water (10 mL), dried over anhydrous magnesium sulfate and then concentrated *in vacuo*. Recrystallization of the residue from hexane gave 236 mg (90%) of iminooxazolidine **4b**.

**Reaction of Iminooxazolidine 4a with Phenol**.- The iminooxazolidine **4a** (124 mg, 0.5 mmol) was stirred with phenol (2.1 g, 22 mmol) at 80° for 20 h. The reaction mixture was extracted with ether (10 mL), and the extract was washed with 5% aqueous sodium carbonate solution (20 mL x 2), dried over anhydrous magnesium sulfate, and then concentrated *in vacuo*. The residue was chromatographed on silica gel (NH-DM1020) with benzene to give urea **6a** (125 mg, 73%).

**1-(β-Phenoxyethyl)-1-phenyl-3-(silylmethyl)urea (6a)**: colorless oil; IR (neat): 3321, 1665, 1247, 859 $cm^{-1}$; $^1H$ NMR: δ -0.08 (s, 9H, $SiCH_3$), 2.63 (d, 2H, J= 5.3 Hz, $SiCH_2$), 3.80-4.25 (m, 5H, $(CH_2)_2$, NH), 6.7-7.6 (m, 10H, Ar-H); EIMS: *m/z* 342 ($M^+$, 13), 106 (100), 102 ([$TMSCH_2NH$]$^+$, 26).

*Anal.* Calcd for $C_{19}H_{26}N_2O_2Si$ C, 66.62; H, 7.65; N, 8.18. Found: C, 66.73; H, 7.54; N, 7.98

**Preparation of 1-Aryl-3-(β-hydroxyethyl)-2-(silylmethyl)guanidines (7). Typical Procedure**.- A solution of carbodiimide **Ia** (224 mg, 1.2 mmol) and 2-aminoethanol (74 mg, 1.2 mmol) in dry benzene (6 mL) was stirred at room temperature for 2.5 h under argon. The reaction mixture was concentrated *in vacuo* and the residue was chromatographed on silica gel (NH-DM1020) with ethyl acetate to give 283 mg (97%) of guanidine **7a**. Similar reaction of **1b** with 2-aminoethanol gave the corresponding guanidine **7b** in 96% yield. **7a**: colorless prisms (hexane), mp 79.5-80°. IR: 3430, 3318, 1624, 1585, 1263, 857 $cm^{-1}$; $^1H$ NMR: δ -0.01 (s, 9H, $SiCH_3$), 2.44 (s, 2H, $SiCH_2$), 3.48 (t, 2H, J = 4.5 Hz, $NCH_2$), 3.76 (t, 2H, J = 4.5 Hz, $OCH_2$), 4.0-4.4 (br s, 1H, OH), 4.6-6.5 (br s, 2H, NH), 6.87-7.29, (m, 5H, Ar-H); $^{13}C$ NMR: δ -2.89 ($SiCH_3$), 31.23 ($SiCH_2$), 45.19 ($NCH_2$), 65.16 ($OCH_2$), 122.03, 123.79, 129.29, 148.41 (Ar-C), 155.07 (C=N); EIMS: *m/z* 265 ($M^+$, 94).

*Anal.* Calcd for $C_{13}H_{23}N_3OSi$: C, 58.83; H, 8.73; N, 15.83. Found: C, 58.87; H, 8.80; N, 15.81

**3-(β-Hydroxyethyl)-2-(silylmethyl)-1-*p*-tolyl)guanidine (7b)**: colorless prisms (hexane), mp 76-77°. IR: 3430, 3298, 1622, 1253, 862 $cm^{-1}$; $^1H$ NMR: δ 0.00 (s, 9H, $SiCH_3$), 2.28 (s, 3H, $CH_3$), 2.44 (s, 2H, $SiCH_2$), 3.48 (t, 2H, J = 4.2 Hz, $NCH_2$), 3.76 (t, 2H, J = 4.2 Hz, $OCH_2$), 3.90-4.30 (br s, 1H, OH), 4.50-6.40 (br s, 2H, NH), 6.79, 7.06 (each d, 2H, J = 8.0 Hz, Ar-H); $^{13}C$ NMR: δ -2.86 ($SiCH_3$), 20.79 ($CH_3$), 31.28 ($SiCH_2$), 45.26 ($NCH_2$), 65.26 ($OCH_2$), 123.52, 129.88, 131.23, 145.44 (Ar-C), 155.13 (C=N); EIMS: *m/z* 279 ($M^+$, 79).

*Anal.* Calcd for $C_{14}H_{25}N_3OSi$: C, 60.17; H, 9.02; N, 15.04. Found: C, 59.89; H, 9.13; N, 15.21

**Reaction of 1:1 Adduct 7 with Carbodiimide 1. Typical Procedure**.- A solution of **7a** (530 mg, 2.0 mmol) and **Ia** (420 mg, 2.1 mmol) in dry acetonitrile (3 mL) was refluxed for 2 h under nitrogen. The solution became turbid during this time. After the mixture was concentrated *in vacuo*, the semicrystalline residue was triturated with acetonitrile (1.5 mL). Filtration gave **8a** (239 mg) as colorless needles. The filtrate was evaporated *in vacuo*, and the residue was chromatographed on silica gel (NH-DM1020) to give **8a** (89 mg), **9a** (52 mg, 7%) and guanidine **10a** (234 mg, 39%) with a mixture of hexane-ethyl acetate (5:1), and then unreacted **7a** (101 mg, 19%) with ethyl acetate, respectively. The total yield of **8a** is 328 mg (44%).

**3-Phenyl-2-(silylmethyl)-1-{3-[2-(silylmethyl)imino]oxazolydinyl}guanidine (8a)**: colorless needles (hexane), mp 141.5-142°. IR: 3253, 1686, 1649, 1251, 857 $cm^{-1}$; $^1H$ NMR: δ 0.00, 0.03 (each s, 9H), 2.26 (d, 2H, J= 4.7 Hz), 2.85 (s, 2H), 3.96, 4.19 (each t, 2H, J = 7.16 Hz), 6.70-7.35 (m, 5H), 9.15 (br s, 1H); $^{13}C$ NMR: δ 34.16, 38.01, 45.62, 63.31, 120.05, 121.92, 128.34, 148.19, 149.22, 149.81.EIMS: *m/z* 376 ($M^+$, 9).

*Anal.* Calcd for $C_{18}H_{32}N_4OSi_2$: C, 57.40; H, 8.56; N, 14.88. Found: C, 57.12; H, 8.60; N, 14.87

Crystal data of **8a**. A single crystal (0.12 x 0.32 x 0.88 mm) grown from 80% ethanol was used. $C_{18}H_{32}N_4OSi_2$, FW = 376.65, monoclinic, space group $P2_1/n$ (#14), a = 6.210(7) Å, b = 18.841(7) Å, c = 19.541(4) Å, β = 95.51(4)°, V = 2276(3)Å$^3$, Z = 4, Dcalc = 1.099 g/cm$^3$, R=0.065, Rw=0.063.

**Mixture of 3-Phenyl-2-(silylmethyl)-1-{3-[2-(silylmethyl)imino]oxazolydinyl}guanidine (9a) and Its Isomer (9'a)**: colorless needles (80% ethanol), mp 112-113°. IR: 3250, 3150, 1669, 1249, 855 $cm^{-1}$; $^1H$ NMR: δ 0.00 (s, 9H), 2.25 (d, 1H, J = 4.2 Hz, $SiCH_2$ of **9a**), 2.85 (s, 1H, $SiCH_2$ of **9'a**), 3.97, 4.20

(each t, 1H, J= 7.6 Hz, oxazolidine 4,5-$CH_2$), 4.21, 4.33 (each 1H, J = 8.0 Hz, oxazolidine 4,5-$CH_2$), 6.79-7.32 (m, l0H, ArH), 8.96, 9.12 (each br s, 0.5H, NH); EIMS: *m/z* 366 ($M^+$, 10).

*Anal.* Calcd for $C_{20}H_{26}N_4OSi$: C, 65.54, H, 7.15, N, 15.29. Found: C, 65.43; H, 7.31; N, 15.54

**1,3-Diphenyl-2-(silylmethyl)guanidine (l0a)**: pale yellow oil. IR (neat): 3312, 1636, 1251, 857 $cm^{-1}$; $^1H$ NMR: δ 0.04 (s, 9H), 2.76 (s, 2H, $SiCH_2$), 4.30 (brs, 2H, NH), 6.92-7.34 (m, l0H, Ar-H); $^{13}C$ NMR: δ -2.60 ($SiCH_3$), 31.40 ($SiCH_2$), 122.88, 123.68, 129.16, 129.36 (Ar-C), 149.55 (C=N); EIMS: *m/z* 297 ($M^+$, 24).

*Anal.* Calcd for $C_{17}H_{23}N_3Si$: C, 68.64; H, 7.79; N, 14.13. Found: C, 68.58; H, 7.56; N, 14.33

**2-(Silylmethyl)-1-{3-[2-(silylmethyl)imino]oxazolydinyl}-3-(*p*-tolyl)guanidine (8b)**: colorless needles (80% ethanol), mp 134-135°. IR: 3245, 1684, 1249, 862 $cm^{-1}$; $^1H$ NMR: δ 0.00, 0.02 (each s, 9H), 2.26 (s, 3H, $CH_3$), 2.27 (d, 2H, J= 6.3 Hz, $SiCH_2NH$), 2.85 (s, 2H, $SiCH_2$), 3.92 (dd, 2H, J= 7.2, 8.0 Hz, oxazolidine 4-$CH_2$), 4.19 (dd, 2H, J = 7.2, 8.0 Hz, oxazolidine 5-$CH_2$), 6.65-7.0 (m, 4H, Ar-H), 9.04 (br s, lH, NH); EIMS: *m/z* 390 ($M^+$, 3), 309 (100).

*Anal.* Calcd for $C_{19}H_{34}N_4OSi_2$: C, 58.41; H, 8.77; N, 14.34. Found: C, 58.25; H, 8.81; N, 14.52

**2-(Silylmethyl)-1-{3-[2-(silylmethyl)imino]oxazolydinyl}-3-(*p*-tolyl)guanidine (9b)**: colorless prisms (80% EtOH), mp 155°. IR: 3220, 1657, 1251, 861 $cm^{-1}$; $^1H$ NMR: δ 0.01 (s, 9H), 2.25-2.34 (m, 8H, $SiCH_2$ and $2CH_3$), 4.09 (dd, 2H, J = 7.6, 8.2 Hz, oxazolidine 4-$CH_2$), 4.31 (dd, 2H, J= 7.6, 8.2 Hz, oxazolidine 5-$CH_2$), 6.74-7.14 (m, 8H, Ar-H), 8.91 (br s, 1H, NH); EIMS: *m/z* 394 ($M^+$, 4), 308 (100).

*Anal.* Calcd for $C_{22}H_{30}N_4OSi$: C, 66.96; H, 7.66; N, 14.20. Found: C, 66.81; H, 7.75; N, 13.98

**Preparation of 2-Arylamino-5-(*p*-chlorophenyl)-2-oxazolines (11). Typical Procedure**.- To a solution of **8b** (235 mg, 0.6 mmol) and *p*-chlorobenzaldehyde (700 mg, 5 mmol) in dry DMF (7 mL) was added TBAF (1 M solution, 0.6 mL, 0.6 mmol) at room temperature. The mixture was warmed to 40° and stirred for l0 h under argon. The mixture was concentrated *in vacuo* and the residue was extracted with benzene (30 mL). The organic layer was washed with water (10 mL x 3), dried over anhydrous magnesium sulfate, and evaporated *in vacuo*. Chromatography (silica gel BW-200) of the residue gave unreacted aldehyde (396 mg, 57%) from elution of hexane-ethyl acetate (5:1), and **8b** (68 mg, 29%) and 2-(*p*-toluidino)-5-(*p*-chlorophenyl)-2-oxazoline (**11b**) (82mg, 47.5%) from elution of ethyl acetate, respectively.

**11b**: colorless needles (cyclohexane), mp 154-154.5°. IR: 3184, 1671 $cm^{-1}$; $^1H$ NMR: δ 2.28 (s, 3H, $CH_3$), 3.57 (dd, IH, J= 7.6, 11.8 Hz, 4-$CH_2$), 4.26 (dd, 1H, J= 8.9, 11.8 Hz, $4CH_2$), 5.50 (dd, 1H, J = 7.6, 8.9 Hz, 5-CH), 7.07 (d, 2H, J = 8.0 Hz, Ar-H), 7.21-7.37 (m, 7H, Ar-H, NH); $^{13}C$ NMR: δ 20.72 ($CH_3$), 59.86 (4-C), 79.90 (5-C), 118.94, 127.20, 128.96, 129.54, 131.98, 134.19, 138.81 (Ar-C), 156.91 (2-C); EIMS: *m/z* 288 ($M^+$, 20), 286 ($M^+$, 60), 148 (100).

*Anal.* Calcd for $C_{16}H_{15}ClN_2O$: C, 67.02; H, 5.27; N, 9.77. Found: C, 66.93; H, 5.32; N, 9.82

The similar fluoride-induced reaction of **8a** with *p*-chlorobenzaldehyde gave 2-anilino-5-(*p*-chlorophenyl)-2-oxazoline (**11a**) in 46% yield.

**11a**: colorless needles (benzene), mp 156-157°. IR: 3240, 1651 $cm^{-1}$; $^1H$ NMR (dimethylsulfoxide-$d_6$): δ 3.62 (dd, 1H, J = 6.7, 12.2 Hz, 4-$CH_2$), 4.24 (dd, 1H, J = 9.3, 12.2 Hz, 4-$CH_2$), 5.58 (dd, 1H, J= 6.7,

9.3 Hz, 5-CH), 6.88-6.94 (m, 1H, Ar-H), 7.21-7.28 (m, 2H, Ar-H), 7.40, 7.47 (each d, 2H, J= 8.4 Hz, Ar-H), 7.51 (d, 2H, J= 7.2 Hz, ArH), 9.13 (br s, 1H, NH); $^{13}$C NMR (dimethylsulfoxide-$d_6$): δ 60.65 (4-C), 77.67 (5-C), 117.48, 121.00, 127.40, 128.64, 132.52, 140.14, 140.64 (Ar-C), 155.59 (2-C); EIMS: *m/z* 274 ($M^+$, 7), 272 ($M^+$, 20), 119 (100).

*Anal.* Calcd for $C_{15}H_{13}ClN_2O$: C, 66.06; H, 4.80; N, 10.27. Found: C, 65.87; H, 4.74; N, 10.42

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12. For example, the reaction of **1a** (1 mmol) with ethanol (10 mmol) in the presence of CuI (0.5 mmol) under reflux for 3 h gave the expected isothiourea as pale yellow oil in a quantitative yield. IR (neat): 3434, 1655, 1251, 857 $cm^{-1}$; $^1$H NMR: δ 0.02 (s, 9H), 1.38 (t, 3H, J = 7.1 Hz), 2.62 (s, 2H), 3.72 (br s, 1H), 4.31 (q, 2H, J = 7.1 Hz), 6.75-7.45 (m, 5H); $^{13}$C NMR: δ -2.82, 14.53, 31.43, 62.03, 122.19, 123.04, 129.21, 149.21, 154.23.
13. E. Vowinkel and P. Gleichenhagen, *Tetrahedron Lett.,* 139 (**1974**).
14. The investigation of fluoride-induced reaction of **4** with electrophiles is now in progress, and the results will be reported elsewhere.
15. X-Ray crystallographic analysis of **8a** was carried out on a Rigaku AFCSS four-circle diffractometer. The diffraction data were collected with the use of graphite-monochromated Mo *Kα* radiation (λ = 0.71069 Å) and 2312 independent reflections were used for solving the structure by the TEXSAN program.

16. The reaction of **7** with DCC in place of **1** resulted in the formation of a complex mixture.

17. The ratio of **3b**, **4b** and **5b** was determined from the intensity of $SiCH_2$ in each compound on the basis of that of NH at δ 5.66 in **5b** in $^1H$ NMR.

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