

Reaction of Trimethylsilyl Azide with C=N-O Bond

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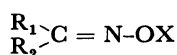
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Synopsis. Trimethylsilyl azide (TMSA) was reacted with an oxime ester or a Reissert salt in the presence of trimethylsilyl trifluoromethanesulfonate to give tetrazole derivative. The details of these reactions are examined.

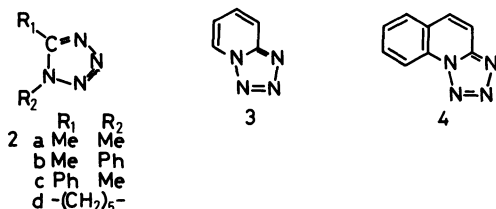
Trimethylsilyl azide (TMSA) has a high potential in the synthetic chemistry of heterocycles and azido compounds.¹⁾ We have reported that the decomposition reaction of *gem*-diazidoalkane, which was obtained by a reaction of ketone with TMSA, gave tetrazole derivatives in excellent yields and, therein, imidoyl azide was postulated as a reaction intermediate.²⁾ As a part of the investigations concerning the reactivities and synthetic utilities of TMSA, we would now like to describe reactions of TMSA with oxime esters or *N*-acyloxy(or *N*-sulfonyloxy)pyridinium(or quinolinium) chloride, which possess C=N-O bonding.

Results and Discussion

When a solution of acetone oxime methanesulfonate (**1a**) and TMSA in acetonitrile was heated to reflux for 24 h, 43% of 1,5-dimethyltetrazole (**2a**), along with trimethylsilyl methanesulfonate, was obtained by the usual work-up of the reaction mixture followed by column chromatography on silica gel. Oxime esters (**1a–g**) with TMSA were treated under various con-



- 1, a**, $R_1 = R_2 = \text{Me}$, $\text{X} = \text{MeSO}_2$
b, $R_1 = R_2 = \text{Me}$, $\text{X} = p\text{-MeC}_6\text{H}_4\text{SO}_2$
c, $R_1 = R_2 = \text{Me}$, $\text{X} = \text{PhCO}$
d, $R_1 = \text{Me}$, $R_2 = \text{Ph}$, $\text{X} = \text{MeSO}_2$
e, $R_1 = \text{Me}$, $R_2 = \text{Ph}$, $\text{X} = \text{PhCO}$
f, $R_1, R_2 = -(\text{CH}_2)_5-$, $\text{X} = \text{MeSO}_2$
g, $R_1, R_2 = -(\text{CH}_2)_5-$, $\text{X} = \text{PhCO}$



ditions and the results are summarized in the Table 1. From acetone oxime esters (**1a–c**), 1,5-dimethyltetrazole (**2a**) was yielded as the sole product. Acetophenone oxime esters (**1d** and **1e**) and cyclohexanone oxime esters (**1f** and **1g**) were similarly transformed to 5-methyl-1-phenyltetrazole (**2b**) as a major product (a regioisomer, 1-methyl-5-phenyltetrazole (**2c**), was also obtained less than 5%) and 6,7,8,9-tetrahydro-5*H*-tetrazolo[1,5-*a*]azepine (**2d**), respectively. However, the yield of tetrazole **2** obtained from oxime carboxylates with

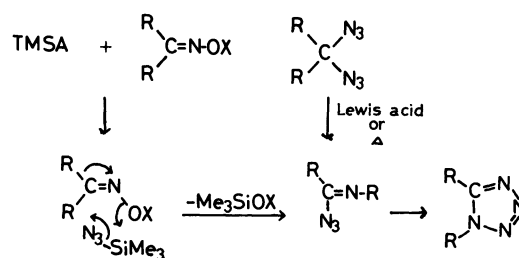
TABLE 1. REACTION OF VARIOUS OXIME ESTERS WITH TMSA^{a)}

Run	X in	Solvent	Product	Isolated Yield/%
$\begin{matrix} \text{Me} \\ \text{Me} \end{matrix} \text{C} = \text{N}-\text{OX}$				
1	MeSO ₂ (1a)	CH ₃ CN	2a	43
2	MeSO ₂ (1a) ^{b)}	CH ₃ CN	2a	95
3	MeSO ₂ (1a)	Benzene	2a	0
4	MeSO ₂ (1a) ^{b)}	Benzene	2a	69
5	MeSO ₂ (1a)	PhCl	2a	98
6	<i>p</i> -MeC ₆ H ₄ SO ₂ (1b) ^{b)}	CH ₃ CN	2a	92
7	PhCO (1c) ^{b)}	CH ₃ CN	2a	42
$\begin{matrix} \text{Me} \\ \text{Ph} \end{matrix} \text{C} = \text{N}-\text{OX}$				
8	MeSO ₂ (1d) ^{b)}	CH ₃ CN	2b	95 ^{c)}
9	PhCO (1e) ^{b)}	CH ₃ CN	2b	20 ^{c)}
$\text{Cyclohexane ring} = \text{N}-\text{OX}$				
10	MeSO ₂ (1f) ^{b)}	CH ₃ CN	2d	94
11	PhCO (1g) ^{b)}	CH ₃ CN	2d	84

a) The reactions were carried out at refluxing temperature of the employed solvents for 24 h. b) TMSOTf was used as a catalyst. c) Regioisomer **2c** was contained less than 5%.

TMSA was not so good, compared with those of oxime sulfonates and TMSA. Even with oxime sulfonates, the addition of trimethylsilyl trifluoromethanesulfonate (TMSOTf) as a catalyst markedly improve the yields of tetrazoles **2** (*vide* Runs 2, 4, and 6). Especially, as shown in runs 3 and 4, such a tendency was more remarkable in benzene. In refluxing dichloromethane, only trace amounts of **2** were obtained, even if TMSOTf was added.

In a mechanistic consideration, we assume that the reaction of oxime esters with TMSA takes place *via* a pathway as shown in the Scheme; the Beckmann



Scheme

rearrangement of the oxime esters in the presence of TMSA gives the imido azides, followed by cyclization to tetrazoles **2**. As for the Beckmann rearrangement, a similar reaction in which oxime esters and iodotrimethylsilane afforded imido azides, has been reported by Yamamoto *et al.*³⁾ The equilibrium

between imidoyl azide and tetrazole was well established.⁴⁾ According to these investigations, tetrazole form, in most cases, exists predominantly at a low temperature (around room temperature). Thus, 1,5-disubstituted tetrazoles (but not imidoyl azides) were obtained in the reaction of oxime esters with TMSA.

The treatment of *N*-(methylsulfonyloxy)pyridinium chloride, which was prepared from pyridine *N*-oxide and methanesulfonyl chloride *in situ*, with TMSA gave tetrazolo[1,5-*a*]pyridine (**3**) in 29% yield. When acyl chloride instead of sulfonyl chloride was employed, the reaction did not occur. Pyridine *N*-oxide (itself with TMSA) did not give **3**, in contrast to the reaction of pyridine *N*-oxide and sulfonyl azide.⁵⁾ Similarly, *N*-(methylsulfonyloxy)quinolinium chloride and TMSA gave tetrazolo[1,5-*a*]quinoline (**4**) in 64% yield. These reactions seem to be modified Reissert reactions.^{6,7)} The difference in the yields between **3** and **4** may be due to the considerable loss of resonance energy caused by the formation of dihydro intermediates in monocyclic compounds.⁸⁾

In conclusion, TMSA readily reacted with oxime esters or Reissert salts to give tetrazoles (**2**, **3**, and **4**). In these reactions, the sulfonyloxy group was better than an acyloxy group as the leaving group. The temperature dependence, solvent effect, and catalytic effect of TMSOTf were distinctly observed.

Experimental

Melting points are uncorrected. ¹H NMR were determined with a Hitachi R-600, Varian XL-100 or XL-300 spectrometer using tetramethylsilane as an internal standard. IR spectra were taken on a Hitachi 260-10 infrared spectrometer and the MS spectra were measured with a JEOL DX-300 spectrometer.

Materials. Trimethylsilyl azide was prepared from chlorotrimethylsilane and sodium azide in dibutyl ether,¹⁾ bp 95–96°C. Oxime esters (**1a–g**) were synthesized by a reaction of the corresponding oximes with sulfonyl (or acyl) chlorides in the presence of triethylamine or pyridine in benzene according to the reported methods.^{9,10)} **1a**, mp 46–47°C (lit.¹¹⁾ 45–46°C); **1b**, mp 86–87°C (lit.¹²⁾ 87–88°C); **1d**, mp 63–64°C (lit.⁹⁾ 64–65°C); **1e**, mp 98–100°C (lit.¹⁰⁾ 100–102°C); **1f**, mp 43–45°C (lit.⁹⁾ 43–45°C); **1g**, mp 57–58°C (lit.¹³⁾ 58°C). In addition, these compounds were confirmed by spectroscopic analyses (IR, ¹H NMR, and MS). Acetone oxime benzoate (**1c**), pyridine *N*-oxide, quinoline *N*-oxide, and TMSOTf were commercial products and were purified if necessary.

Reaction of Oxime Ester (1a–g) with TMSA. A solution of acetone oxime methanesulfonate (**1a**, 2 g, 13 mmol) and TMSA (2.3 g, 19 mmol) in anhydrous acetonitrile (20 cm³) was refluxed for 24 h with stirring. After a careful removal of low-boiling substances followed by distillation of trimethylsilyl methanesulfonate (570 mg, 26%), bp 54°C/3 mmHg (1 mmHg=133.322 Pa), the residue was chromatographed on silica gel using various mixtures of benzene–chloroform and chloroform. Elution with a mixture of benzene–chloroform (1:2) afforded 0.56 g of 1,5-dimethyltetrazole (**2a**, 43%), which was recrystallized from hexane to give colorless needles, mp 72–73°C (lit.²⁾ 72–73°C); ¹H NMR (CDCl₃) δ=2.50 (s, 3H) and 4.00 (s, 3H); MS, *m/z* 98 (M⁺). Elution with chloroform gave the starting sulfonate **1a**. Other oxime esters were treated in a similar manner. The yields of tetrazoles are shown in Table. TMSOTf

was used in a range of 0.05–0.1 equiv of oxime esters. From acetophenone oxime ester (**1d**), 5-methyl-1-phenyl- (**2b**) and 1-methyl-5-phenyltetrazole (**2c**), of which ratio was 95:5 from ¹H NMR spectrum, δ=2.60 (s, *C*-Me), 4.10 (s, *N*-Me), 7.40 (s), and 7.50 (s), were obtained. After recrystallization from benzene–hexane, only **2b** was isolated, as colorless needles, mp 97–98°C (lit.¹⁴⁾ 98–99°C); ¹H NMR (CDCl₃) δ=2.60 (s, 3H) and 7.50 (s, 5H); MS, *m/z* 161 (M+1). From cyclohexanone oxime esters **1f** and **1g**, 6,7,8,9-tetrahydro-5*H*-tetrazolo[1,5-*a*]azepine (**2d**), recrystallized from hexane, colorless needles, mp 57–58°C (lit.²⁾ 57–58°C); MS, *m/z* 138 (M⁺), was obtained.

Reaction of Pyridine (or Quinoline) *N*-Oxide with TMSA.

A mixture of pyridine *N*-oxide (1.0 g, 11 mmol) and methanesulfonyl chloride (1.2 g, 11 mmol) in anhydrous acetonitrile (20 cm³) was stirred for 3 h at room temperature. TMSA (2.4 g, 11 mmol) was added to the suspension and then the mixture was heated to reflux for 24 h. The dried dichloromethane extract was evaporated and chromatographed on silica gel. Elution with chloroform gave 0.36 g of tetrazolo[1,5-*a*]pyridine (**3**, 29%), recrystallized from ethanol, colorless needles, mp 156–157°C (lit.¹⁵⁾ 156–158°C); ¹H NMR (CDCl₃) δ=7.30 (m, 1H), 7.76 (m, 1H), 8.12 (d, *J*=9.2 Hz, 1H), and 8.92 (d, *J*=6.7 Hz, 1H); MS, *m/z* 120 (M⁺). When a reaction of quinoline salt, which was prepared from quinoline *N*-oxide (6 g, 41 mmol) and methanesulfonyl chloride (5.2 g, 45 mmol), was similarly performed for 24 h, the precipitated solid was filtered and the filtrate was concentrated to dryness. Recrystallization of the combined solid gave 4.5 g of tetrazolo[1,5-*a*]quinoline (**4**, 64%) as colorless needles from ethanol, mp 153–155°C (lit.¹⁶⁾ 155°C); MS, *m/z* 170 (M⁺). ¹H NMR (CDCl₃) δ=7.73 (m, 1H), 7.88 (d, *J*=9.4 Hz, 1H), 7.90 (m, 1H), 7.97 (m, 1H), and 8.72 (d, *J*=8.0 Hz, 1H).

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